# Democratizing Mobile Technology in Support of Volunteer Activities in Data Collection

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# ABSTRACT

Mobile technology is advancing our ability to connect and share information in ways that were not possible before. It makes an ideal platform for people to participate in volunteer activities for data collection, as mobile technology can transform simple data sharing in our daily lives into meaningful participation in solving real-world problems. Volunteer participation is a powerful method for collecting data, as the availability of so many volunteers allows the collection of a large amount of data that could not be obtained with the use of professionals only. Also, it enables collection of data over spatial and temporal scales at reduced cost and time.

However, despite its potential, the actual usage rate of mobile technology in volunteer activities has been low, and our understanding of why the domain of volunteering has a lower rate of mobile technology adoption remains weak. Furthermore, how mobile technology is perceived, evaluated, adopted, or declined to adopt for data collection in volunteer activities has yet to be fully determined. This dissertation first conducts a series of investigations into current practices, challenges, and opportunities associated with mobile technology use in volunteer activities from the perspective of the community organizers. From this, an authoring system was developed to enable users to create mobile data collection solutions, which democratizes the capabilities of mobile technology to support digital data gathering efforts. Finally, through a longitudinal field deployment of the system, this dissertation advances our understanding of volunteerism-themed mobile applications by first studying the underutilization of such mobile technology *in situ* and later developing a series of potential opportunities for designing more effective mobile volunteer activity technologies.

The contributions of this dissertation are threefold. First, it extends our knowledge of the current mobile technology landscape in volunteer activities for data collection. Secondly, it presents an authoring system that helps create mobile data collection solutions under resource-constrained environments. Lastly, it suggests design strategies for effectively leveraging mobile technology in volunteer data collection activities through an investigation of the entire cycle of mobile technology adoption.

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# 1 Introduction

The term ‘volunteer’ is defined as “to freely offer to do something”, and volunteering refers to any activity that involves spending time and effort free of charge to do something that aims to benefit another person, group, or society other than, or in addition to, close relatives (Wilson, 2000). Among a wide range of volunteer activities, this thesis primarily concentrates on volunteer contributions to data collection. The availability of so many volunteers allows the collection of a large amount of data that could not be obtained with the use of professionals only. It enables collection of data over spatial and temporal scales at reduced cost and time. Mobile technology can facilitate volunteer efforts in data collection because it saves resources, reduces risk associated with traditional modalities (such as loss of paper forms in transit), and minimizes errors during data entry and analysis. It also can help volunteer activity coordinators keep in touch with volunteers in the field, and improve the ability to respond to issues in real time.

Despite these potential gains, the actual adoption and usage rate of mobile technologies in volunteer activities has been low. Nonprofit organizations, which often coordinate such volunteer activities, are generally known to be slow in adopting and adapting to emerging technologies (Hackler & Saxton, 2007), and advanced mobile technology in volunteer activities is no different. Currently, the common usage pattern of mobile technology in nonprofits’ volunteer activities is limited to leveraging its mobility aspect by using information and communication technologies on the fly. Considering the extensive capabilities of mobile technologies that can enhance the process of data collection efforts, namely location detection, photo taking, media recording, digital note taking, wireless network connection, built-in sensor usage, etc., broader application potentials have yet to be fully explored.

Furthermore, our understanding of mobile technology use in volunteer data collection activities still remains weak. Most studies in information systems research have focused on the use of information technologies and social media in organizational settings (*e.g.*, Zorn et al., 2011; Burt & Taylor, 2003; Voida et al., 2011), or the relationship between information technology and the effectiveness in the work process of nonprofit organizations (*e.g.*, Lovejoy & Saxton, 2012; Latonero & Shklovski, 2011), with little focus on mobile technology and its unique capabilities. The studies in technological applications have suggested ideas to employ available mobile technologies or solutions to support mobile technology adoption (*e.g*., Maisonneuve et al., 2009; Sheppard & Terveen, 2011; Sullivan et al., 2009), without a concrete understanding of mobile technology use in volunteer activities.

Therefore, the goal of this thesis is to develop a holistic understanding of the organizational phenomena in its current state and future prospects of mobile technology in volunteer efforts for data collection. Ultimately we intended to democratize the capabilities of mobile technology to promote volunteer activities for data collection by finding and removing barriers to its adoption. To achieve this goal, this thesis first conducts extensive investigation of the current practices of information technology use in general, and mobile technology in particular, in volunteer activities through a series of empirical field explorations and literature reviews. These findings help bridge the gap between the underutilization of mobile technology and its potential. With the goal being to improve the experience of volunteer data collection activities using mobile platforms from the perspective of organizational leaders, we first study such mobile experiences through the development of a stand-alone mobile application, Creek Watch, which was designed to support citizens' activities in water quality monitoring. We report how adoption of such mobile solutions can affect the existing experiences of volunteer data collection activities. Grounded in those findings, this thesis designs, develops, and deploys an authoring environment, Sensr, that allows creating mobile solutions to support digital data collection with minimal technical and financial resources, and is intended to promote digital data collection in volunteer activities. Finally, through an investigation of how organizations select, evaluate, adopt, or avoid use of mobile tools in situ, this thesis examines contextual factors that are associated with the success and failure of mobile technology adoption in volunteer data collection activities. This reveals the gap between the perceived and actual reasons for the underutilization of mobile technology in volunteer activities.

This dissertation foregrounds the pervasive influence and implications of evolution in mobile technology, and in particular, it leverages the ubiquity of mobile technologies across everyday location and life. As a research community, we ought to consider the ways that mobile technology can be designed to support volunteer activities more effectively. In this regard, the first contribution of this dissertation is a better understanding of the landscape of mobile technology in digital volunteerism.

The second contribution is the development of Sensr, a combination of a mobile application and an authoring framework that enables people without technical skills to create and manage a mobile data collection campaign (effort). Sensr was designed to reduce the technical challenges surrounding the creation of mobile volunteerism applications. After several developmental iterations and pilot studies, this system was deployed in the wild, and is being used by a number of real-world users.

Lastly, from a comprehensive description of the organizational factors that are associated with mobile technology use in volunteer data collection activities, this dissertation proposes specific strategies and design guidelines to support an accelerated adoption of mobile technology within volunteer driven data collection efforts. Ultimately, we hope that the work within this dissertation will broaden our knowledge of digital volunteerism and promote democratizing mobile technology within the domain of volunteering.

# 2 Conceptual Framework

This chapter describes existing theories of understanding technology use in organizational contexts. It serves as a lens for focusing the research, identifies several practical considerations for volunteer activities in collecting data, and provides a theoretical foundation for building our model of organizational factors in relation to technology use in volunteer activities. These will also be applied in the study design and analysis of this thesis.

## 2.1. Adaptive Structuration Theory

Research has shown that people's behaviors in using information technology in context often differ from the intended impact (Sproull & Kiesler, 1986; Siegel et al., 1986). Oftentimes, people appropriate information systems for their particular needs, or they resist them, or fail to use them at all. To study such complex interactions of organizations and information technology, Desanctis & Scott (1994) proposed Adaptive Structuration Theory (AST), a framework for studying variations in organization changes that occur as technologies are used. According to AST, adaptation of technology by members of an organization is a key factor in organizational change (Desanctis & Scott, 1994).

AST provides a general approach to the study of how groups organize themselves, a process that plays a crucial role in group outcomes and organizational change. It helps to describe "the interplay between advanced information technologies, social structures and human interaction" (Desanctis & Scott, 1994, P.5). AST focuses on social structures, rules, and resources provided by technologies and organizations as the basis for human actions. AST examines the change process from two vantage points: 1) the types of structures that are provided by the information technologies, and 2) the structures that actually emerge in human action as people interact with these technologies (Desanctis & Scott, 1994, P.1). AST also illustrates the importance of understanding the contextual factors when studying systems usage in organizations. Capturing these processes and tracking their impact can reveal the complexity of technology-organization relationships, as well as providing a better understanding of how to implement technologies.

Also, it may help us develop improved designs or educational programs that promote productive adaptation. In all, the major concept of AST covers the entire sequence from input to process and output as an organizing paradigm for organizational research.

Based on AST, technology and task affect attitudes when the other process factors were controlled, which in turn affect outcomes. I adapt and modify the model of AST to pursue the goal of this thesis (See Figure 1). The *input* variables of our model are organizational factors, both internal and external, including members' differences in characteristics, group characteristics, tasks, and environmental factors. In particular, I focus on types of activities and domains that an organization works for as major input variables, since the major difference between volunteer organizations and other forms of organizations is their missionary activities. The *process* variables refer to perceived attitudes of the system use among members. Lastly, the *output* variables include perceived satisfaction, looking for appropriation of technology in context and accompanying changes in any of the constructs in the original sequence.

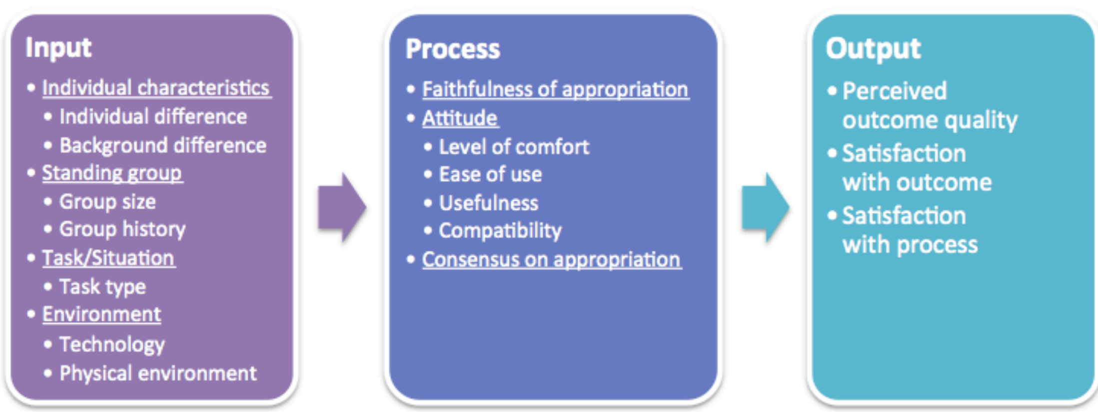


**Figure 1. The model of Adaptive Structuration Theory (from Gopal et al., 1993)**

## 2.2. Activity Theory

Based on the concept of tools mediating between subjects and objects, Activity Theory is a framework to analyze social and cultural issues. It provides a language to describe what people do in context as a holistic approach for the study of organizations (Hashim & Johns, 2007). Activity Theory is particularly useful for the study of organizational work, since the collective nature of activities by multiple stakeholders in context may be represented in the system's development process. We use Activity Theory as a lens to explore the organizational context where members in an organization manage their activities. Also, Activity Theory will guide the structure of semi-structured interviews that we will conduct in the study.

### 2.2.1. Basic Principles

Activity Theory is formed around a set of principles to constitute a general conceptual system (Kaptelinin, 1997; Nardi, 1996). The basic principles of Activity Theory are as follows.

*The space between activity and consciousness*: In Activity Theory, activity and consciousness are treated in an integrated way. Consciousness means the human mind as a whole, and activity means the human interaction with its objective reality. This principle states that the human mind emerges and exists as a special component of the human interaction with its environment. The mind is a special organ that developed through the process of evaluation to help complex organisms survive. Thus, it can be analyzed and understood only within the context of human activity.

*Object-orientedness*: This principle focuses on the environment-centric approach. People live in an environment that consists of objective features that influence the ways people interact with those objects.

*Internalization/externalization*: This principle describes the basic mechanisms in the source of mental processes. Mental processes are derived from external actions through internalization. Internalization refers to the information absorption process of the human mind, which is derived from contact with the environment. Externalization is the inverse process of internalization.

*Mediation*: Human activity is mediated by tools, both external (or material) and internal (or immaterial). Tools are created and transformed during the development of the activity itself, and carry with them in a particular context. Tool use influences external behaviors and also the mental functioning of individuals.

### 2.2.2. Elements in Activity Theory

In Activity Theory, an activity consists of three basic elements (subject, object and mediation tool) and three mediating elements (rules, communities and division of labor) (see Figure 2). The framework starts from the elements of a mediated action by an individual (the subject or actor), and then moves to the object of the action, the instruments or means (both mental and physical) needed for the action, as well as the goal (Vygotsky, 1978), which all take place within a work process.

*Subject (member)*: The subject is part of an activity, such as a member doing his/her work and focusing on a shared goal, based on the motive for the activity. In practice, it requires several actions by several members to produce any useful service or product.

*Tool*: Subjects work on their objects using specific tools (*e.g*., facilities, artifacts and also mental skills, knowledge). There is a need for information about how to use the tools, and it is important to consider where subjects get the information needed in the work process, how they use that information, and where they record or save new information. There are many kinds of information, *e.g*., formal information and tacit information, as well as professional skills.

*Object*: An object is the target of actions as part of the shared goal, and subjects should recognize the object of the work. The first experiences with the object are focused on external features, which are transformed into deeper knowledge of the object as the work process continues. In the work process, the subject (or collective subjects) and the object are in interaction, mediated by the tool.

*Work process*: The work process includes an object of the activity, and a transformation towards an outcome. The object is where the subjects aim to contribute, to create a transformation process to achieve an intended outcome. The primary focus is on work processes by professionals within an activity, as well as the information flows, and information management. It is crucial to create a collective understanding among subjects about how they are working, what kinds of tasks are being carried out, what information tools are used and how, who are the other actors involved, and so on. A subject has a goal, tools, colleagues, and rules when s/he is working on the goal, and transforms it into the intended outcome.

*Means of coordination and communication*: In addition to the instruments or means of the individual actions, other kinds of mediating instruments – social infrastructure – are also needed within an activity (Engeström, 1987). The actions need to be oriented by means of coordination and communication. Among the means of coordination and communication, I included *the division of work* and *rules* in multiple stakeholder systems.

## 2.3. Models of Technology Adoption in an Organizational Context

In order to manage a multi-stage process of data collection by multiple stakeholders, activities need to be *organized*. Organizing is an act of arranging elements following one or more rules, and is comprised of goal-oriented activities. Therefore, it is a proper term to describe the managing process of volunteer activities. For this reason, I call a group of people who team up to run a volunteer activity an *organization*.

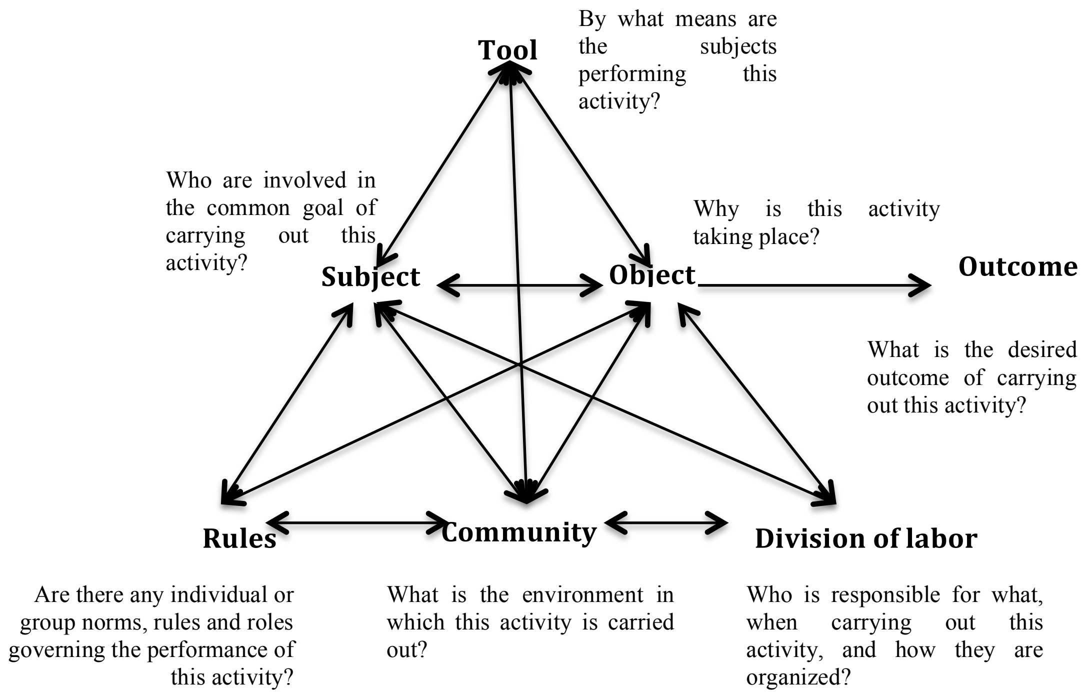


**Figure 2. A model of an activity system (Engestrom, 2012)**

As organizations maintain an increase in spending on new information technology, the relationship between information technology and organizational structure continues to be of great interest to both researchers and practitioners. Within the context of Contingency Theory, Woodward's (1958; 1965) research and Thompson and Bates' (1957) theoretical article paid attention to technology as a determinant of organizational structure (Scott, 1992). Later models of technology and organization by Thompson (1967), Perrow (1967; 1970), and Galbraith (1973; 1977) developed the information processing view of structure, and added to a growing understanding of technology's role in shaping organizational structure. Now, it is no longer possible to design and modify organizations without recognizing information technology, as it is central to the organizational structure (Belassi & Tukel, 1996). Moreover, it does not make sense to explore human behavior within organizations without taking into account how information technologies might affect organizational behaviors (Zammuto et al., 2007).

Research has shown that the use of information technology in an organization is dependent upon two major factors: characteristics of the organization and the system (Alexander, 1989). Other studies also indicated that organizational characteristics are one of the crucial issues to be looked into when implementing information technology (*e.g.*, Grover & Goslar, 1993). Organizational characteristics are factors that define an organization's character, property, function, and impact. Examples include organizational leadership, structure, climate, politics, process and procedure, culture, and members (Lai & Guynes, 1997). Therefore, the impact of organizational factors on information technology use has been a major issue for both organizations and information systems studies.

The impact of information technology on organizations is often indirect, and is influenced by many factors (Petter et al., 2008). In an effort to better understand the tangible and intangible benefits of information technology, the studies on organizational behavior have turned their attention from traditional measures, such as financial return on investment, to new methods, such as technology adoption, user satisfaction, service quality, and net benefits (DeLone and McLean, 2003; Venkatesh and Bala, 2008). This leads to need for a theoretical framework that supports understanding the complex dynamics of information technology within an organization (Bannon & Schmidt, 1989). This thesis adopts two major schools of thought regarding the measures of technology use in organizational settings: *Technology Readiness* (Parasuraman & Colby, 2001) and *Technology Acceptance Model* (Davis, 1989).

### 2.3.1. Technology Readiness

People's reaction to new technology often reflects conflicted feelings. For instance, new technology may simultaneously free a user from some tasks, but enslave them to another task. Or, engaging in a technology-oriented task may lead to disengagement in another task. These paradoxes imply that new technology may trigger both positive and negative feelings. The combination of positive and negative feelings underlies the domain of Technology Readiness.

Technology Readiness gauges people's propensity to embrace and use new technologies for accomplishing goals using four personality traits, namely optimism, innovativeness, discomfort, and insecurity. *Optimism* refers to "a positive view of technology and a belief that technology offers people increased control, flexibility, and efficiency in their lives" (Parasuraman & Colby, 2001, p. 34). It captures a positive view of technology and a belief. *Innovativeness* refers to "a tendency to be a technology pioneer and thought leader" (Parasuraman & Colby, 2001, p. 36). It measures the individual's propensity to being advanced in technology adoption. *Discomfort* refers to "a perceived lack of control over technology and a feeling of being overwhelmed by it" (Parasuraman & Colby, 2001, p. 41). It measures feelings of uneasiness or anxiety when confronted with new technology. *Insecurity* refers to "distrust of technology and skepticism about its ability to work properly" (Parasuraman & Colby, 2001, p. 44). It focuses on the uncertainty that people feel when interacting with new technology.

### 2.3.2. Technology Acceptance Model

Successful use of new technology leads to enhanced productivity, while failed systems can lead to undesirable consequences in an organization, such as financial losses and dissatisfaction among employees. While there has been significant technological advances and increasing organizational investment in new technologies, the problems of underutilized systems can also impede businesses. Thus, understanding user acceptance, adoption and usage of new systems is a high priority for researchers and practitioners alike (Venkatesh, 2000). A significant body of research in information systems and human-computer interaction supports the importance of initial acceptance and sustained usage of new systems (*e.g*., Davis et al., 1989; Venkatesh, 1999; Gould & Lewis, 1985). This work adopts the most widely applied model of user acceptance and usage, Technology Acceptance Model (Davis, 1989).

Technology Acceptance Model (TAM) is a framework to predict and explain users' adoption of information technology in organizational settings. Adapted from Fishbein and Azjen's theory of Reasoned Action (1975), TAM has been successful in explaining usage behavior in adoption of information technology in general (Malhotra & Galletta, 1999; Yi & Hwang, 2003). TAM postulates that user acceptance of a new technology is determined by the intention to use it, which is then influenced by the user's belief about its *perceived usefulness* and *perceived ease of use. Perceived usefulness* is "the extent to which a person believes that using a particular system will enhance his or her performance," and *perceived ease of use* is "the extent to which a person believes that using a particular system will be free of effort" (Lin et al., 2007. p. 643). Perceived ease of use is hypothesized to be a determinant of perceived usefulness, while both beliefs are influenced by organizational factors, technological factors and individual factors (Sun & Zhang, 2006).

# 3 Literature Review

This chapter presents a literature review on the current practices of information technology use in volunteer activities. Because most volunteer-driven activities are led by nonprofit organizations, we first review existing literature on the use of information technology in nonprofit sectors in general, and social media in particular, with respect to the role of such technologies in volunteer activities, as well as the reasons for the slow adoption of innovative technologies in nonprofits. We then review the specific domains that have appropriated mobile technology for public engagement in societal services beyond the scope of nonprofit sectors: participatory sensing and citizen science. The intersection between understanding the use of general information technology in nonprofits and mobile technology for public engagement will present insights into mobile technology use in nonprofit activities.

## 3.1. Information Technology Use in Nonprofit Organizations

Information technology has proven helpful in increasing work efficiency within resource-constrained environments (*e.g.*, Dewett & Jones, 2001; Nieto & Fernández, 2005). Thus, a large volume of literature in information systems research has investigated the effects of information technology use on nonprofits' work processes. In particular, researchers have shown that information technologies can improve organizational efficiency in an extensive scope of nonprofit applications, including recruiting volunteers (Herr & Anderson, 2005), fundraising (Goecks et al., 2008), coordinating events (Voida et al., 2011), enhancing inter-organizational coordination (Stoll et al., 2010), supporting general volunteering (Pereira & Cullen, 2009), and improving general management practice (Merkel et al., 2007).

Although most nonprofits make use of modern information technologies with diverse applications to some degree, the adoption of new, advanced technology has been very slow (Idealware, 2012). A 2011 survey conducted by the Nonprofit Technology Network[1] reported that the average technology budget was less than 5% of a nonprofit's total budget, and over

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1 NTEN, 4th Annual Nonprofit SocialNetwork Benchmark Report 2012.

50% of small nonprofits did not plan to adopt any technology within a year. As such, nonprofits have generally lagged behind for-profits in investment in and adoption of advanced technology (Schneider, 2003). Researchers have identified diverse reasons for such slow adoption, including financial and technical constraints (Saeed et al., 2011), lack of understanding of the social context into which technologies are deployed (Carroll, 2004), organizational cost of creating and preserving the knowledge necessary to make effective use of deployed information technologies (Le Dantec & Edwards, 2004), imbalance between those who receive the benefit of new technologies versus those who must do the work of using them (Grudin, 1988), and diversity in the organizational structure, scope, application area and working of nonprofits (Saeed et al., 2011). Among those, the significant constraints in financial and technological resources are a fundamental factor in determining the strategies for advanced technology adoption in nonprofits (Merkel, 2007; Voida, 2011).

Contrary to the extensive studies on information technology use in nonprofits (*e.g.*, Burt, 2003; Waters, 2007; McPhail, 1998; Voida et al., 2011), there has been very little exploration of mobile technology. Mobile technology is beginning to dominate web functionality, and some nonprofits that have tapped into this trend are seeing benefits. For example, a research report on mobile technology's impact on fundraising in 2013 revealed that donations made through mobile devices had increased by 205 percent within a year, and that nonprofits who had integrated mobile technology into their fundraising practices raised 2.95 times more contributions (Artez Interactive, 2013). This demonstrates the potential of mobile technology to enhance the work process in nonprofits. Soon, mobile technology will become an essential part of how nonprofits engage with volunteers and expand their reach of the public (Westmoreland, 2014). However, the actual use rate of mobile technology in nonprofits is still marginal (Kim et al., 2013), and thus nonprofits have a long path to utilize the full potential of mobile technology.

## 3.2. Social Media Use for Public Engagement

Social media have opened up greater possibilities for improving interpersonal and inter-organizational communication among stakeholders, as it is free of charge and have built-in interactivity through supporting two-way exchange of information, network creation, and open public dialogue (Lovejoy & Saxton, 2012). In their work, Lovejoy and Saxton demonstrated that the effective use of social media strategically engages their stakeholders via dialog and community-building practices compared to traditional websites.

Scholars have identified diverse ways in which social media may empower nonprofits, including forming a sense of community (Jave et al., 2007), fostering and maintaining social capital in community members (Ellison et al., 2007), supporting information-sharing (Hughes & Palen, 2009), building and fortifying relationship among members (Briones et al., 2011), and furthering dialog among stakeholders (Rybalko & Seltzer, 2010).

Studies into social media use for public engagement have been highly informative in the domain of community crisis management. From a holistic review, Starbird and Palen (2011) asserted that even small technical features in social media could increase individual capacities for collective action. Latonero and Shklovski (2012) found that the affordances of social media allow emergency managers to better communicate, interact with, and respond to the public, and Shklovski et al. (2010) showed that online spaces in social media are vital to connect people with their local communities.

As such, these studies have shown that social media can enhance public engagement in volunteer activities. Combined with mobile technology, social media become even more powerful, as the benefits of social media are available at any place at any time. We will reflect later upon these benefits by exploring the opportunities of mobile technology beyond mere mobile social media to leveraging its full capacity.

## 3.3. Mobile Technology Use for Public Engagement

Whereas mobile technology is relatively underutilized in nonprofit contexts, there are specific domains that leverage the power of mobile technology to facilitate public engagement beyond nonprofit sectors: participatory sensing and citizen science. They are sometimes not structured organizations or nonprofits, but rather a group of individuals, for-profits, or public sectors that extensively rely on public participation to operate activities in common. Examining the practices of mobile technology use in these domains can help better project the potential benefits and opportunities in volunteer data collection activities.

### 3.3.1. Participatory Sensing

Participatory sensing involves forming interactive, participatory sensor networks that enable people to participate in gathering, analyzing, and sharing local knowledge through the ubiquity of everyday mobile devices (Burke et al., 2006). The basic concept of participatory sensing is to utilize embedded sensors and other hardware features in smartphones to automatically collect in-situ contextual information (Cuff et al., 2008; Willet et al., 2010). In other words, smartphones become distributed sensor nodes to automatically collect a large volume of data.

Using sensing-equipped smartphones, it is possible to monitor a wide range of socio-environmental factors, such as urban air quality (Aoki et al., 2009; Mendez et al., 2011; Bales et al., 2012; Hasenfratz et al., 2012), noise pollution (Lane et al., 2010; Rana et al., 2010; Zhang et al., 2012; D'Hondt & Jacobs, 2013), real-time prediction of public transportation arrival (Zimmerman et al., 2011; Zhou et al., 2012; Farkas et al., 2014), controlling indoor (Erickson & Cerpa, 2012) and outdoor (Kuznetsov & Paulos 2010; Abecker et al., 2012; Silva et al., 2013) environmental conditions, and traffic patterns in metropolitan areas (Hull et al., 2006; Ganti et al., 2010; Hu et al., 2013). An aggregation of such information is used to assess urban living-quality conditions without the deployment of large-scale systems.

Participatory sensing is a subset of volunteer data collection activities, as it does not necessarily require human actions. It often captures a stream of data automatically through mobile technology. Though the processes of data collection are different, both heavily rely on voluntary participation of the public to achieve their goals. Mobile technology use in participatory sensing demonstrates how proper use of the extensive technical capabilities in mobile technology can be facilitated in diverse applications.

### 3.3.2. Citizen Science

Citizen Science is a kind of volunteer data collection activity that harnesses the power of the public to solve real-world problems or to answer scientific questions (Silvertown, 2009). Citizen science is different from participatory sensing in that it emphasizes the roles and characteristics of volunteers. Citizen scientists conduct data collection without much specific scientific training in performing or managing tasks, whereas participatory sensing refers to a process of automatic data collection through personal mobile devices (Estrin, 2010).

Citizen science leverages the diffusion of personal mobile technology and its technical capabilities to lower the threshold for the public's systemized participation in scientific work. Because citizen science relies on the efforts of non-experts for systematic data collection and analysis, the ease of use of the tools often determines its success. Smartphones equipped with embedded sensors may support such activities without an additional device, which improves the quality of the data collected. Several ongoing projects have adopted mobile applications to facilitate citizen science, such as eBird and Great Sunflowe (Sullivan et al., 2009; Prestopnik and Crowston, 2012).

The scope of citizen science ranges extensively from environmental observation to scientific tasks, from data collection to analysis, and from monitoring to discovery. Currently, the citizen science model contributes the most to generating peer-reviewed publications in the field of ecology (Dickinson et al., 2012). The advance in information and communication technologies armed with geo-tagging capabilities has allowed people to collect large volumes of location-based ecological data and submit them electronically to a centralized database (*e.g.*, COASST[2], StreamWatch[3], MLMP[4], CoCoRaHS[5], GLOBE at Night[6]). Another prominent area is to bring a collection of local knowledge into improving community-living conditions. As shown in a series of case studies by Corburn, citizen-gathered data can easily go beyond direct measurements of the environment, for instance, understanding neighborhood health effects, increasing community living conditions, and improving urban planning (Corburn, 2002; Corburn, 2003; Corburn et al., 2006). To further empower community members, the Extreme Citizen Science[7] research group contributes to the guiding theories, tools, and methodologies in order to enable any community to deal with issues that concern them.

While mobile applications could be a powerful tool to promote public engagement in citizen science, there are also limitations and hidden costs of adopting mobile technology (Wiggins et al., 2011). These include poor usability when inappropriately designed (*e.g.*, user interface, screen size), network connectivity, etc. These limitations have to be taken into careful consideration when exploring the adoption of mobile technology in volunteer data collection activities.

## 3.4. Summary and Next Steps

[2] COASST: Observing and conserving marine life, http://depts.washington.edu/coasst/
[3] StreamWatch: Community water monitoring, http://streamwatch.org/
[4] Monarch Larva Monitoring Project (MLMP): monitoring monarch populations in the north America, http://www.mlmp.org/
[5] CoCoRaHS: measuring precipitation across the nation, http://www.cocorahs.org/
[6] Globe at Night: monitoring night sky brightness, .http://www.globeatnight.org/
[7] Extreme Citizen Science, University of Collage London, http://www.ucl.ac.uk/excites/

In this chapter, we reviewed the extensive literature on general information technology and social media use, as well as two specific domains that use mobile solutions for public participation, participatory sensing and citizen science. The discussion provides a foundation for the focus of this dissertation on the volunteer activities in which participants contribute to data collection.

As such, a large volume of work has been conducted to understand technology use in nonprofit contexts, hinting at the opportunities and challenges of mobile technology use in volunteer activities. We believe that this work expands the scope of existing knowledge related to the relationship between technology use and volunteer activities from general information technology to mobile technology.

Next, this dissertation looks into a specific kind of volunteer activity, a citizen science project for water quality monitoring, in order to understand the work process, needs, and challenges of volunteer participation in data collection empirically. It will also explore how mobile technology can support such activity in the real world.

# 4 Creek Watch: Pairing Usefulness and Usability for Successful Volunteer Activities in Data Collection[8]

It seems logical to engage with scientists who need data as key stakeholders, yet the design community has neglected them. In our research we address this disconnect by focusing on the *usability* and *usefulness* of collected data, rather than just on the interface presented to users. We wanted our design to be driven by the scientists who need the data and by the volunteer groups that support their investigations. By first understanding the needs and abilities of these groups, we are more likely to build a mobile application that is useful as well as usable.

To find suitable groups of scientists and volunteers, we met with a variety of organizations. The California Environmental Protection Agency helped us identify watershed health as a critical area that is also amenable to data gathering by average citizens. Interviews and brainstorming sessions with the California State Water Resources Control Board and the City of San Jose Environmental Services Water Resources helped us understand their priorities and needs for data. We then met with local watershed monitoring organizations to understand the capabilities and limitations of their current citizen monitoring practices.

Having assessed the data needs of the stakeholders and the abilities of volunteers we designed and developed Creek Watch. Creek Watch combines both an iPhone application and website. The iPhone application enables citizens to contribute water flow and trash data from creeks and rivers. The website, (http://www.creekwatch.org) allows them to view contributed data, and provides scientists access to all of the collected data. We validated our design in a usability study with subjects who had no previous experience with water quality monitoring.

We then conducted an intensive user study with 10 scientists from the City of San Jose Environmental Services Water Resources team that were not involved in our earlier study and design sessions. We tested the Creek Watch interface, assessed the usefulness of data it collected, and identified potential improvements in the application and website. Overall the

8 This chapter is adapted from a paper published at the CHI'11 conference (Kim et al., 2010)

scientists were very pleased with Creek Watch, and are now using the data it collects. The interviews and user studies enabled us to identify what data would be useful to the scientists and the standards the data must comply with.

In the following sections we describe our series of contextual inquiries with water control boards and volunteer watershed monitoring groups. Next, we explain our design of the Creek Watch iPhone application and website, how we took the needs of these different groups and converged upon a set of data and collection standards, and our user study with members of our local water control board. We then discuss lessons for the design of mobile applications and key implications of our work, and conclude by identifying future directions for research.

## 4.1. Prior Work

The recruitment of the public to participate in large scale monitoring has a long history, particularly in observing phenomena in the environment. Animal population research has been aided by citizens in a number of ways: in addition to the annual Christmas Bird Count, Cornell Lab's bird monitoring program[9] attracts over 200,000 volunteers each year. A similar project exists for counting fish[10]. Technology has enhanced the participation of citizens providing communication, documentation and measurement tools. The CONE project at UC Berkeley allows volunteers to contribute to bird sighting numbers using autonomous robotic cameras deployed in birding hotspots (Song & Goldberg, 2007). In the Lost Ladybug Project[11] citizens submit digital photos of Ladybugs along with location and weather information.

Citizen science provides a mechanism for participants to learn about and improve their community. Participants in the GarbageWatch project contribute pictures of garbage to help figure out where to place recycling bins[12]. Urban citizens equipped with sensors track neighborhood air (Kim & Paulos, 2010; Sukhatme, 2009; Willet et al., 2010) and noise pollution (Maisonneuve et al., 2009). Citizens in Virginia have organized a volunteer group to monitor, consolidate and share data on local stream and rivers to maintain and improve the health of the Rivanna watershed[13]. Beyond science, many cities use the non-emergency number 3-1-1 to implement a citizen service center for residents to report needed roadwork, abandoned

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9 Cornell Lab of Ornithology (2010), Mission: Citizen Science. September 2010
10 http://www.fishcount.org
11 http://www.lostladybug.org
12 http://www.garbagewatch.com
13 http://www.streamwatch.org

vehicles and other neighbor-hood code enforcement issues[14]. On-line versions of 3-1-1 developed by several cities provide citizens the ability to digitally interact with city services[15].

The value of mobile phones as tools for volunteer data collection has been recognized (Kim & Paulos, 2010), with examples such as air quality (Paulos et al., 2008), and the Oil Reporter service, which allows volunteers to report on areas affected by the Gulf Coast oil spill[16].

Citizens' role is not just limited to data collection. Technology makes it possible for citizens to volunteer their computer and brainpower. Idle time on volunteers' home computers is being used to search for extraterrestrial life[17] and study protein folding[18]. The Galaxy Zoo[19] leverages the human brain's exceptional pattern-recognition skills, recruiting citizens to classify galaxies from photos taken by a robotic telescope. This type is a form of crowdsourcing; wherein people can perform distributed tasks towards a greater goal (Irwin, 1995).

Unlike prior work, an important contribution of our work is the use of HCI methods to focus on the data consumers as a stakeholder group. Much work from the HCI community has focused on projects where users are both producers and consumers, so there was no need to study separate stakeholders. While Cohn considers the scientific quality of the data collected by volunteers, he does not discuss its utility to existing projects that need the data (2008). Paxton & Benford did not explore the importance of data consumers in their design of a participatory sensing system to collect environmental data (2009), and Cuff et al. nicely delineated citizen sensing network infrastructure without describing the use of the collected data by data consumers (2008).

## 4.2. Understanding the Problem

We began the Creek Watch project with a discussion with the California Environmental Protection Agency of areas in which volunteers equipped with mobile devices could be empowered to help their environment. We conducted a series of interviews and brainstorming sessions with ecologists in the state agency to understand current practices and problems in environmental management. Our discussions identified the monitoring of watershed health as an

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14 http://www.ci.knoxville.tn.us/services/codes/
15 http://open311.org
16 http://www.oilreporter.org
17 http://www.setiathome.ssl.berkeley.edu
18 http://www.folding.stanford.edu
19 http://www.galaxyzoo.org

ideal application of mobile data collection: waterways are numerous and geographically distributed, local water agencies lack the staff and resources to monitor all of them, and citizens are aware of the importance of water. While we chose to focus on waterways, the same basic issues of large geographic scope and limited resources occur in many environmental domains.

### 4.2.1. Resources and Access

Watersheds are geographically large, and monitoring all of the waterways within them would require resources that exceed most organizations. For example, the city of San Jose, California's third largest city, has over 700 miles of creeks – far too much ground for a local agency to cover, especially when creeks run through private land that officials cannot access without permission. In practice, this means many areas are never visited by officials and receive no monitoring.

However, many of these creeks run through parks and recreation areas visited by citizens every day; these citizens could perform some monitoring if the process were sufficiently convenient. Creeks that run through private land could be monitored by the landowners. As a result, watershed monitoring is well positioned to take advantage of the key potential of citizen science: there are many more people who care about the environment than just those who are professionals in the field.

### 4.2.2. Interacting Stakeholders

In addition to resource demands, environmental monitoring programs must address data standardization and sharing among stakeholders:

- Government organizations: these organizations are responsible for enforcement of regulations pertaining to water use, wastewater discharge, and pollution, on state, regional, county and city levels.

- Private groups: these are typically consulting companies, which work closely with these government organizations, typically funded by grants, for example by private parties to conduct evaluations for environmental permits.

- Volunteer groups: these are typically organized on a city or county level and meet anywhere from twice-a-year to pick up trash, to monthly to monitor water quality with professional equipment.

### 4.2.3. Data sharing, re-use, and standards

Beyond collecting data, one of the biggest challenges faced by organizations is sharing data - if two groups do not gather data in precisely the same fashion (*e.g.*, follow the same protocol), the data may be incompatible. Even for programs where collection techniques have been standardized, the problem of data sharing typically remains unsolved. Historically each government organization has maintained its own databases with poor interoperability. Currently, data is most frequently exchanged as completed reports or as spreadsheets. Recent legislation in California has mandated a statewide system to share this data, but the system is still under development.

Getting information from private and volunteer groups can be even more difficult. Watershed volunteer groups typically aggregate data they have collected into a yearly report that is made available to government organizations as a summary document. More sophisticated groups may include a spreadsheet of the original data. Because these groups typically have a specific driving mission (*e.g.*, searching for mercury or other toxins local to their area, tracking water flow rates which affect fish spawning, etc.), the data they collect is focused on a specific problem and may not include information that other organizations need to make further use of the data.

Our discussions with the California EPA revealed that there are over 250 organized and recognized groups in California working on watershed health[20], yet their idiosyncratic data collection and sharing practices make it likely that only a few will have their data used by others. In our work we apply human-centered design methods to the design of the data collection and format to ensure usefulness by the scientists, the primary users of the data.

## 4.3. Contextual Inquiries

Following on our brainstorming sessions with the California Environmental Protection Agency, we conducted a series of contextual inquiries to guide the design of a mobile application for watershed health monitoring (Beyer & Holtzblatt, 1988). We conducted in-depth interviews, on the phone and in the field when possible, with eleven scientists, environmental workers, and water monitoring volunteers from across seven organizations. From the government side, we interviewed four ecologists in the California State Water Resources Control Board and the City of San Jose Environmental Services Water Resources. From the private sector, we interviewed three ecologists from San Francisco Estuaries Institute (SFEI) and the Southern California

20 Environmental Protection Agency (2010), TMDL Program Results Analysis Fact Sheet # EPA Office of Water, January 2010. http://www.epa.gov/waters/ doc/factsheets/303d_impaired_waters_gis.pdf

Coastal Water Research Project (SCCWRP). In the volunteer sector, we interviewed three volunteers from two local groups, the Stevens & Permanente Creeks Watershed Council (SPCWC) and the Alameda Creek Alliance. We also interviewed the volunteer outreach organizers of the Water Environment Federation, an international federation of water quality experts with over 80,000 members, including most of the environmental scientists we interviewed.

The primary goal of these interviews was to identify (1) the data most needed by environmental organizations that could be gathered by citizens, (2) how it would be used, and (3) how to best ensure that the data would actually be useful, including understanding the protocol and format required to make the data acceptable to the scientists. The challenge of getting useful data from citizens was confirmed by our first interview subject:

> *"In the early days it was an activity to engage understanding in water quality. It didn't matter what they did as long as they did something. Then we realized no one uses the data and they aren't monitoring for things we care about." Interview #1, State Water Control Board*

## 4.3.1. Critical Data: Water Flow and Trash

Problems in watershed management are numerous and varied, including the improvement of habitats for aquatic life, water collection for drinking and irrigation, flood and erosion control, and the identification and control of pollution. The data that could help these areas are equally numerous (*e.g.*, water flow, turbidity, pH levels, dissolved oxygen, measurements of contaminant levels, aquatic life surveys). While much of this data requires specialized measurement equipment, some very useful data requires only simple observation. We identified water flow rate as a candidate datum from our interviews:

> *"Wherever people go, if there's a creek, it would be great to get info on flow. Qualitative and quantitative: take a picture and send to a database, GPS tagged. This would be tremendous – we need data on flow." Interview #1, State Water Control Board*

Water flow data is needed by several of the stakeholders we interviewed. Water flow rate in creeks is critical to understanding the health of a watershed: these small waterways, which in aggregate hold most of the water in California, are habitat for aquatic life, a source for drinking water and irrigation, and are unfortunately also a pathway for pollution. Without an accurate picture of when and where water is flowing, it is very difficult to understand the health and capacity of waterways, making water management more difficult. Capturing water flow data using the format and protocol required by the scientists assures that the stakeholders could use this data. Unfortunately, water flow data available to environmentalists is spotty at best.

> *"We're not getting a lot of [flow] data. Most is generated by discharge permits: when someone has a permit to discharge [waste water] into a stream, they are required to monitor flow, so we get that information. But…there are many more places we can look then we have people or resources for. ... Flow is kind of hidden, but it's really important. What happens is when we have to get it its too late to go back in time." Interview #4, State Water Control Board*

Fortunately, flow data is easy for citizens to collect. No equipment is needed to determine if water is flowing or not, and if creeks are full or low. Furthermore, people pass by these waterways all the time while walking or biking in parks and around their neighborhoods.

Each of the groups we interviewed had a different reason for wanting flow data. At the state-level, flow data is desired for water management and planning. At the city level, flow data is desired for tracking pollution. One of the local volunteer groups (SPCWC) wanted flow data to study fish spawning. One of the private consulting groups (SCCWRP) wanted flow data for clients applying for construction permits. The other (SFEI) wanted flow data for a longitudinal study of human effects on bay area water supply. To service the data needs of these different stakeholders; flow data collection must conform to standards to ensure maximum re-usability.

We also identified data concerning trash as important to our stakeholders and amenable to citizen reporting.

> *"Many of the most serious water quality problems in California are associated with non-point source pollution. ... Trash is a severe non-point source problem. Trash clogs our waterways blocking fish migration paths, impairs aquatic life and poses a threat to many beneficial uses of our creeks and streams." – Interview #1, State Water Control Board*

While many groups regularly conduct trash surveys and cleanups, there is simply too much area to cover. The California State Water Resources Control Board is required by the U.S. Environmental Protection Agency (EPA) to maintain a list of waters that are considered "impaired", *e.g.*, they are too polluted to be used for swimming, fishing, drinking, or other beneficial uses (Weiner, 2010). In California, trash is the second most common impairment pollutant[21].

To identify impaired waters, the state water board must collect and assess water quality data and determine if it meets standards. The process starts with stakeholders who alert the water board of locations where water quality standards may not be met. Citizens can alert state boards of pollution but need to present evidence. Photographs, tagged by location and time, provide tangible evidence of trash in waterways. Photos can help identify the type of trash (*e.g*., bottles, paper, car parts, and medical waste) and potential sources (*e.g*., individual littering, illegal dumping of landscape and construction debris). Trash occurs most frequently in sites with high public access (Moore et al., 2007), which bodes well for citizen monitoring of trash levels. The culprits for watershed pollution are often unaware of the extent to which their activities are damaging the environment.

> *"It used to be that industry was the problem. But the average resident (collectively) is now the problem. People's pesticides, car washing, dog poop, garbage that we drop it's a really big problem." – Interview #7, City of San Jose Environmental Services*

The problem of getting data on such simple measures as flow rate and trash is complicated by the fact that good news is often assumed not to be worth reporting.

> *"We have a citizen stream keeper program: people go out at least once a month to a creek to observe it … but if they don't see anything bad they don't report, so we don't know." Interview #6, Local Water Monitoring Volunteer Coordinator*

To be successful, we concluded that our application must equally support and encourage the reporting of both problems and situations where nothing seems amiss.

We concluded from these contextual inquiries that water quality data consumers would benefit from an application that enabled citizens to report on water flow and trash, and that the data needed to be collected following a protocol and format acceptable to the end users (scientists). A smart phone is ideal for collecting this data, since it is always on hand, can collect pictures and accurate location data, and can simplify submitting data to a central organization.

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21 Environmental Protection Agency 2006 Section 303(d), List Fact Sheet for California. EPA Office of Water, http://oaspub.epa.gov/tmdl/state_rept.control?p_state=CA

### 4.3.2. Advanced needs

In addition to flow and trash data, we identified several other standard measures of water quality that would be useful, such as temperature, turbidity, dissolved oxygen, and pH level. Unfortunately, for a citizen to report on this data, they need to have water testing kits or more specialized equipment, complete with the training to collect data according to accepted protocol in order for this data to be acceptable for scientific studies. For example, the SPCWC volunteer group used tools ranging in price from several hundred to several thousand dollars, operated by a trained biologist, and even so would only take samples on a monthly basis due to limitations on lab time for sample analysis.

Designing an application with a focus on consumers as well as producers of the data creates a trade-off between the advanced data needs of scientists and the capabilities of citizens without specialized training or equipment. To some extent this tradeoff occurs in all projects started by domain experts. Working with these stakeholder groups, we were able to look at the trade-offs in a new way. We identified the importance of collecting data that complies with the format and protocol required by scientists. We pair this with the citizen's need for an easy way to collect data in a reliable and predictable way.

## 4.4. System Design and Implementation

We designed and built Creek Watch to be a participatory creek monitoring system that allows citizens to capture water flow and trash data and scientists to view and analyze the collected data. We designed the system as two parts: a data collecting iPhone application, and a data sharing and viewing website, creekwatch.org.

### 4.4.1. Data Format: Conforming to Standards

To ensure that the collected data would be usable by existing programs, we drew on the California Environmental Protection Agency's Surface Water Ambient Monitoring Program Bio-assessment Standard Operating Procedures[22] and the Rapid Trash Assessment Protocol[23]. These manuals define procedures for reporting on water flow (composed of water level and

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22 California EPA (2010), Surface Water Ambient Monitoring Program: Bioassessment Standard Operating Procedures. http://swamp.mpsl.mlml.calstate.edu/ resources-and-downloads/standard-operating-procedures
23 California EPA (2004) Surface Water Ambient Monitoring Program: Rapid Trash Assessment Protocol. http://www.swrcb.ca.gov/rwqcb2/water_issues/program s/stormwater/muni/mrp/WaterBoard%20Trash%20Assessment%20Method%20SWAMP_v8.pdf

flow rate) and trash levels. With consultation from the California State Water Resources Control Board, we adopted the definitions in Table 1 for Creek Watch. These observations, combined with a photo of the creek, GPS location and timestamp, provide the data that water monitoring organizations most requested.

**Table 1. Water observation definitions used in Creek Watch, from the California EPA's Surface Water Ambient Monitoring Program**

| Water Level | Flow Rate | Trash |
|---|---|---|
| **Dry**: No water Present | **Still**: Water is present but is not visibly flowing | **None**: no trash in the water and surrounding area |
| **Some**: Water fills less then 75% of the channel | **Slow**: Water is present but is barely moving | **Some**: A few items of trash such as cans, bottles |
| **Full**: Water reaches up almost to the top of the banks | **Fast**: Water is present and flow is easily detected | A **lot**: Ten or more items of trash |

## 4.4.2. Data Collection Application

We developed the data collection tool as a mobile application for the iPhone (see Figure 3). The application contains five views divided into tabs: Report, My data, Browse, Instructions, and About. Central to the application is the data reporting view, where users can Report on a creek they are looking at using the data format described above. From the report view users can access a set of photo examples defining the different choices for each data item.

While the application attempts to immediately post reported data to the server, it can also store reported data locally on the phone when the network is unavailable (as is often the case for creeks alongside hiking trails). Users can browse through data they have uploaded as well as data that still needs to be uploaded in the My Data section. Users can initiate another upload attempt for any data that the application has not yet loaded. Users can also manually specify the location for a report if necessary (if, for example, the GPS on the phone could not determine the user's position) before uploading a report.


**Figure 3. Creek Watch iPhone application screen shots**

The Browse view provides a map visualization that enables users to see recent data points collected by others in their area, including photos. The [About] and [Instructions] views provide general information about and detailed instructions for using the application, respectively.

### 4.4.3. Data Sharing Website

The server we implemented at creekwatch.org collects data submitted by iPhones running the Creek Watch application, and presents this data in two interactive formats – a map and a table (see Figure 3).

*A map-based data visualization* A map of all collected data points is the central visualization on creekwatch.org. We designed the map to enable browsing of the data by data contributors who wish to view their own and others' data. We built the visualization as a Google Maps mash-up with the Creek Watch database that displays the location of every data point as map pins, centered on the user's current location. The detailed data collected at each location is available as a popup window with a photo of the creek, or as hover text over each pin (see Figure 3).

*Table based data visualization* We designed the table view for scientists to easily work with the collected data (see Figure 4). Each column provides filters (time, location, data values), and scientists can export the filtered data to a csv (comma separated values) file for inclusion and integration with existing projects. The table view is publically available, such that anyone can manipulate and download the data in this fashion; however the intended audience is scientists in environmental management organizations.

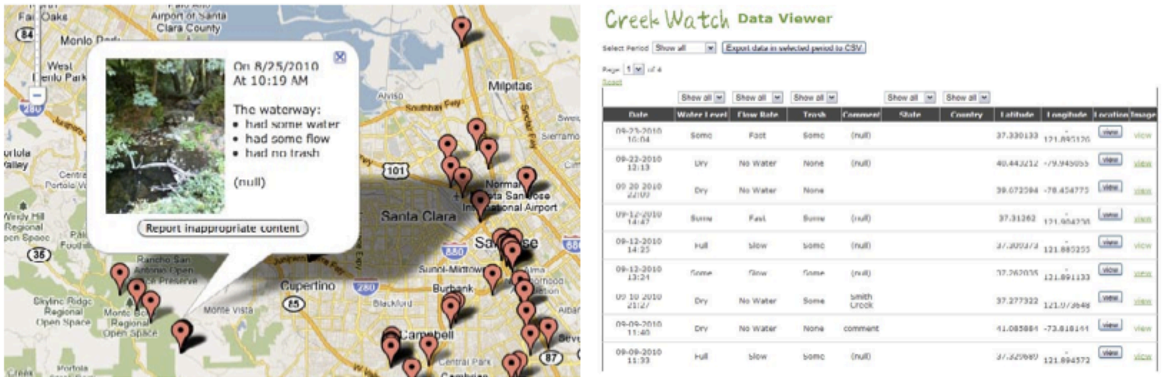


**Figure 4. Map view and Table view with filters of the data collected from left to right at creekwatch.org**

### 4.4.4. Design process

In building Creek Watch we employed a classic iterative design process. Following our contextual inquiry interviews, we built an early version of the application to collect flow and trash data. We demonstrated this first version at an open community meeting with members of the state and local water control boards, and local volunteers. The initial feedback was positive, and we made several small changes to the workflow and appearance based on this review. Examples changes include adding an Instructions view to more clearly explain how to use the application.

### 4.4.5. Usability Study

We conducted a usability study on the user interface with four iPhone users who had no previous experience with water quality monitoring. The study was conducted in two parts: in a controlled environment in the lab, and in the field by local creeks. Our study identified some user interface glitches and workflow issues. For example, in response to our findings in this study, we employed a higher contrast between interface text and the background for easier reading in sunlight, and left more space between buttons to reduce accidental clicking. We also improved the instructions, and re-organized the application to begin with data entry, rather then with data browsing.

## 4.5. User Study

We designed and conducted a field deployment study to evaluate the effectiveness of our system at providing useful information to scientists. We recruited 10 environmental scientists in the City of San Jose Environmental Services Water Resources Department who own iPhones. The study participants included four environmental agents; three environmental outreach or volunteer coordinators, two managers, and one environmental analyst. Six participants were male and four were female. The average age was 45 years old with a standard deviation of 9.7 years. All participants had academic degrees related to environmental management or ecology. We chose to focus on environment scientists for our study participants in order to assess both the usability of the Creek Watch system and also the utility of the data it collects. None of our user study participants were involved in the brainstorming, early interviews, or design of Creek Watch. While we did work with other scientists from their departments to develop the application, for the user study we wanted to see how unbiased scientists would react. The user study consisted of three steps: a pre-study interview, a deployment period, and a post-study interview. The study lasted for 3 weeks.

### 4.5.1. Pre-study interview

The purpose of a pre-study interview was to understand the data needs and collection practices of the participants. Pre-study interview questions included:

- When you need data/information, how do you collect/access it?
- Do you share data you collect? How do you share it, and how is it used?
- How often do you participate in fieldwork?
- What are the difficulties you perceive in water monitoring?

Each interview lasted about thirty minutes, followed by an introduction to the Creek Watch application and website. At the end of each interview we collected demographic and occupational information.

### 4.5.2. Deployment period

We asked participants to use both the Creek Watch application and the websites whenever they felt was convenient over a three-week period. During this time they logged 65 data points in the greater San Jose area.

### 4.5.3. Post-study interview

The purpose of the post-study interviews was to understand both how useful our users felt this data would be and what their reactions were to using the app as a data collector. Post-study interview questions asked about the subjects' use of, opinions about, and recommendations for the Creek Watch application and website. Each interview lasted between thirty minutes to an hour. At the end of the interview, we gave participants a $10 Amazon gift coupon as compensation for their time.

## 4.6. Findings

In our pre-study interviews, participants reinforced the lessons from our initial investigations: traditional scientific methods are expensive and don't scale. The watersheds are too vast to be monitored adequately by their small staff. Several of the participants were in the process of deploying a river monitoring system in Coyote Creek, one of the largest waterways in San Jose. The system consists of nine autonomous units, each costing approximately $8000. The units continuously measure five basic characteristics of the water but must be periodically visited to retrieve data and clean the sensors. With units this expensive, widespread deployment is not an option; most of the creeks will remain unmonitored.

While autonomous units are not the only way to measure creek health, site visits by field agents cannot provide complete coverage of the watershed either. When describing the most important difficulty he faces in his job, one of the field agents stated:

> *"Access is a problem. The big thing is we can only measure in places we can get to, resulting in data gaps."*

This access problem was echoed as the top problem by three out of the four field agents. As our participants are both collectors and consumers of the data, our study provides insights into both aspects of Creek Watch. We therefore divide the findings from our user study into those relating to the consumption of data and those relating to the collection of data.

### 4.6.1. Data Consumption

Our participants agreed that Creek Watch provided very useful data while also providing a low barrier to entry for users. They found the trash data of particular interest. Participants saw opportunities to immediately make use of the data for existing programs in tracking watershed health:

> *"We would use this data... That's our big focus right now- trash." (Project manager)*

> *"A great tool to monitor creeks and help us identify problem areas- one of my coworkers is on creek cleanup and trash keeps coming up." (Project manager)*

> *"For our work in particular [enforcement of dumping regulations], I would be interested in the trash information-to see where folks are finding trash along the creeks." (Field agent)*

As an example, several participants commented on the particular usefulness of this data for local trash cleanup events. One of the volunteer coordinators who manages cleanup events identified the value provided by being able to easily identify "trash clusters" in the data points contributed by other users:

> *"When you get a lot of data points you can see where most of the trash is in the creeks. When groups have cleanup events, now we can find these trash areas."*

These findings were particularly interesting because during our initial contextual inquiries flow data appeared to be in greater demand than trash data. This difference in emphasis may be a reflection on the particular responsibilities of our study participants. While the scientists we interviewed during the contextual inquiry discussed longer term plans for the data's use in environmental planning, the city water board workers seemed more concerned with immediate action items. We note that the ability for a project to yield such short-term wins may increase participation in both contributing and consuming the data.

Participants did also consider flow data to be useful. One participant commented that Creek Watch was "a good way to inventory streams and maybe even keep track of the ephemeral nature of some streams and creeks." The general consensus among our participants was that flow data is useful in the long run for planning, trending and mapping. These results suggest that combining data that potential consumers can use immediately with data designed for longer-term use may increase the likelihood of success for a project by increasing the potential set of people interested in the data.

All of the participants emphasized their belief that Creek Watch would promote public engagement, increase awareness of watershed health, and provide informal science education for volunteers. One of their goals is to make city residents think more about their water and where it comes from, and twice about littering. Creek Watch provides a way for them to engage with their constituents over watershed management.

While participants were largely pleased with the desktop web interface for accessing data, they did make several suggestions for improvements. These suggestions centered on new ways to filter the contributed data. For example, a number of participants wanted to be able to easily filter the data in the table by city. Others wanted the ability to filter the data presented in the map view as well so that they could use the map view for their work.

The latter suggestion was somewhat unexpected, as in our pre-study interviews most participants agreed that they would prefer to access data in table form. However, we found in our post-study interviews that the map view was more popular for data consumption. Participants described "getting a sense of the area" by browsing photographs, as well as "finding trash" using the map view. The preferred presentation mode may depend on the intended uses, with more immediate uses (such as identifying locations with lots of trash) drawing more heavily on the map while uses that involve longer-term analysis (such as changes in flow) may rely on the table format or on the ability to download and work with the data separately.

### 4.6.2. Data Collection

All participants commented how simple and easy to use they found the application. As one participant commented:

> *"Very easy, very quick. I pull up at the creek next to the business I am inspecting and use it."*

Participants also uniformly stated that making the application as easy as possible to capture data was critical.

Five out of ten participants had friends/family members try the application out with similar results; other people found the application "simple to use," and "easy." These results suggest that, in general, volunteers without a scientific background will be able to use the application easily.

Furthermore, our study revealed that participants considered using the application fun. One example participant described how they turned using the application into a game:

> *"We played find the creek: pull over at a creek, jump out of the car, find a good vantage point, enter the data."*

Both of our participants with children of school age took their kids out to a creek to use the application and employed it as teaching tool. One participant recalled,

> *"We talked about recording only what you see and not what you think- a nice teaching moment."*

This participant was reacting to an interesting data collection phenomenon:

> *"When we went to a place that I could not see any trash, [my son] said 'some trash' because of what he knew from other times he'd seen in the area."*

We make two observations about this comment. This behavior emphasizes a potential problem with any user-contributed data: errors that occur to user mistakes, biases, etc. Because data consumers are unlikely to use any data that they do not trust, an application should thus ideally provide a mechanism to allow consumers to easily verify the data. We believe that the inclusion of pictures in the data helps provide this "check". In this case, scientists can see if the picture actually shows any trash.

Several participants requested a comment field to write down what they were seeing. This request is particularly interesting because none of these participants could think of a way that, as data consumers, they would have a use for this data. They simply "wanted to be able to add a little more data." The disparity between their desires as data collectors and as data consumers reinforces the value in studying both aspects of an application.

Five participants reported using the website to compare the data they had collected with existing data. One reported:

> *"I would occasionally browse data [on the map view looking where other people were making observations and checking out their photography."*

Checking data on the map "as a reference" to make sure they were taking data at least as good as their peers was a common theme. We note that this behavior presents an opportunity to seed expected use by ensuring a site has an initial set of "ideal" data points for early adopters to refer to. Previous work in this area has not highlighted this as important, perhaps because most projects started by HCI researchers, practitioners and designers (*e.g.*, Song & Goldberg, 2007) focus on widespread and/or rapid adoption by users.

Overall our participants were very pleased with Creek Watch both as data collectors and data consumers. Even after the study formally concluded they continue to use the application. Subsequent conversations revealed that two of the field agent users plan to incorporate the application into their regular data collecting practices, replacing their current pen-and-paper data collection. While we did not intend Creek Watch to primarily be used by experts in their professional data collection, we regard that acceptance as validation of the usefulness of data.

## 4.7. Conclusion

Our goal in this research was to design an application that would provide scientists with useful data as well as providing a usable interface for untrained volunteers. A key part of that process was the use of HCI methods to investigate the needs of data consumers. We worked closely with state, local, and volunteer environmental groups and employed a variety of contextual inquiry tools to determine what data they wanted and the requirements to make the data usable (*e.g.*, format, reliability, standardization).

Those investigations revealed the following lessons that we believe generalize to other applications:

- When HCI methods are applied to the data as well as the interface, the resulting system can collect more useful data
- Providing reliable and standardized data enables organizations beyond initial stakeholders to benefit from the data in unanticipated ways
- New users make use of sample data to validate their collection practices, suggesting the utility of planting "seed" data
- Combining captured data that organizations can use immediately with data that provides long-term, aggregate value may increase the chance of success for an application.

## 4.8. Follow-up study

As part of a follow-up study of Creek Watch use, Robson et al. examined the report submission at Creek Watch for two years, since its launch in July 2010 (Robson et al., 2013). Since its official launch, fifty submissions on average have been made every month, as seen in Chart 1. (The two predominant peaks in Chart 1 show the initial launch of Creek Watch and the Snapshot Day in June 2011, a campaign to make coordinated observations of the local waterways in California).

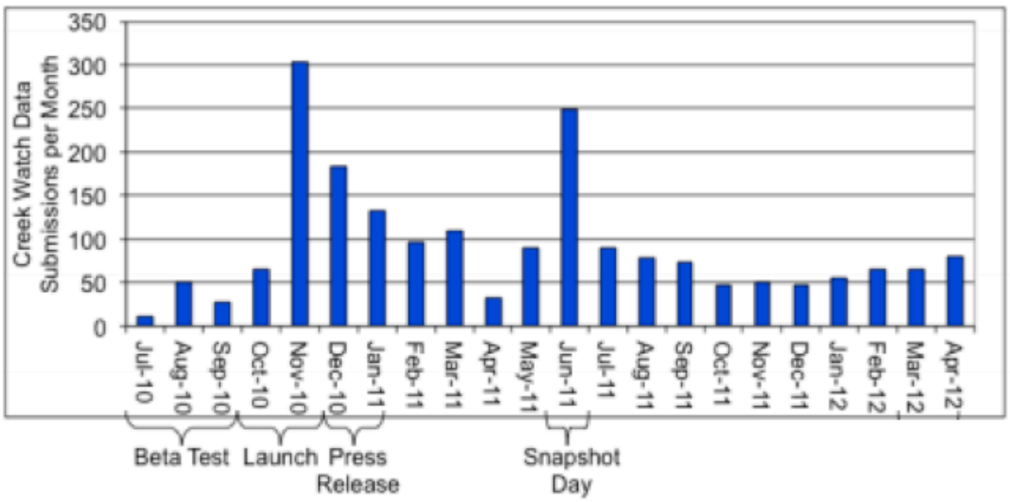


**Chart 1. Creek Watch report submissions for two years since July 2010**[24]

## 4.9. Summary and Next Steps

To provide a focus for this exploration we designed and implemented Creek Watch, an iPhone application and website that allow volunteers to report information about waterways to aid water management programs. Working with state and local officials and private groups involved in water monitoring, we conducted a series of contextual inquiries to uncover ways to figure out what data they wanted and could immediately use, and how to most effectively deliver that data to them.

This study revealed that the data collected through Creek Watch was indeed useful for existing watershed-management practices and was in immediate use in water and trash management programs as soon as data was reported. Overall the participants were pleased with Creek Watch both as data collectors and data consumers. Even after the study formally concluded they continued to use the application. Subsequent conversations revealed that two of the field agent

[24] The graph was excerpted from Robson et al.'s work (2013).

users plan to incorporate the application into their regular data collecting practices, replacing their current pen-and-paper data collection. While we did not intend Creek Watch to primarily be used by experts in their professional data collection, we regard that acceptance as validation of the usefulness of the captured data through Creek Watch.

The collected data has been used by the City of San Jose, including new uses that we did not originally foresee (*e.g.*, using the data for trash clean up site identification and as a data collection tool by field agents). Other water management organizations within California have expressed interest in using Creek Watch.

While successful in designing a mobile application for data collection, we also noticed that the final output could be appropriate to other activities without much modification because its interface was simple, and the components for data collection (*e.g.*, a photo, short comment fields, radio buttons, location information, etc.) were applicable to and required by a wide variety of activities. This shed light on the creation of a flexible framework where people without programming skills can build, distribute, and manage mobile tools for volunteer activities like Creek Watch.

# 5 Field Investigation: the Current Technology Use in Volunteer Activities

The previous chapter demonstrated that a customized use of mobile technology would significantly enhance the work process of volunteer activities in collecting data. Since high technical threshold is one major challenge in the customized use of mobile technology, we took the technical approach to enhancing volunteer activities by enabling to create custom mobile solutions with little technical skills and resources. To build a technical framework that can best support leveraging mobile technology, we first need to understand how the technology is currently used in volunteer activities. In order to gain a comprehensive understanding of the current practices of technology use, we conducted a series of field studies with different methods: an **online observation** of 340 current citizen science online repositories (Chapter 5.1), a **survey** of 46 volunteer organizations on their current technology usage (Chapter 5.2), and **in-person interviews** with 11 local organizations on how they operate volunteer activities using various technologies (Chapter 5.3). We chose to conduct field studies using these multiple methods in order to gain both breadth and depth of insight into the phenomena. The online observation and survey helped to shape the contour of mobile technology penetration in the domain of volunteering, both nationwide and within the geographic region of this study, whereas in-person interviews allowed us to delve deeper into every aspect of current mobile technology use practices in volunteer activities. We conclude this chapter with a discussion of our collective findings across these three studies.

## 5.1. Online Observation: Technology Use in Citizen Science

We reviewed over 340 existing contributory, co-created or co-created projects in an online citizen science repository. We chose SciStarter[25] because it has the largest number of citizen science projects registered among similar services.

25 SciStarter, http://www.scistarter.com/

### 5.1.1. Technology adoption

Only 39 projects (11%) provided companion mobile applications to facilitate data collection efforts. Compared to a wide adoption range of personal mobile devices, this shows that the use of mobile devices is underrated in citizen science. About 180 campaigns (53%) used websites as their primary point of data submission. These websites relied on custom servers or existing web services such as blogs, SurveyMonkey, Twitter, or Flickr.

### 5.1.2. Sensing

A common theme among the projects was the use of location meta-data associated with the data being sourced. Location data is both highly relevant to citizen science data collection and easily sensed with smartphone technologies. In the majority of these applications (*e.g.*, Aoki et al., 2009; Mun et al., 2009), location data is gathered and associated with other information, which varied by the type of observation and equipment used. Photos with accompanying text or numeric data were also common sources of data.

### 5.1.3. Distribution

There are a few web services that offer searchable databases to help individuals find and join projects in local neighborhoods, such as Citizen Science Central[26], Citizen Science Alliance[27], and SciStarter[28]. We examined a random sample of 50 projects registered across a variety of services.

## 5.2. Survey

We sent out survey invitation emails to over 900 organizations listed in a directory of local nonprofit organizations[29]. In total, we sent an invitation email to each organization up to three times in a one-week interval. Because the directory only listed the names of organizations, we searched their websites to retrieve email addresses, and sent invitations to those addresses.

### 5.2.1. Recruitment

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[26] http://www.birds.cornell.edu/citscitoolkit
[27] http://www.citizensciencealliance.org/
[28] http://scistarter.com/
[29] http://pittsburghgives.org/

The target of recruitment was organizations that collect data from volunteer activities. However, the organizations listed in the directory included charities, educational, and research associations that do not involve volunteers, as well as organizations that rely on volunteers to collect data, but were not categorized. Thus, we were not able to filter out in advance the organizations that were beyond the scope of the study. Instead, we described the study and queried those who were eligible to respond, saying “Please answer our survey if your organization coordinates a volunteer activity of any kind and collects data from volunteers”.

### 5.2.2. Survey Questions

Based on the four elements in Activity Theory, we set up a framework of four categories to structure survey questions. The four categories and example questions are as follows:

- Subject: Organization and its members
    - Goal and mission
    - Structure (the number of staff)
- Object: Data collection
    - Data to collect from volunteers
    - Process to collect data from volunteers
- Work process: Volunteer activities
    - Size and frequency of a volunteer activity
    - Role of volunteers in the activity
- Tool: Technology used to work with volunteers
    - Technology/tool used in volunteer activities
    - Social media used in volunteer activities

Most questions in the Tool category allowed selecting more than one answer (The exact questionnaire sent in the survey and their results can be found in Appendix A and B).

### 5.2.3. Participating Organizations

We kept the survey live on Google Forms, where it was available for public access, for two weeks, and received **46 responses in total**. We assume that the number of responses was low because the available email addresses might be poorly maintained or outdated in some organizations. Other organizations might have been either too busy to respond to the survey or deemed themselves beyond the scope of the study.

### 5.2.4. Findings

#### *5.2.4.1. Subject and Object*

The categories of the organizations that participated varied widely. Some examples of responses include those from organizations focused on animal protection, conservation, education, gardening, healthcare, human services, science, and welfare.

One immediate finding of interest was that among the organizations that responded, 77% were run by 10 or fewer staff members. In addition, only 23% had staff members with skills and capabilities in basic web programming and database management, while all organizations extensively used basic IT applications, such as email, spreadsheets, and searching websites.

#### *5.2.4.2. Work Process*

All organizations sought volunteer efforts in a wide variety of tasks, from fundraising to general labor, teaching, reporting incidents, and building their extended community (See Table 2. Multiple answers were allowed in this question). The predominant channels through which an organization's staff members communicated with volunteers were email, in person, web submissions, and phone calls (See Chart 1). Interestingly, 92% of organizations communicated with their volunteers face to face. This might be possible because they are community-based organizations addressing needs in a neighborhood or city scale.

**Table 2. The types of volunteer activities and media used for public engagement (multiple answer question)**

| Type of volunteer activities | % |
|---|---|
| Fundraising | 78% |
| General office services | 73% |
| General labor | 62% |
| Tutor or teaching | 41% |
| Reporting incidents | 24% |
| Environmental project & research | 22% |
| Building community | 19% |

#### *5.2.4.3. Tools*

To the question "Do the volunteers use mobile devices of any form for their activities?", a large proportion of the organizations – 40% – answered that they used mobile devices in their field activities. However, the specific use cases were exclusively for emails and phone calls for communication between coordinators and volunteers using mobile phones on the fly (See Chart 1). We asked whch media volunteers used to submit data in order to understand the current trend of volunteer data submission. Among the unsurprising result of conventional communication media being a dominant tool for data submission, a fairly high ratio of in-person submission – 58% – is noticeable (See Chart 2. Multiple answers were allowed in this question). Additional comments explained that in-person data submissions happen during an activity in the field when volunteers hand over their observation records to the coordinating organizer on site. The formats of data that volunteers collect were fairly evenly distributed between descriptive and numeric with a slight skew to descriptive data: 66% vs. 50% (See Chart 4). In addition, location information and pictures often come with those data as auxiliary information. Lastly, all organizations said that they wanted to incorporate mobile technologies somehow in their volunteer activities, but none of them clearly described concrete ideas.

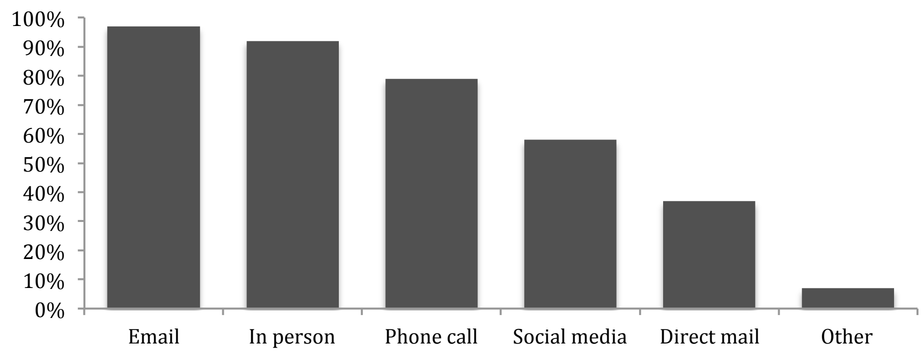


**Chart 2. Media through which an organization communicates with volunteers (multiple answer question)**

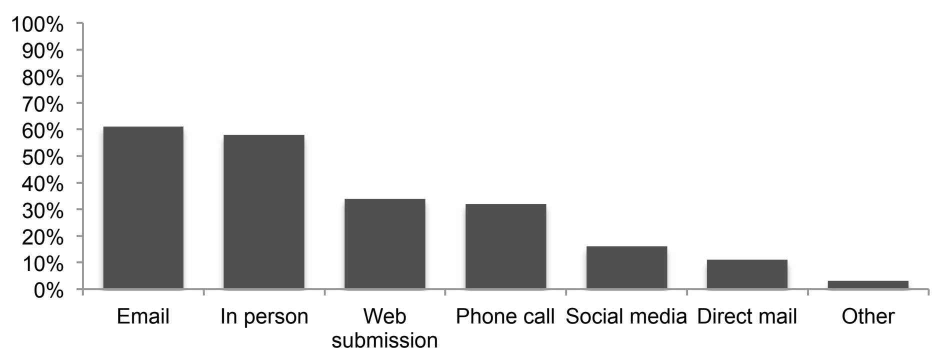


**Chart 3. Media used for data submission in volunteer activities (multiple answer question)**

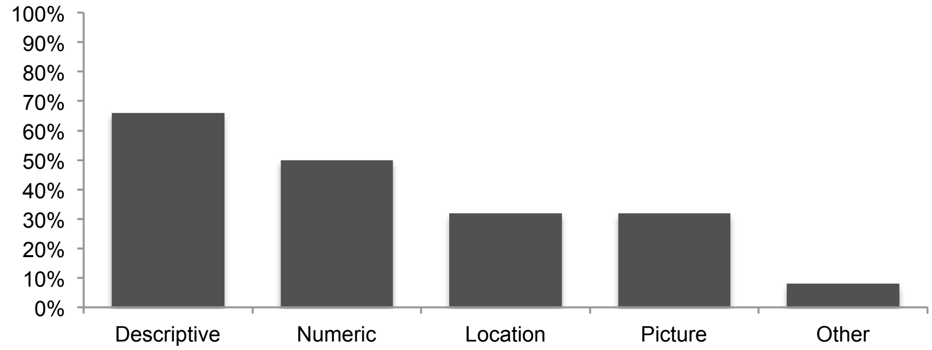


**Chart 4. Data format in volunteer activities (multiple choice question)**

### 5.2.5. In Summary: Survey

In all, the findings from the survey indicate that the patterns of technology use in support of volunteer activities have one trend in common: extensive use of conventional communicating technologies, such as email, phone call, and social media. While use of mobile technology was mentioned in volunteer activities, the extent to which they leverage its capabilities was limited to the mobility aspect of conventional communicating technologies on the go through mobile devices. While strong interests in making use of mobile technologies exist, the concrete ideas of leveraging mobile technologies further in depth through building custom mobile applications had not been explored. These findings were used to list candidate organizations to recruit for in-depth qualitative investigations.

## 5.3. In-Person Interviews

From the findings of the previous two studies, we roughly sketched out the current practices of mobile technology use in volunteer activities. In order to understand further, we conducted in-person **interviews with eleven staff members of local organizations** that coordinate and operate volunteer activities.

### 5.3.1. Recruitment

We spoke with some local organizations contacted in prior research, and asked them to introduce other organizations that might be relevant to the study, following the snowball method of recruitment. Lastly, we looked up on/offline repositories where organizations post their activities and advertise volunteer recruitment, such as local newspapers, community bulletin boards, meetup.com, websites, and mailing lists. From these and survey respondents, we made an initial list of over thirty local organizations that fulfilled our recruitment criteria, and then contacted each of them. Among them, ten groups were filtered out because they did not have any active volunteer activities at the time of recruitment, and ten other groups did not show interest in participating in the study. As a result, we recruited eleven organizations (See table 3).

### 5.3.2. Participating Organizations

The eleven organizations fell under one of two thematic areas based on their goal: (1) environmental activism and (2) community mobilization. We did not initially set out to recruit organizations based on these two types, but rather the types emerged organically through our analysis process. While these two categories do not cover the more broad domain of volunteer-driven organizations, they are representative of popular community groups within this space. In fact, all recruited organizations were not exclusive to a single type, and often did work in both types. For example, the waterfront cleanup group focused not only on keeping water habitats healthy (environmental activism) but also contributed towards a livable community (community movement). Nevertheless, we were able to group the organizations by their primary goals. Therefore, we believe it to be a legitimate starting point to explore ways to make use of mobile technologies in volunteer activities.

The number of full-time staff in the organizations ranged from three to eleven (See Chart 3. Multiple answers were allowed in this question), with an average of 6.4. One exception was a group with eighty-seven staff members. This group was much larger because it operates a warehouse to stock and distribute food, and seventy-five staff members work in food distribution. Only twelve members do general work to operate volunteer activities that nonprofit organizations commonly do, which is similar to the size of other groups. All organizations handled a large volume of volunteers, especially in relation to the number of paid staff. Six organizations had thousands of registered volunteers, with active participation numbering in the hundreds (See chart 5). Seven organizations had hundreds of registered volunteers, with active volunteers varying from tens to hundreds depending on the kind of activity.

**Table 3. A list of participating organizations**

| Type | Site ID | Description of site's programs | The title of the interviewed staff | The number of staff | The number of volunteers |
|---|---|---|---|---|---|
| Environmental Activism | EA1-birds | Bird counting | Leader* | 7 | 1,000 |
| | EA2-birds | Bird counting | Leader* | 5 | 1,500 |
| | EA3-dumping | Cleaning up illegal dumping | Executive director | 3 | 2,000 |
| | EA4-water | Water quality monitoring | Outreach manager | 6 | 300 |
| | EA5-water | Water quality monitoring | Watershed protection manager | 7 | 500 |
| Community Mobilization | CM1-reuse | Waste reclaiming | Executive director | 5 | 200 |
| | CM2-dev | Community development | Executive director | 9 | 500 |
| | CM3-bike | Bike-safe community building | Advocacy director | 7 | 3,000 |
| | CM4-dev | Community development | Executive director | 11 | 300 |
| | CM5-shale | Protest against Fracking | Executive director | 4 | 2,000 |
| | CM6-food | Eliminating hunger in a community | IT director | 87 (12)** | 14,000 |

* Two organizations do not have an executive director, but have a leader representing the organization.

** Among 87 staff, only 12 staff worked for the general administrative tasks, and the rest 75 staff worked for warehouse management in food distribution.

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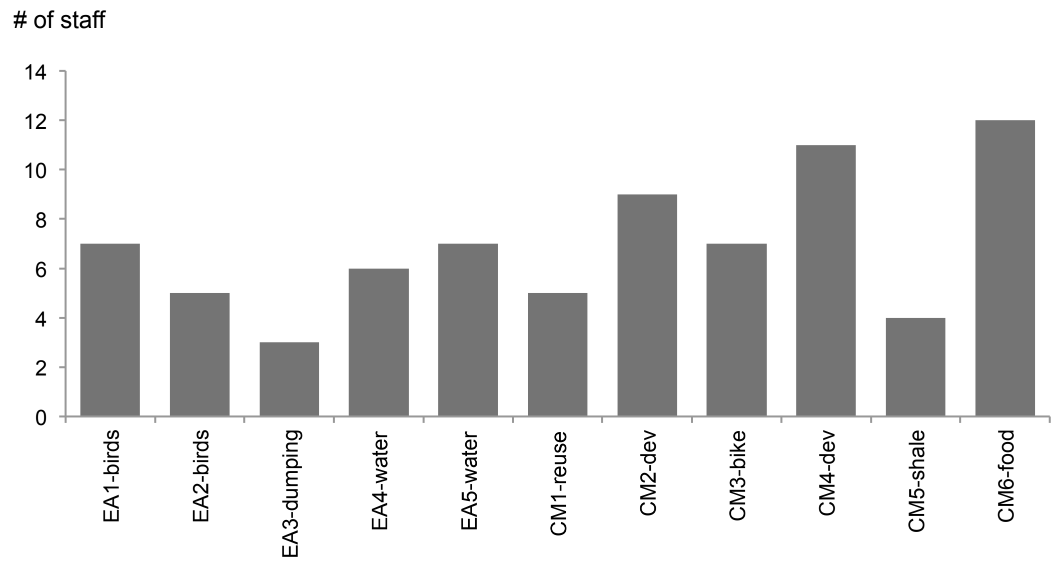


**Chart 5. The number of full-time staff members in each organization**

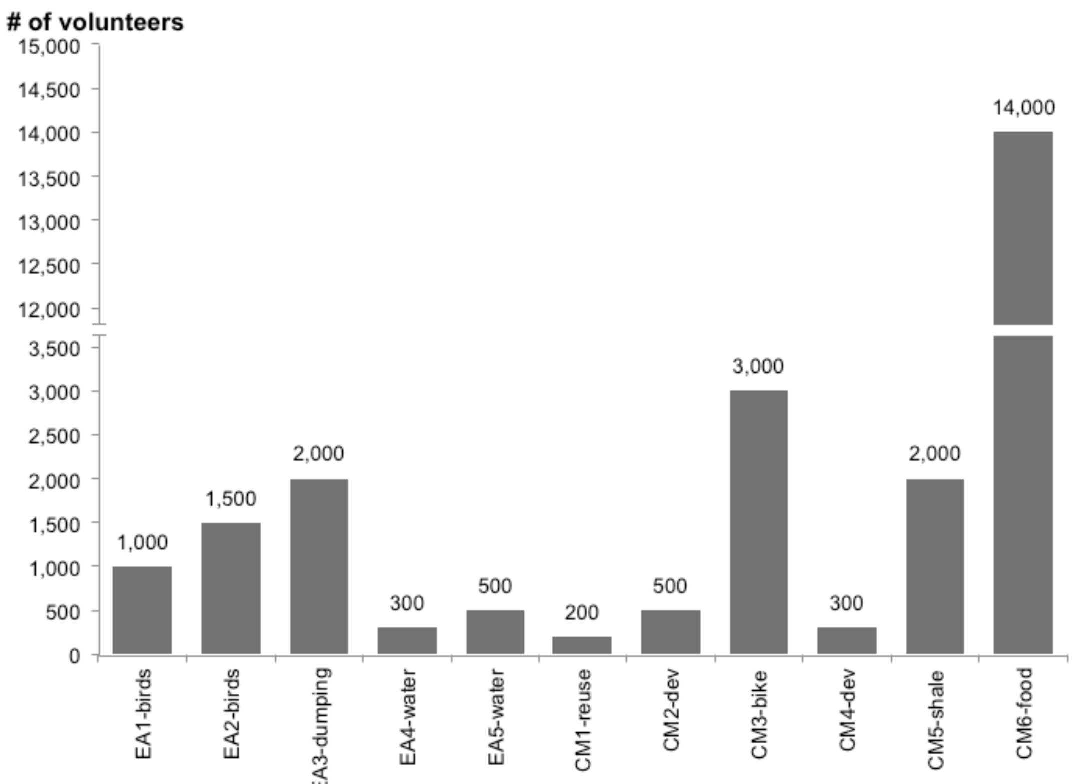


**Chart 6. The approximate number of volunteers in each organization**

To protect anonymity, we refer to each organization with the type acronym and a randomized number (*e.g.*, EA1-birds for environmental activism group 1 for bird counting, CM2-dev for community mobilization group 2).

#### 5.3.2.1. Environmental Activism Organizations

Environmental activism organizations aim to protect wilderness, monitor environmental conditions, and promote eco-friendly activities. We recruited five such organizations.

- EA1-birds organizes bird watching field trips and conservation-related activities. Also, they connect people in southwestern Pennsylvania to birds and nature through their programs. This organization has seven staff.

- EA2-birds organizes local outings and gatherings in the metropolitan area. Through these outings, they aim to educate people on nature and birds, engage people in conservation and data collection for birds, and socialize among members. They have five staff.

- EA3-dumping's goal is to create healthy community, healthy neighborhoods, and healthy green space. They pursue their goal by cleaning and monitoring abandoned dumpsites. This organization has three full-time staff.

- EA4-water provides a sustainable environment for its residents and businesses, and preserves clean and healthy natural habitats in the area. They work to improve water quality in areas such as wastewater treatment, the sale of drinking water, and recycled water. This organization has six full-time staff.

- EA5-water protects drinking water source and watershed. They also do dangerous species act compliances and related regulatory compliances as part of drinking water management programs, and manage compliance with state and federal regulations. They have seven full-time staff.

#### 5.3.2.2. Community Mobilization Organizations

The ultimate goal of community mobilization organizations is to improve the quality of living in the community. These organizations strive to improve or protect various aspects of the community. We recruited six such organizations.

- CM1-reuse promotes resource conservation, creativity, and community engagement through material reuse. They pursue their goal in two primary ways: operating a store where people can obtain reclaimed materials for creative projects, and hands-on educational outreach on creativity and sustainability. The ultimate goal is to contribute to general quality of life in the community through reclaiming materials. They have five full-time staff.

- CM2-dev aims to improve the quality of life in high-poverty areas in their city. They work to eliminate blighted conditions in the community, addressing educational deficits, and bringing social stability to the area. They have nine full-time staff and about a dozen part-time staff.

- CM3-bike makes the streets safer for biking and walking in the city. Their work falls under three categories: advocacy, safety and community. For advocacy, they work to make the environment better for cycling. For safety, they produce a bike map to help people find the safest bike routes. For community, they build up the community so that people get together to go biking. They have seven full-time staff members.

- CM4-dev is a group that enhances quality of life by determining the effective and efficient use of its natural systems, infrastructure, cultural assets, recreational amenities, and economic resources. They work for preservation of cultural heritage, parks, the urban design, the infrastructure, and land uses in the city. There are eleven full-time staff members working for this organization.

- CM5-shale is a coalition that aims to end Fracking and drilling for natural gas from shale. They grew out of a one-time demonstration in 2010 to an organization with a permanent structure. Since then, they have become an umbrella organization for smaller grassroots groups in different neighborhoods. This group does not have any paid staff but have four voluntary staff members.

- CM6-food collects and distributes food. They gather food through solicitation, fund raising, special events, and community partnerships. They distribute millions of pounds of food per year through various outlets, such as soup kitchens, food pantries, shelters, after school programs, drop-in centers, neighborhood food assistance agencies, emergency or disaster-related feeding sites, community centers, and special programs. There are eighty-seven full-time staff members. Twelve among them are involved in general administrative tasks whereas the rest works for operating warehouse for collecting and distributing food.

### 5.3.3. Data Collection and Analysis

We conducted semi-structured interviews to understand the current practices of technology use in the organizations without limiting the freedom of direction of the conversation (Herr & Anderson 2005). We visited the office of an organization when available. If they did not have a physical office space, we either invited them to our laboratory or met them at a place of their convenience.

Based on the four elements in Activity Theory, we set up a framework of four primary themes to lead the interview. The structure was similar to those for the survey, but details in each interview varied in order to allow the researcher to bring up new ideas during the interview based on what the interviewee said. The four themes included:

- Subject: Organization and its members
    - Goal and mission

    - Structure (the number of staff)
- Object: Data collection
    - Data to collect from volunteers
    - Process to collect data from volunteers
    - Challenges in data collection
- Work process: Volunteer activities
    - Size and frequency of a volunteer activity
    - Role of volunteers in the activity
- Tool: Technology used to work with volunteers
    - Currently used tools – Technology, mobile, social media
    - Possible mobile technology use
    - Challenges in the current tool use

One staff representing the organization (*i.e.*, executive director, leader or manager) participated in the interview. In the analysis, we refer to them as "staff". Each interview lasted between one to two and a half hours. All interviews were audio recorded.

We transcribed the interviews, and then coded them using inductive and deductive approaches informed by grounded theory and other qualitative analysis methods (Strauss & Corbin, 1990; Miles & Huberman, 1994). In the analysis, we identified the four themes and the relationships among them, particularly focusing on the interview data that related in some way to how organizations made use of technology in their volunteer activities, and how they coordinated the activities more broadly. Using inductive qualitative methods, we iteratively developed a coding scheme related to technology use in volunteer activities. Our initial set of codes typically related either to specific kinds of challenges or to rationales for using particular technical tools. Subsequent iterations of the coding scheme helped to link the type of organizations and the kinds of challenges in coordinating volunteer activities. Our final iteration of the coding scheme helped us focus on the challenges and opportunities in mobile technology use for volunteer data collection activities.

### 5.3.4. Results

We used Activity Theory to determine and investigate elements that are associated with understanding the technology use practices in volunteer data collection activities. The results will be presented primarily around the Tool theme and its relation to other factors.

We first examined the practices of technology use in the organizations in general, and then explored their differences by the type of the organization. Lastly, we identified the challenges that the organizations faced with regard to mobile technology adoption in volunteer activities.

### *5.3.4.1. Technology Use in General*

Not surprisingly, all organizations extensively used information technologies and social media, as well as conventional technologies, like landline phone, fax, and pen-and-paper, in combination to coordinate volunteer data collection activities.

First, conventional technologies, such as landline phone, fax, and pen-and-paper, are still widely used by all organizations. Even though they are easy to use at hand, however, the temporal distance between manual data capture and digital sharing poses an issue when used for data collection

Volunteers often do not report their findings back promptly, and may forget to do so afterwards. That is why some program coordinators have to remind volunteers to report through another set of conventional technologies.

> *"Our program coordinator calls [volunteers]. Or, they might call or email her without being prompted. But it's usually the other way around because they forget [to report] and because it's not their top priority. For now, it's manageable to call, because it is small, around twenty [volunteers]. But it's going to grow pretty quickly. And if it gets larger, then that will become really cumbersome to call everyone and to email everyone" (EA3-dumping)*

In particular, a pen-and-paper mechanism has two significant drawbacks despite its merits of being easy and simple to use; data retrieval is hard (*e.g*., finding information from a written document), and data need to be digitized manually (*e.g*., entering data on a paper into a spreadsheet). Both processes are time consuming and prone to human error.

> *"Because it uses staff time [to type hand-written data into a database], sometimes the orders are wrong, sometimes they [staff] don't get the date they want quickly [from paper]. So we want to move... drive it to be online. Everything online." (CM6-food)*

> *"It is a paper report. It goes into a file. Then when we need to find any information for data, it is next to impossible to get any information." (CM1-reuse)*

A website is widely used to distribute information to a wider audience affordably and effectively. All organizations operated their own homepage as an online repository to post retrievable data and to share information. However, a website is a passive platform, as people must be prompted somehow to access the website. Thus, when information should be viewed immediately, such as recruiting volunteers for upcoming events, email and social media are often used in combination as a trigger for target populations to access the information faster.

> *"…, putting information [on our homepage] coupled with our social media, which are primarily through Facebook and Twitter, were how we were sending updates and letting people know what's going on." (CM2-dev)*

Also, social media provide a virtual space where people communicate with each other and exchange information, and that is why all organizations used social media.

> *"We want to increase the sense of belonging in our organization, being part of the communities of people who are interested in doing similar things." (CM1-reuse)*

Eight organizations said that they used social media to post news and information about upcoming activities, as well as to communicate with volunteers. Then, a major shortfall of social media lies in a divide between communication dialog content on social media and the internal database of an organization. Even though social media are a powerful tool for communication, all such communicative data is stored on the third-party's database (*e.g.*, Facebook server), making it difficult to have full manipulation of the data. Three organizations sought ways to measure the impact of social media on offline activities. However, without a technical intervention or manual, time-consuming data scraping, it is difficult to determine its effects. Thus, all organizations used social media without any follow-up investigation of its influence.

#### *5.3.4.2. Technology Use by the Type of Organizations*

A difference in the format of collected data has emerged by the type of organization; environmental activism organizations mainly collected objective measurements or observation data from field observation activities (*e.g.*, monitoring water quality), while community mobilization organizations mainly sought public opinion and feedback about the issues of their interest or concern (*e.g.*, feedback about new community facilities). We found that this difference led to a significant distinction in technology use.

##### (a) Environmental Activism Organizations: Objective, Measurements Data

Environmental activism organizations primarily seek objective, factual, standardized, and sometimes, numeric data about the condition of community environments. The data to collect is predefined by particular protocols or requirements, and volunteers are required to follow set rules when collecting data. Therefore, accuracy was regarded as a barometer of data quality.

> *"[The collected data] has a chain of custody requirements to follow. So, you have to have hard copy data formats in the field when you are collecting data." (EA4-water)*

Volunteers who monitor or observe the current environmental conditions gather this type of data. The prevalent practice of collecting environmental observation data involves a combination of pen-and-paper for manual data capture and information technology for digital sharing: people write down their observations out in the field, and then send an email of their findings to a program coordinator.

> *"[Volunteers] write down data and email it to me later." (EA4-water)*

### (b) Community Mobilization Organizations: Opinion and Feedback

Conversely, community mobilization organizations usually collect subjective information from their community members about community conditions and neighborhood issues, such as public opinion, feedback, thoughts, reports, and suggestions.

> *"We want to understand what projects people thought of as priorities, if there were projects people had a problem, concern, or issue with, or if there were certain things that they had comments on" (CM1-reuse)*

Local knowledge and community-based information are critical for the organizations to collect from the public, because community members are (often the only) stakeholders who possess or have easy access to such data. This information helps shape a focus of volunteer activities, such as determining the community living conditions or the problems community members should become aware of.

> *"We gather data on the conditions in the community. We have a night for the residents of the community to come together… to gather living condition of our community and try to put a plan together that embodies that input." (CM4-dev)*

The complicating matter about collecting subjective information is that it is legitimized when it is accompanied with specific descriptive data, such as the locality of respondents or demographics. For example, the respondents' locality helps figure out a geographic region of issue or concern, and demographic breakdown determines community needs by population. To reduce participation cost and promote public engagement, many organizations use free-form communication technologies, such as email and online bulletin boards. One issue with these tools is that it is hard to acquire specific descriptive data. Thus, most community mobilization organizations have sought ways to require specific descriptive data as part of their submission.

> *"Location is important. It is good to know if there is a certain parking garage that's getting hit a lot, for example." (CM3-bike)*

> *"We are looking for more specific data about who the hungry people are, and what legislative districts they are in. If the data has a marked GIS software, we can actually map the data, and if we can get census data, we can map the poverty areas in all counties." (CM6-food)*

While a single content is valuable, data become much more meaningful and representative when the quantity becomes large enough to render a trend. Therefore, the frequency or volume of data submission is considered crucial in community mobilization organizations, and regarded as a barometer of data quality.

> *"Even if you don't take all suggestions, if you look at a road and if there is, like, a hundred suggestions on this road and only five over there, you know that there are a lot of people using this, and we want to try to make this road better first, not that road." (CM3-bike)*

#### *5.3.4.3. Current Use of Mobile Technology*

All staff members mentioned that mobile technologies, and smartphones in particular, might be an additional yet effective channel through which the public could easily engage in their activities. The fact that people carry their smartphones everywhere was counted as the significant advantage of mobile devices.

> *"The thing about being out on a bike is that… when you come into some sort of issue, if you have a mobile device, you can think about it right there and you can report it right there." (CM3-bike)*

However, the actual use of mobile technology was marginal. Among those who participated, only one organization used mobile technology for their field observation activities. They used an off-the-shelf mobile application for monitoring water quality, designed particularly for monitoring streams and creeks, in which water flow is an important measure. However, this organization primarily monitors lakes, which do not have a flow property. Thus, they wanted to tailor this app, either by changing the label of the "flow" field to something else, or getting rid of the data entry for "flow" entirely. However, because it is an off-the-self app, they could not make any changes.

> *"[The water quality monitoring app] has a rating option for flow of the water. The lake [we monitor] is always still, but the app] infers that you are looking at a stream that's not flowing." (EA4-water)*

The rest of the organizations merely used conventional communicating technologies on the go through mobile technology. All organizations mentioned they were using mobile technologies by sending and receiving emails or using social media in the field to communicate with volunteers in real-time (Briones et al., 2011; Liu et al., 2010). We then conducted an additional session in which participants freely discussed potential use cases and ideas of mobile technology adoption. In the beginning, the conversation was not active, because the organizations had little ideas of how to facilitate mobile technologies at hand. All said that they had barely thought about using mobile technologies in depth. All organizations are run by a small staff, and all staff members are in charge of more than one task. Therefore, because their resource capacity is already fully loaded, it was hard to allocate time to explore new ideas of facilitating mobile technology in funded projects or other planned activities. As such, lack of technical expertise and resources prevented the organizations even from exploring the capabilities and potentials of mobile technologies.

> *"We haven't thought much [of using mobile apps]. The [staff is] overworking right now. We will make it too hard for them to think of something new." (CM6-food)*

> *"Unless it's related to funding… [It is hard to spend time on it]" (EA3-dumping)*

However, once one idea came up in the middle of discussion, the conversation gradually became active, associating other ideas with diverse functionalities for varying objectives. Following are some example ideas.

*"Something like… that people could hold the phone over the paper and then information would come up on the phone screen. If you hover over a section on a map, the device would tell you more about the section." (CM3-bike)*

*"If there was some way of including some kind of recycling or reuse data collection on something that you created, so that you can tell yourself like 'I recycled 20 pounds this month' or something. That would help us a lot with quantifying activities both creativity-wise and recycling-wise." (CM1-reuse)*

At the end of the session, all staff members commented that they enjoyed the brainstorming sessions and it helped refresh and broaden their views on their activities with regard to mobile technologies.

#### *5.3.4.4. Challenges in the Adoption of Mobile Technology*

As expected, all organizations mentioned resource constraints as a major barrier to the adoption of mobile technology. All organizations worried about lack of technical expertise and resources even before exploring the feasibility and benefits of mobile technology. All staff members commented that the technical threshold was too high to overcome, and they struggled with resource deficits.

*"We really don't have the expertise to build that app and to test that app and to make sure that it feeds into our existing system. I would say probably that's the biggest reason."(CM2-dev)*

*"We just don't have the staff or budget to do that (build a mobile app)." (CM1-reuse)*

Beyond resource deficiency, we identified two perceived challenges in the adoption of mobile technology for volunteer data collection activities: *questioning the credibility of public participation* and *mobile interaction interfering with field experience*. Compared to various reasons that prior works have determined in the slow adoption of IT in nonprofit organizations, including individual differences, organizational factors, IT capacities, training, performance measurement, and contextual influences (Jelinek, 2006; Hackler & Saxton, 2007; Zorn, 2011), we found fewer challenges with regard to mobile technology adoption. Also, we did not find that the challenges in IT adoption would apply to mobile technology either. We assume that it is not because those challenges do not exist when adopting mobile technology but because mobile technology has yet to be fully explored until other challenges emerge beyond the perceived challenges posed by staff members.

### (a) Questioning the Credibility of Public Participation

Prior works have proven that the quality of novice-collected data is as valid and credible as professional-collected data (Cohn, 2008; Raddick et al., 2010). However, we found that strong distrust regarding the credibility of novice-collected measurements data still exists. This tendency was particularly conspicuous among environment movement organizations that collect measurements data.

The mobility of mobile technology enables anytime, anywhere computing (Davis, 2002). Therefore, when successfully adopted, mobile technology used in data collection activities could result in an increased volume of data. However, a large volume of data may not be considered favorable at all times, because autonomous participation of novice volunteers, especially in the absence of a direct guidance or hands-on instruction, implies a lack of quality in the data. One staff member clearly expressed how much he mistrusted the quality of novice-collected data:

> *"I wouldn't even bother looking at that data if I know that volunteers collected the information." (EA5-water)*

Thus, environmental movement organizations considered most volunteer data collection activities as educational outreach to increase public awareness, change behaviors, and engage the public in protecting the environment, rather than collecting data.

> *"I see those events mostly as educational events rather than monitoring events. To date, that has been the origin of most of our volunteer monitoring." (EA5-water)*

And, as part of education, they wanted to have a mobile tool to support data capture to sharing in the field. Its main purpose was to provide a quasi-real experience to volunteers in order to increase a sense of achievement and to train novice volunteers for "real" data collection activities.

> *"It would be nice to show the volunteers that 'look we are putting your data in to an international database. Your data don't go to a pile of paper on my desk but goes here.'" (EA5-water)*

When volunteers participate in the activities for a considerable amount of time, staff regards them as trusted members with appropriate skills eligible for actual data collection.

> *"Some of the volunteers became skilled. If they would like to get involved in the bigger stuff, then those volunteers often become dump busters (experts in dump site cleaning)." (EA3-dumping)*

#### (b) Mobile Interaction Interfering with Field Experience

Being able to report on the go has been taken for granted to improving the field experience and enhancing the efficiency of the work process in public participation (Newman, 2012). However, we found that interacting with mobile technologies in the middle of the work process may cause harm as well as good. People engage in community activities not only to contribute to civic improvement, but also to experience and learn about the issues of concern or interest. One staff volunteer (a staff in the organization who volunteers, too) expressed her negative feelings from past experiences about interacting with mobile devices in the woods:

> *"Birds are not going to stay dormant. You watch it and take notes on it, and that bird is already leaving. Also, I find it distracting to use my cellphone in the field because then I read emails, and I send text messages. So, I prefer not to actually do any logging in the field on my phone." (EA1-birds)*

When people want to enjoy the moment as part of engaging in the activity, they feel that interacting with technology in the field distracted or interfered with their experience. It indicates that not only is it critical to enhance the efficiency of the data collection process technologically, but also the additional interaction posed by technology adoption should be seamlessly integrated into the existing process.

### 5.3.5. In Summary: In-Person Interviews

In this section, we reported our findings of how local organizations make use of different classes of technologies to facilitate public engagement in their data collection activities. We observed that the ease and simplicity of use directly influence the wide adoption of the tools, and various tools are used in combination to supplement respective shortcomings. However, the tools currently used have several limitations that mobile technology may overcome, although its capabilities and opportunities have been hardly explored. Lastly, we identified the perceived challenges from leveraging mobile technology in the organizations: questioning the credibility of public participation and mobile interaction interfering with field experience. These must not be an exhaustive list, and more challenges might emerge as the adoption and actual use of mobile technologies increase. However, we believe that they are a critical starting point to consider, since the perceived challenges constitute the initial obstacles to overcome in the first step towards the adoption of mobile technology.

## 5.3.6. Discussion

Based on our findings, this section discusses ways to leverage mobile technology for volunteer data collection activities, focusing on its capabilities to cope with the impediments lingering in the current practices of technology use. We draw from the results across all three studies, online sites, community surveys, and in-person interviews.

### *5.3.6.1. Enhancing the Process of Data Collection*

The first and foremost goal of public participation in data collection activities is of course to collect data. The appropriate use of mobile technologies through a combination of its wide adoption rate and the extensive technical capabilities can significantly enhance the process of data collection technically through the following three ways.

#### (a) Increasing the Quality of Volunteer Collected Data

Oftentimes, volunteer-collected data cannot be used until its quality is validated somehow, and thus it is important to have systematic ways to assure or validate the quality of volunteer-collected data (Newman, 2012). We found that the type of organization determines the barometer to measure the quality of data – data accuracy in environmental activism organizations, and large volume of data in community mobilization organizations.

The use of mobile technology can inherently improve the quality of collected data, satisfying both kinds of quality barometers. Data accuracy will be enhanced by the customized use of extensive technical capabilities of mobile technologies: a cluster of built-in sensors embedded in modern smartphones will turn into personal monitoring equipment for accurate measurements, a pre-defined set of questions to answer in a mobile application will become a reference to collecting data accurately without external guidance, and a simple mobile user interface with large buttons will reduce human errors in data entry. A large volume of data can take place because the high adoption rate of mobile technologies increases the chances for the public to participate in volunteer activities digitally at anytime and anywhere.

### (b) Bridging the Temporal Distance Between Data Capture and Share

Currently, the prevalent tools used for data collection are a combination of pen-and-paper and email. While easy and simple to use, those tools are inevitably accompanied with a temporal distance between the time to capture data using pen-and-paper in the field, and the time to share it using email at home. This causes delay or omitting to share the collected data. A Wi-Fi-enabled mobile application can easily bridge this temporal distance by enabling users to share the data on site right after capturing it.

One concern is that interacting with technology in the field may interfere with the existing practices of an activity. Especially when an activity involves aspects to appreciate the moment of participation as is, such as an environmental observation or community gathering, having to use technology could be bothersome and incongruous. Thus, it is critical to ensure that the additional step of interacting with mobile technology must be interwoven seamlessly into the current work process of an activity.

### (c) Making it Easy to Manage Data

As the amount of the collected data increases, the question of how to effectively manage the large volume of data emerges. Because the intent of involving volunteers in data collection activities is often to collect more data than the amount that a single person could collect, handling a large volume of data should be taken into consideration.

In volunteer activities, an email is used most often to turn in data, and a phone call and hand-written notes are also widely used. Consequently, it requires a substantial amount of time and effort to digitize analog data, to organize the collected data, and to store the data on a database server. A mobile application that allows digital data submission would significantly reduce the efforts for data management, as the data will be organized and stored in a digital format automatically.

In addition, it is important to consider effective ways to make use of the collected data, since the collected data would have no value until used properly. Therefore, a systemized management tool for data storage, control, analysis, and visualization needs to be considered to operate digital volunteer activities successfully.

### *5.3.6.2. Promoting Deeper Engagement with Volunteers*

Another critical goal of volunteer activities is to educate the public, raise their awareness, and promote community engagement in the issues of concern. Mobile technology could be a platform to make the experience more engaging, and to foster a sense of community among participants.

### (a) Making the Experience Tangible

Engaging actively in hands-on activities can increase knowledge acquisition and general cognitive development, as well as promoting a sense of achievement. Because of the concern about the quality of novice-collected data, many volunteer data collection activities are intended to increase public awareness and involvement in the activities, rather than collecting data itself (Mueller, 2012). Since one's mobile device could be used as a personal tool to manipulate the entire process of data capture and share, using mobile technology can make the experience of participation tangible. And, providing tangible experiences will help increase the public to engage more in activities by making the field experience fun and persuasive.

Through active engagement in hands-on activities, novice participants often naturally turn to trained volunteers who are eligible to conduct more sophisticated, actual data collection activities. Thus, not only does making the volunteer experience tangible make the activity more vibrant and engaging, but it also develops expertise and sophistication in data collection activities.

### (b) Improving a Sense of Community

Because volunteering normally does not provide direct personal benefits, many volunteer-driven organizations have tried to formulate indirect benefits for volunteer participation. Fostering a sense of community is one form of indirect benefits that many volunteer activities provide (Nov et al., 2011). Furthermore, attachment to other members in a group can increase commitment to the group as a whole (Sassenberg, 2002). As this attachment can be raised easily through communication among members in a group, social media are frequently used to encourage community members to share experiences for community engagement.

While social media are an effective tool to improve a sense of community, it also has a drawback: it is not easy for the organization to obtain the data generated through social media, such as communication dialog and shared media, except through time-consuming, manual data scraping. This is why many organizations were looking for customized, in-house systems to serve similar needs as social media, while having the full managerial capabilities in data manipulation. Custom mobile applications to support data collection activities could easily facilitate simple features for sharing auxiliary information about the collected data. The increased sense of community will ultimately have a positive influence on offline participation to promote public commitment to field activities.

#### *5.3.6.3. Considerations*

Currently, information technologies are the most prevalently used media for electronic data submission, and our discussion proposes that a proper use of mobile technology will fulfill the needs and challenges that those tools pose. Technical capabilities of mobile technology including photos, location, and other built-in sensors could be used to enhance the process of data collection, but require custom mobile applications to be effectively incorporated into data collection, something non-profits have not yet invested in for the most part. Hence several providers have emerged in the last several years to serve the non-profit market with off-the-shelf solutions for a variety of mobile needs (*e.g*., Aanensen et al., 2009; Hartung et al., 2010; Ramanathan et al., 2012). Another caveat is that mobile technology is still a supplementary tool to support activities, not an almighty magic wand to solve all problems. Therefore, a thorough understanding of the context in which mobile tools will reside in, and a strategic approach to the goal that such tool use will pursue, should precede the adoption of mobile technology.

### 5.3.7. Conclusion

Two categories in the organizations by the goal of volunteer participation have emerged through the analysis: environmental activism organizations for nature conservation, and community mobilization organizations to enhance the living conditions of a community. We found that these categories determine the opportunities of mobile technology with regard to data quality assurance. Environmental activism organizations collect measurement data so that the technical capabilities of mobile solutions can support validating data accuracy. Community mobilization organizations seek a large volume of public opinion so that the widespread of mobile technology can expand the channel through which the public participates in the activities.

We explored how the organizations make use of different classes of technologies, including conventional technologies, information technologies, and social media, in volunteer data collection activities. From this exploration, we identified two perceived challenges that contributed to the underutilization of mobile technology: questioning the credibility of public participation, and mobile interaction interfering with the field experience. Then, we discussed the implication areas to leverage mobile technology for enhancing data collection process and promoting deeper volunteer engagement, focusing on its capabilities to cope with the impediments lingering in the current practices of technology use.

The challenges and opportunities in mobile technology adoption that we identified must not be an exhaustive list, and more might emerge as the adoption and actual use of mobile technologies increase. However, we believe that they are critical starting points to consider, since the perceived challenges constitute the initial obstacles to overcome as the first step towards the adoption of mobile technology, and the identified opportunities are fundamental elements for successful volunteer activities. We believe our findings will help empower the organizations to achieve their goals for volunteer activities through the appropriate use of mobile technology.

## 5.4. Review: Existing Technology to Author Mobile Solutions

Recently, a small number of web platforms and tools that focus on making it easier to create a mobile tool for data collection have emerged (Aanensen et al., 2009; Joki et al., 2007; Liu et al., 2010). For example, Ushahidi (Okolloh, 2009) is a web-based collaborative reporting environment that aggregates and share information provided by citizens. Both Open Data Kit (ODK) (Hartung et al., 2010) and ohmage (Ramanathan et al., 2012) are open-source participatory sensing technology platforms, supporting mobile phone-based data capture. And, crowdmap[30] is a tool to crowdsource information and to visualize it on a map and timeline. While powerful and flexible, all of these platforms require programming skills and/or infrastructure to some degree. Infrastructure and basic knowledge from JSON, xml, PHP and/or MySQL are required for most platforms, and a custom software download for Ushahidi.

Two platforms support authoring without programming: Project Noah and EpiCollect. Project Noah[31] is a tool for citizens to explore and document wildlife, and EpiCollect allows people to collect and submit data to a central project from mobile phones (Aanensen et al., 2009). Project Noah focuses on wildlife exploration, and EpiCollect supports application creation but does not have a distribution platform where volunteers find or subscribe to campaigns. Table 4 summarizes some of the design options applied to the existing systems we observed.

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30 crowdmap, http://crowdmap.com
31 Project Noah, http://www.projectnoah.org/

Drawn from the exploration of the current technology use and existing tools, we came up with the following design considerations for mobile data-collection applications. We outline each of the columns in Table 4.

- *Data*: What types of data that can be recorded by the system (*i.e.*, time, location, photos, accompanying text, etc.)? The data and type that are supported can be essential in facilitating various fieldwork type activities.

- *Distribution*: To what extent and how are created mobile campaigns distributed to volunteers?

- *Data quality*: How is data quality controlled and managed? Is the system open? Moderated? Edited? Are there quality checks or controls in place? Are they automated or user managed? How is control, if any, enforced?

- *Privacy*: What mechanisms, if any, are in place to provide anonymity for volunteers and the data they collect? To what degree can volunteers control this level of anonymity? Where is the data ultimately stored and how is it safeguarded?

- *Authoring type*: What support is there for users to author their own campaigns? What technologies and tools are required and how flexible is the overall authoring system?

**Table 4. Summary of authoring technology design considerations for mobile data collection**

| Authoring tool | Use of technology | | User acceptance factors | | Authoring type |
|---|---|---|---|---|---|
| | Data | Distribution | Data quality | Privacy | |
| Typical | Various | No support for distribution | Various | Various | Use a custom or existing system (*e.g.*, Twitter) |
| Sensr | Locations/Photos/Text | Automatically launched in a web platform | Filtering/ Validation | Anonymity | Via web Forms |
| Ushahidi | Various | Automatically launched within an app | Various | Anonymity | xml, PHP and MySQL + custom s/w download |
| Noah | Locations/Photos/Text | No support for distribution | Collection process | Social Negotiation | No support for authoring |
| Epicollect | Locations/Photos/Text | No support for distribution | Not specified | Not specified | Via web Forms |
| Crowdmap | Location/Photos/Text | Automatically launched in a web platform | Not specified | Not specified | Via web Forms |
| ohmage | Various | No support for distribution | Not specified | Not specified | Java + MySQL + custom s/w download |

## 5.5. Summary

In all, we found that mobile technology in volunteer sectors has been underutilized in spite of its rapid growth and widespread adoption. Both the online observation and the survey results point out the underutilization of mobile technology in the field in spite of the interest and need to adopt mobile technology in volunteer activities. For all organizations which participated in in-person interviews, *Lack of technical expertise and resources* counted by staff members as the major barrier that prevented them from adopting mobile technologies. However, many failures in groupware are not due to technical problems, but result from not understanding the unique demands this class of software imposes on developers and users (Grudin, 1988). We identified two perceived challenges, including *questioning the credibility of public participation* and *mobile interaction interfering with field experience*.

# 6 Factors for Consideration in Mobile Data Collection[32]

The nature of citizen-science volunteering involves participation of the untrained general public in doing scientific work. This brings up several concerns regarding the success of public participation. This chapter examines the widely acknowledged factors for consideration including: quality of data, privacy, and motivation for participation.

## 6.1. Quality of data

Volunteers are essential to gathering the information in citizen science activities (Cohn, 2008). One potential issue in a system where a crowd becomes the source of data is the integrity and quality of data[33]. Although data collected by amateurs can be of high quality (*e.g.*, Raddick et al., 2009; Bhattacharjee, 2005), amateur-collected data has potential for accidental submissions of bad data or malicious submissions of junk data (Cuff et al., 2008). This is arguably a fundamental issue of volunteer participation in scientific work in general, and has potential to be mitigated by training users prior to participation. Many projects have tried to show decent quality and validity of data collected by laypeople (*e.g.*, Bhattacharjee, 2005). For a more systematic approach to address this issue, Liu et al. proposed several non-exclusive ways to address these issues (Liu et al., 2010): 1) using other co-existing infrastructure to validate citizen-provided data, 2) using scientific models to simulate the entire region of interest, 3) adopting methods presented in previous works, such as (Aoki et al., 2009) to provide mobile trusted platforms, and 4) using both legal agreements similar to Campbell et al. (2006) and information network analysis to safeguard or determine the integrity and trustworthy of citizen-provided data (Krumm, 2009). Moreover, several research efforts have proposed additional mechanisms to supplement crowd-sourced data to increase the reliability of citizen-collected data. A reputation model can be effective in autonomous environments. For example, Huang et al. (2010) propose a reputation system for evaluating the trustworthiness of volunteer

32 This chapter is adapted from an extended abstract published at the CHI'12 conference (Kim & Paulos, 2013)
33 EPA, http://www.epa.gov/diesel/

contributions in participatory sensing applications (Huang et al., 2010). Much more effort to ascertain the quality of crowd-sourced data is underway.

In order to control the quality of collected data at the micro-level, several simple possibilities include: 1) deleting inappropriate or poor-quality data, 2) confirming a data submission before displaying it to the public, and 3) accessing volunteers' contact information. There are also system-driven approaches from the macro-level as well, including: 1) automatic filtering of photos that include inappropriate content, and 2) monitoring and blocking volunteers who frequently upload bad quality or inappropriate data. Interestingly, the quality of data was not the only reason that authors wanted to control data accessibility. Because many citizen-monitoring activities seek to prevent illegal abuse cases, some authors worried that people might use the data for malicious purposes, such as finding spots that are seldom monitored. Overall, it was considered important to provide monitoring and authoring features of data both to improve the quality and to ensure the proper use of the data.

A popular computational approach is redundancy, where multiple workers repeat the same task (Ipeirotis, 2010). A reputation model is another mechanism proposed to increase the reliability of citizen-collected data (Luther et al., 2009). Meanwhile, Sheppard and Taveen (2011) showed that quality could be maintained by implementing a qualitative process, such as training users prior to participation or providing standard data collection procedures to engage volunteers in data analysis. We selected the latter approach, standard data collection procedures, for Sensr.

## 6.2. Privacy

Digital volunteering takes advantage of sensor-rich mobile phones and their extensive adoption, turning people from passive consumers to active producers of sensed data. Unavoidably, this raises privacy concerns, as people transfer considerable amounts of personal information when sensing (Krontiris & Maisonneuve, 2011). Sensory data is our digital footprint, embedding details of everyday life. Mining it in conjunction with easily available auxiliary information allows one to draw a rich set of behavioral inferences, like addictions (Emre et al., 2009), travel routes (Kruum, 2009), personal habits, or social inclinations (Raij et al., 2011) that are sensitive in nature (Chakraborty et al., 2012; Pascoe et al., 2000). GPS and location data are a fundamental part of the data being collected in many of the sensory crowdsourcing applications like our system, which coupled with date and time data raises a number of additional concerns about privacy (Williams, 2010).

There is an inherent conflict between data sharing and privacy (Hauser et al., 2010). Location data is a fundamental part of the data being collected in volunteer data collection applications, which when coupled with date and time raises a number of additional concerns about privacy. It might cause a severe privacy threat if all information available from personal mobile devices is collected for data visibility. If we choose to protect privacy by anonymizing the data and hiding any identifying information from the data, then the visibility and information accessibility of the data are instead lost (Krontiris & Maisonneuve, 2011). Therefore, it is important to consider such a conflict when collecting sensor-based data from the crowd, in order to increase visibility while ensuring that people gain privacy protection at the same time. There exists an abundance of literature related to privacy concerns and possible solutions in data crowdsourcing, participatory sensing, and social media. For example, Shilton et al. (2008) argues that participants should be engaged in the process of negotiating and decision-making, claiming that urban sensing systems must allow people to negotiate social sharing and discretion for themes. In the technology perspective, a prevalent approach is to blur identifying information from the original data either by introducing pieces of data to, or removing pieces of data from, the real data. Cristofaro et al. proposed an infrastructure that automatically alters identifying information from the original data to be identifiable but anonymized before submitting to the third party (Cristofaro et al., 2011). In designing an application that calculates personalized estimates of environmental impact using location data, Mun et al. (2009) applied selective hiding, deletion, and retention mechanisms by which the system can provide a selective hiding mechanism that generates proxy traces without revealing a real location (Mun et al., 2009).

A similar concern is with the explosion of location-based, mobile social networking services in the last few years, such as Foursquare, Twitter, Tinder, and Grindr. The increasing interest in these services has generated a flood of publicly accessible, geo-tagged, personal footprints, which raises several concerns about privacy violation. A study of Foursquare demonstrated that one could easily infer the home city of around 78% of the analyzed users within 50 kilometers (Pontes et al., 2012), and other studies showed that it is possible to infer a user's explicit personal information, including a user's personal interests, location, home city, etc., through other features which contain implicit information (Mislove et al., 2010; Cheng et al, 2010; Davis et al, 2011).

Public debate about privacy concerns posed by social media has been increasingly polarized. One side is what is called the privacy-is-dead perspective: if people are willing to share their personal information, they must have abandoned any reasonable expectation of privacy, or they are somehow unconcerned about privacy. Another side is that people do care deeply about privacy, but they do not understand or are not informed enough about potential risks of involuntary information leakage (Lam et al., 2008). This perspective emphasizes the need for mechanisms to provide awareness of the privacy impact of users' daily interactions. Accordingly, several recent papers have proposed novel user interfaces for specifying privacy settings in order to help users understand the privacy settings and to quantify the risk posed by a user's privacy settings (*e.g*., Lipford et al., 2008; Liu & Terzi, 2009; Fang & LeFevre, 2010).

As a passive approach, our system will provide an option on the mobile application-side where volunteers can select whether to provide their personal information set in the mobile app (name, email and the area of residency) to an author or not, which is in line with the concept of participatory privacy regulation that Shilton et al. (2008) proposed. Also, the system restricts access to personal information on a website to an author only, while the rest of the data are publicly accessible. Compared to the concern regarding data quality, little concern about privacy was raised in the case studies. We assume this is because the target participants in the study are authors who are the recipients of data, while privacy concern arises from the data provider.

## 6.3. Motivation for participation

Attracting and retaining volunteers is crucial for designing technology-mediated volunteer campaigns. Thus, motivational factors have to be addressed when building a tool (Nov et al., 2011). Researchers have discovered that intrinsic and collective motivations like personal interests, enjoyment, following social norms, or acknowledgement are the dominant factors, while reward motives are arguably less salient (Nov et al., 2011). While our system provides several lightweight features to attract and retain members of the public in volunteer campaigns (*e.g*., various ways for volunteers to explore existing campaigns), we do not discuss them here in detail, as the main focus of this paper is to explore the authoring side of our system evaluating Sensr to allow creating custom mobile applications.

## 6.4. Other issues

Studies of the data collection needs for mobile fieldworkers (Pascoe et al., 2000) reveal several usability factors to consider. First, when possible, a user's attention must be focused on the observation of the event or object, not on the interface. Also, a user should be able to enter data quickly and accurately across a variety of usage contexts, such as sitting, standing, or walking, and the interface needs high contrast colors for outdoor use. Finally, it should support a range of data fields to satisfy varying user needs.

Mobile technology could enhance the process of volunteer data collection but require custom mobile applications to be effectively incorporated into data collection, something non-profits have not yet invested in for the most part. Many of those who wish to develop a mobile data-collection application are non-profits or local groups that lack the resources to hire experts or the in-house technical skills to support such development. Beyond programming, managing data poses a significant challenge, as most of these communities do not possess server farms and storage to manage collected data.

# 7 Sensr: System Design and Implementation

Based on the findings in the previous chapters, we developed a stand-alone mobile application that support volunteer activities of collecting neighborhood water quality information within the domain of citizen science, and studied its design process and use in the wild, as a test bed to verify how the potentials of mobile technology would be operationalized in real world settings. In particular, we focused on the extent to which different stakeholders are involved in the design process to best leverage the available capabilities of mobile technology to meet the needs in situ.

## 7.1. Introduction

To take full advantage of the mobile technologies, it must become easy to develop digital campaigns on mobile devices. Sensr aims to do precisely this, providing a transparent campaign-creation interface for people with limited technical skills to easily create campaigns to which users of the Sensr app can subscribe and contribute data. To clarify our work, we provide several definitions: a mobile request for data collection is called *a campaign*, a person or organization who creates and manages the campaign is refereed to as *an author*, an individual who contributes data to a campaign is *a volunteer*. As shown in Figure 5, Sensr system consists of two parts: (1) a website hosted through Amazon Web Services where authors create and manage campaigns, and where the public can access to the list of active campaigns along with data visualizations, and (2) a mobile application with which volunteers can explore, subscribe to, and participate in campaigns. The mobile application runs both on an iOS platform.

For the server, we created two separate MySQL database tables: Campaign DB and Data DB. Campaign DB stores the basic schema of a campaign, including an interface structure, GUI components, and the general campaign information. Data DB stores data that volunteers report via the mobile application as well as discussion entries submitted from website. Then, JSON serializes and transmits data over the network (see Figure 5). We used jQuery UI, Ajax, and PHP to build the interactive webpage where people can author a campaign. To build a mobile application running on iOS, we used objective-C with Apple's Cocoa API. The mobile application running on Android was built on Android SDK 2.2.

## 7.2. Website Experience

When designing the website, our main concern focused on accessibility for people without programming skills when authoring and managing a campaign. For that, we provide only two steps to create a campaign: (1) completing a general information page to describe the campaign (See Figure 6, top), and (2) designing a data collection user interface using a simple drag and drop method (See Figure 6, bottom).

First, an author provides general information about the campaign, including a title, contact information, campaign description, a logo image, *etc*. The author fills out the form fields, and those are automatically displayed on a mock-up iPhone interface on the right. This page will be displayed on the mobile application when volunteers explore existing campaigns (See Figure 5).

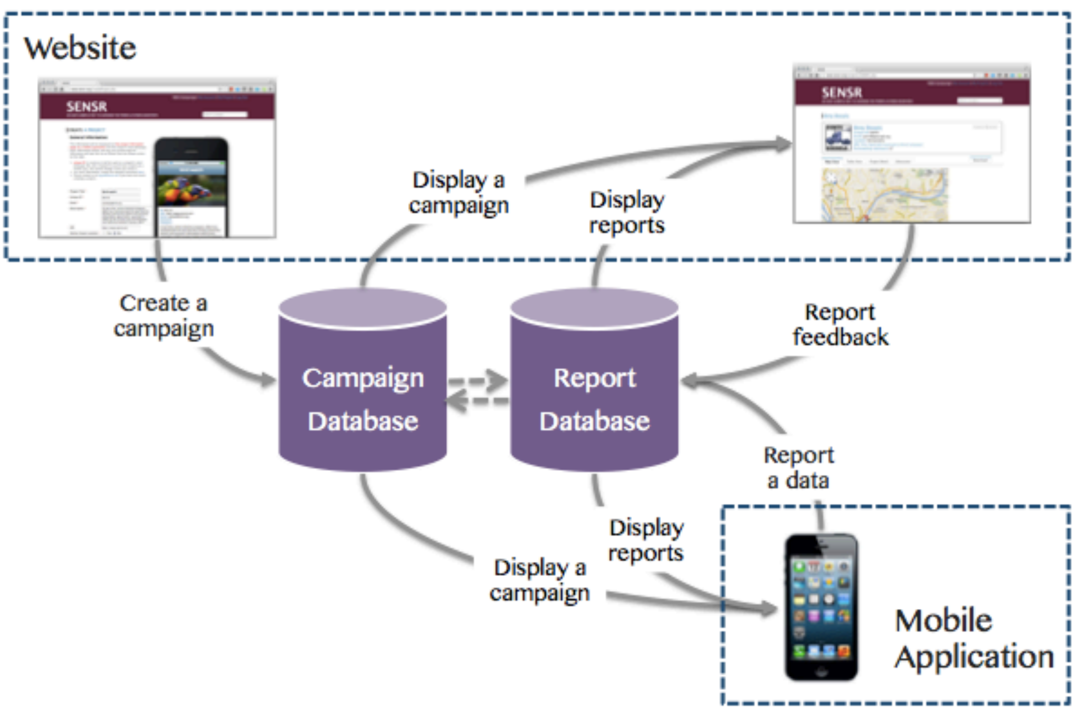


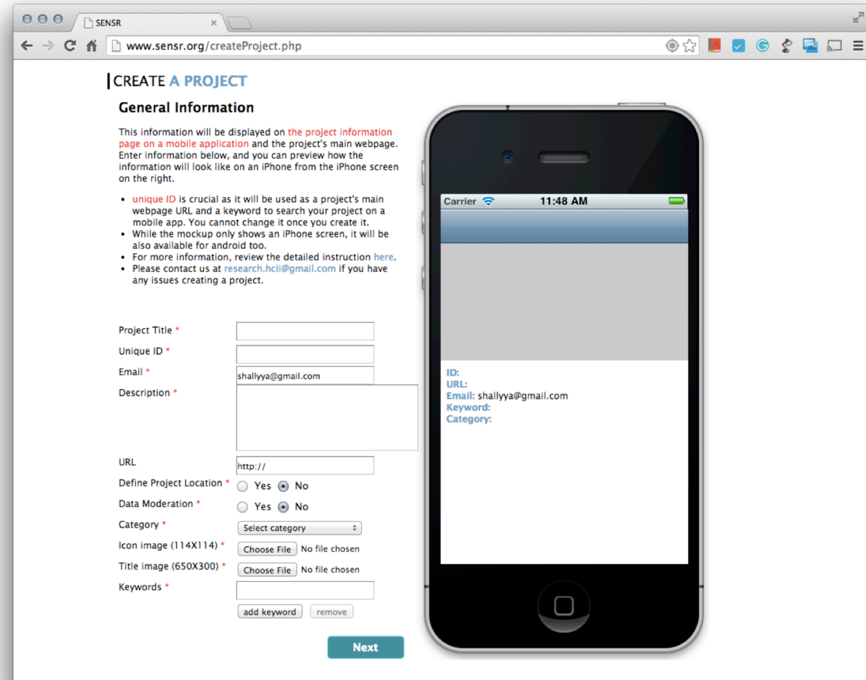

**Figure 5. Functional architecture of Sensr**

Second, the author designs the data collection user interface by dragging and dropping widgets from a predefined pallet on a simulated iPhone screen (See Figure 6 bottom). Following the design considerations in the previous chapter, widgets are selected from iOS user interface elements. Three different types of widgets are provided: photo, radio buttons (with two or three options), and a freeform text entry field. Currently, only one photo widget is allowed, and multiple radio buttons and text entry fields can be added. Radio buttons are especially useful because they prevent users from struggling to type on the go.

On the mock-up iPhone screen the author can rearrange the order of widgets, delete a widget, and edit the labels of widgets. Besides the widgets that volunteers need to complete, the system automatically captures other sensor data such as a timestamp and GPS location. This page will be used as the mobile interface for volunteers to report data.

When satisfied with the design, the author submits the final campaign interface, which is then converted into a version accessible by mobile application. Our system avoids any technical burden, complexity, and cost of submitting apps to an app store for approval to distribute.

Once the campaign is created, the system automatically generates a hosting webpage to display, all information and collected data for the campaign (See Figure 7). From this page, the author can modify campaign information, and view, filter, and operate aggregated data. This data is displayed in three different formats including a map-based visualization, a table view, and a downloadable file format. Additionally, the system provides a webpage where people can discuss and share opinions about the campaign. The campaign's hosting page and data visualizations can be open to the public or shared among volunteers upon the author's setting.



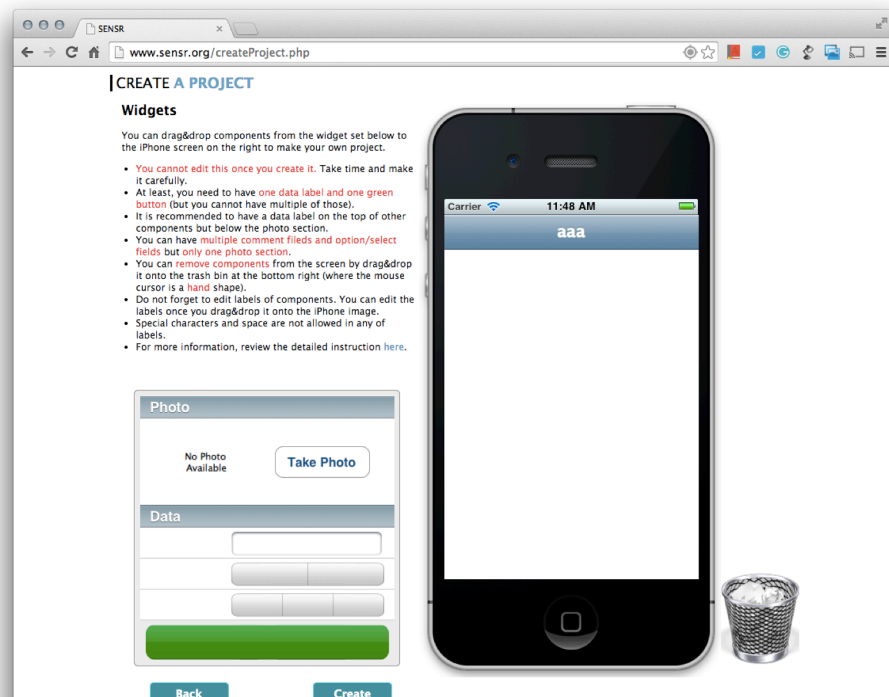
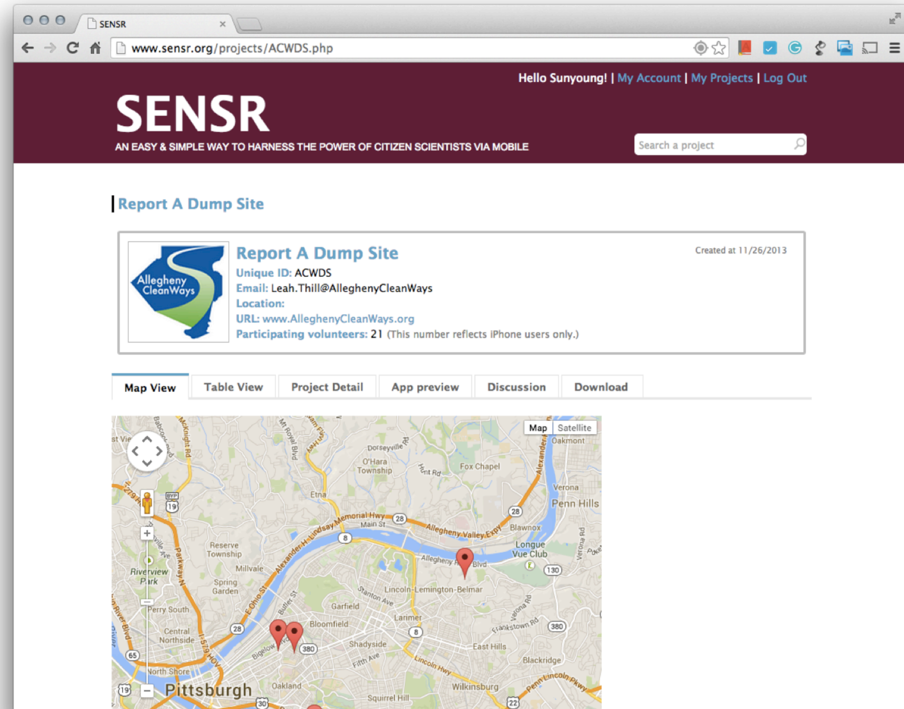




Figure 6. Sensr web interfaces to author a mobile campaign for data collection



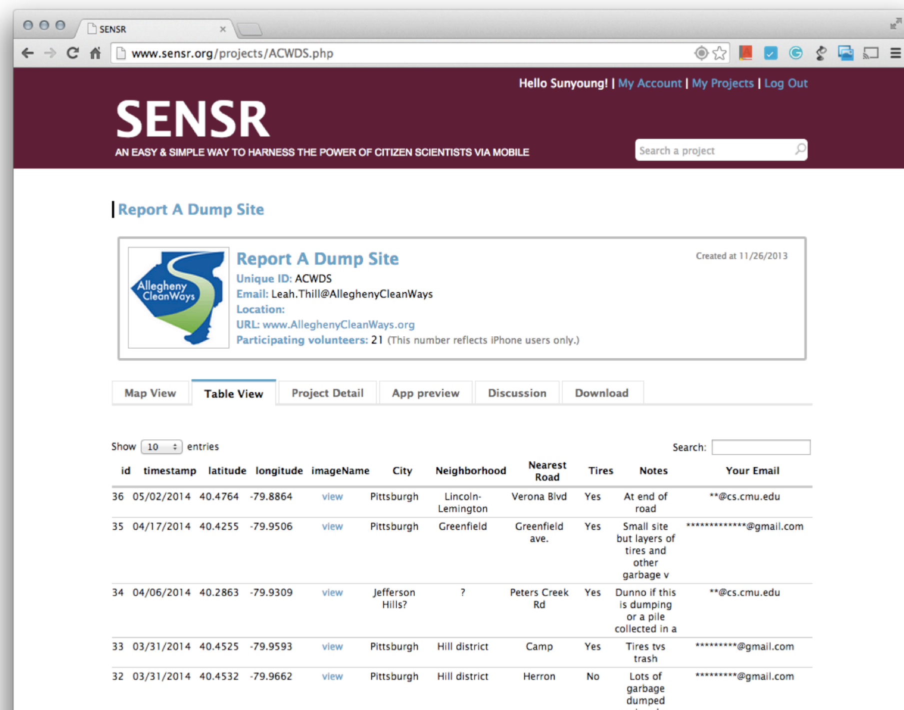




**Figure 7. SESNR web interfaces to review collected data of a mobile campaign**

## 7.3. Mobile Experience

On the mobile application, volunteers can subscribe to campaigns and collect, report and review data. Its interface consists of three tabs: My Campaigns, My Data, and Settings (See Figure 8). The first tab, My Campaigns, lists all campaigns to which a volunteer is subscribed. When a volunteer wants to participate in other campaigns, he can visit the [add campaigns] page to explore campaigns by category or to search a particular one using a unique ID provided when a campaign is created. A volunteer clicks the [participate] button to subscribe. Then, the campaign is listed under My Campaigns. Clicking the title of each campaign leads to its main page where volunteers can explore existing data on a map or list view. A volunteer clicks the [report] button on this page to report data. The report page interface differs by campaigns, according to the author's design. When connected to a network, volunteers can report data on the fly. When offline, data is saved locally to report later when networked.


**Figure 8. Mobile application screenshots. From left to right, a list of campaigns that a user added, a category to find and add a campaign, a campaign main page, a repository of data, and a form to report data**

The second tab, My Data, stores data reported by the volunteer. Under the Settings tab, a volunteer can optionally set personal information including name, email, and the place of residency. If a volunteer sets personal information to expose, it will be included with other report data when reported. Otherwise, personal information will not be included. Even when submitted, personal information is only visible to the author of the campaign.

## 7.4. Summary

Sensr combines a visual environment with a mobile application where people with limited technical expertise can author mobile data collection tools. Sensr radically simplifies creating a mobile data collection tool. Authors only need to fill out a project description and design data-entry forms before launching their campaign within the mobile Sensr application for wide distribution, freeing authors from worrying about technical requirements and infrastructure constraints. Then, Sensr displays the data to share within contributors for collaborative data analysis and interpretation.

# 8 Case Study: A System to Author Mobile Data collection Tools[34]

We conducted a case study in which we **presented Sensr to seven participants** across three different organizations, who were interested in initiating mobile data collection campaigns. Our objectives were to discover how quickly and easily authors without technical skills could develop and maintain campaigns on Sensr, and to expose any system flaws before the application's launch. The method was as follows. First, managers from each organization gathered to discuss campaign organization issues in terms of volunteer recruitment and data collection. Next, we presented a working prototype of Sensr and explained its purpose. Managers browsed the interface before selecting one of their activities to deploy in Sensr. They created a mobile application using the Sensr website and tested the resulting mobile app in a separate room. Finally, the managers regrouped to discuss issues, benefits, and difficulties in using Sensr. All sessions were recorded and relevant portions transcribed.

## 8.1. Case I: Air Quality Monitoring

Group Against Smog and Pollution (GASP, http://gasp-pgh.org) is a non-profit organization in Southwestern Pennsylvania working for a healthy, sustainable environment. Founded in 1969, GASP has been a diligent watchdog, educator, litigator, and policy-maker on environmental issues with a focus on air quality. GASP selected a diesel cleanup initiative to create a campaign.

### 8.1.1. Diesel Clean-Up Campaign

Diesel exhaust is one of the nation's most pervasive sources of toxic air pollution. Diesel engines such as buses, trucks, trains and construction equipment, are known for their durability, but older engines emit a toxic mixture of particles, metals and gases including over 40 hazardous air pollutants as classified by the EPA[35] unless properly maintained. While old diesel engines are known as a major source of diesel exhaust, it is relatively difficult to collect

34 This chapter is adapted from a paper published at the CSCW'13 conference (Kim et al., 2013).
35 EPA, http://www.epa.gov/diesel/

evidence because incidents are transient, and the exhaust disappears within several seconds. Distributed urban sensor nodes (*i.e.*, citizens equipped with smart phones) can be an appropriate medium to capture such incidents. GASP has sought ways to encourage everyday people to monitor neighborhood diesel emissions and share experiences with visual evidence like photos or videos. A photo of a fuming vehicle's license plate could be great evidence against companies with illegal emissions control. While aware that the use of a mobile application will facilitate their efforts, lack of software development skills has hindered them from developing a mobile application.

### 8.1.2. Creating a campaign

Three managers used Sensr to create a campaign, and they did not have any problems interacting with the web interface. Everyone easily figured out how to interact with the drag-and-drop interface and created a campaign with few mistakes. We did not find evidence for any usability issues when interacting with our system. The final interfaces were identical across managers: one photo and one comment field widget. We assume this is because the campaign is already underway, making the design of an interface for a mobile application obvious.

### 8.1.3. Issues and possible solutions

Data quality was of particular concern to this organization for several reasons. First, the party who contributes data is the non-expert public. Also, a participant's data report could include photos containing inappropriate content, which could be detrimental to their reputation. However, the authors who tried Sensr felt that Sensr's mechanism for handling this issue addressed their concerns. Sensr provides a filtering process with which an author can confirm data before displaying it in public to ensure its quality. While this mechanism brought up a separate concern about extra time spent filtering data, they agreed to manage such a commitment if it increases citizens' participation and the amount of data collected.

> *"There are always people who try strange things. We are the one who officially organizes and runs this data collection activity. I am worried if people may think that our activities are full of useless incidents if the data quality is not decent."*

> *"Our logo will be put on top of all these data. We do not want to represent any junk data, and need ways to control its quality."*

While mostly satisfied with Sensr, they found it lacks the support for localization. Many grassroots activities are based in a particular area where locals monitor neighborhood environments. Because GASP runs activities solely for and within the Southern Pennsylvania region, they have no means to act upon data from outside the supported area. To prevent such wasted efforts, they suggested a feature to author a campaign by region.

> *"It won't hurt if someone in California reports us a picture of diesel emission there. But we can do nothing about it. Then that person's effort becomes useless... It would be nice if we can specify a locational boundary."*

## 8.2. Case II: Watershed monitoring

The Mountain Watershed Association (MTWatershed, http://www.mtwatershed.org) focuses on the conservation, restoration and protection of watersheds in Pennsylvania. They aim to remediate abandoned mine discharges, develop community awareness, promote cooperative community efforts for remediation and encourage sound environmental practices. MTWatershed selected a Marcellus visual assessment program for a campaign.

### 8.2.1. Marcellus Visual Assessment Program

Marcellus shale is a rock formation that underlies approximately two-thirds of Pennsylvania and the adjacent area. The shale is believed to hold trillions of cubic feet of natural gas. Recently developed drilling technology makes extracting the natural gas from the formation more feasible. The drilling process relies on a mixture of chemicals and a large amount of water, ranging from 3 to 7 million gallons, which may be illegally dumped afterwards, causing serious water and environmental pollution. MTWatershed offers a basic training course, called the Marcellus Visual Assessment program, that instructs how to monitor Marcellus drilling sites. People learn to use their sight, hearing, and smell to identify potential issues resulting from drilling operations on site. Then they go into the field, observe sites, and come back home to report data via an online form in the website. Since location information is critical, MTWatershed wanted to develop a mobile application to automatically capture geo codes.

### 8.2.2. Creating a campaign

Two managers created a campaign on our system and did not have any problems interacting with the web interface. We observed how they were using Sensr, and everyone easily figured out how to interact with the drag-and-drop interface, creating a campaign with few mistakes. While we did not find evidence for usability issues, we saw a disparity in the final two interfaces: one interface was almost identical to the online form currently used by the organization, and another interface modified the current form with an additional photo widget and fewer data fields. (The preexisting form consists of seven selection fields and eight text-entry fields to report.) They explained that one manager simply copied the existing form to a mobile campaign while the other tried to adapt the existing format for the mobile interface. Even though the existing field campaign was converted to a mobile version, the result conflicts with the finding from the previous case where the final interfaces were identical across managers. This finding reveals that the complexity of the preexisting data entry form strongly influences the mobile application design. The form in the previous case has only two data fields, which makes it easy to translate to the mobile version, while the form in this case has fifteen data fields.

### 8.2.3. Issues and possible solutions

The discrepancy between the interfaces reflects a possible difficulty when creating a mobile version of existing campaigns. The current data entry form was not applicable to a mobile interface because it was lengthy and complex. In such cases, modifying an existing form is necessary to sustain mobile usability, which in turn causes the disparity in the formats of data collected from different media. Since the activity was already underway, the managers were hesitant to generate a separate module for a mobile version. This suggests the need to build in prompts to guide authors toward mobile-friendly reporting interfaces. Through discussion, they optimized the form suitable for a mobile platform.

> *"I know that it cannot be the same from a web form to a mobile one. But I don't want to have two different sets for the same activity. We can merge a few questions to reduce the number of fields, and add a photo to remove some."*

> *"Our current format is somewhat complicated as it needs to measure data using sensors we lend. If we can make it simple to fit into this system, we will have more people participate in it."*

They raised another concern about the possibility of malicious data use. Public access to the data has both benefits and problems: the aggregated data shows volunteers where popular monitoring sites are and where more data is needed, but it also tells companies which locations are rarely monitored and thus, would be ideal for illegal dumping sites. The managers did not come up with any specific solution, but all agreed that more citizen participation would cover more sites and lessen the chances for such ill-purposed use cases.

> *"We monitor illegal wastewater dumping. If companies know where people are monitoring, they could use that information to find a site where no one monitors so that they can go dumping wastewater there."*

## 8.3. Case Study III: Local Parks Conservation

The Pittsburgh Parks Conservancy (http://www.pittsburghparks.org) was founded by a group of citizens concerned with the deteriorating conditions of Pittsburgh's parks. The Conservancy participates in all aspects of park management to improve parks, and thus, boost quality of life for the people of Pittsburgh. They conduct projects with environmental sensitivity, respect for the parks' historic landscape design, and an appreciation for the recreational needs of modern users. The Conservancy selected to create a campaign for an invasive species management program.

### 8.3.1. Invasive Species Management Program

Although many plant species are introduced to the United States from other countries without causing ecological damage, a small percentage of non-native plants become invasive and have a devastating impact. Left unchecked, invasive species can completely take over sections of parkland, kill a wide variety of native vegetation and destroy the biological diversity that creates habitat for wildlife and keeps an ecosystem functioning. The Conservancy has been working to monitor and control the spread of invasive species in the parks. Volunteers can help by simply comparing plants in the wild with a provided list of invasive plants and reporting suspicious plants to the Conservancy. Currently, this program is only devoted to educating community members about invasive species and the proper way to remove them. Since school children partake in a variety of extracurricular activities, the Conservancy has sought ways to encourage these children to participate in the program using mobile phones.

### 8.3.2. Creating a campaign

Two managers used our system to create a campaign. While we did not find evidence for any usability issues in interacting with our system, both managers struggled to create a campaign from the provided widgets alone. They wanted to create an extra page to display pictures of invasive species that the system does not provide. Setting this aside, both managers came up with similar interfaces consisting of one photo widget and a couple of text and selection fields for extra information about the photo. After a discussion between the managers and researchers, they decided to create a web page to display pictures of invasive species, and link it to the campaign's mobile page to fulfill their needs.

### 8.3.3. Issues and possible solutions

We did not find any usability issues from the case study with this organization, but they demonstrated a strong intent to use Sensr as a tool to reach broader population. The Conservancy has sought ways to promote youth population participation in their conservation activities. The manager said that it was particularly difficult to make students interested in the activity. The managers appreciated the ease with which Sensr allowed them to operate a mobile application since the use of mobile devices would more easily allow and excite younger participants.

> *"It is hard to reach out to the younger population. Having a simple mobile application like this, we can attract them."*

## 8.4. Implication

Overall, our system was verbally well received by all participants in the case study. The most positive comments dealt with the simplicity in interacting with the interface to author a campaign. Also, we received feedback about possible positive impacts of our system on volunteer participation in data collection activities. While different in details, all of the feedback fundamentally stemmed from the need to increase public participation: volunteer activities cannot be sustained without citizens' participation, and authors felt that Sensr could be a powerful means to reach a wider population. In some cases, authors had difficulty in converting pre-existing campaigns into the form suit to Sensr because of the complexity and length of existing forms. This suggests the need to build in prompts to guide authors toward mobile-friendly reporting interfaces.

Many volunteer activities require training and special equipment to collect data in order to increase the quality of data, which in turn makes it hard for laypeople to participate in activities. The fact that Sensr is designed for simplicity so that non-experts with no extra equipment and with little training can participate in the activities allows for a broader range of participation in campaigns.

One goal of citizen-participatory activities is to make everyday people think more about environmental protection and ecological prevention. While direct effects of public participation may not be visible, it helps volunteers identify relevant phenomena and generate local knowledge, which can result in an active advocacy of citizens (Wiggins & Crowston, 2011). All authors emphasized the belief that mobile applications would promote public engagement, increase awareness of their activities and provide volunteers with informal science education, and our system can support them to pursue those ends.

Location is crucial to interpreting data and protecting privacy (Cohen, 2008), and findings from the case study confirmed it. Several authors requested a feature to specify a geographic bound of a campaign. Also, authors intensively discussed ways to use geo-coded data during the case studies, which demonstrates how the geo-coded data could influence not only privacy issues but also volunteer behaviors in data collection efforts, opening a wider consideration for facilitating location data.

# 9 Investigating Mobile Technology Use in Volunteer Activities for Data Collection

After conducting case studies, several developmental updates were applied to Sensr, such as fixing bugs, updating description texts, and adding new features, including defining the geographic location of a campaign, in order to incorporate the needs that participating organizations suggested. Then, the beta version of Sensr was released for public use. With this, we conducted the final study that investigated the entire cycle, from assessment to creation to appropriation of, or failure to adopt, mobile solutions in volunteer data collection activities through Sensr in situ.

## 9.1. Introduction

The most widely employed model of IT adoption is the technology acceptance model (TAM) that considers a user's "perceived ease of use" and "perceived usefulness" of a technology as major factors influencing the adoption of new technology (Davis, 1989). Its theoretical extension encompassed social influence and cognitive instrumental processes in TAM (Venkatesh & Davis, 2000). However, there is limited research in the information systems and IT implementation literature that deals with the entire cycle, from creation to adoption, of mobile solutions in an organizational context. Particularly, there is a need to understand what factors can influence mobile technology adoption when organizations possess enough technical affordance. To address this gap in the literature, we investigated how organizations valued and appropriated mobile solutions through the use of Sensr.

We **conducted a six-month deployment study of Sensr**, exploring the practice of mobile solution adoption **in six environmental campaigns within two organizations**. Unlike most previous studies, which observed existing technology-use practices, this work investigated the entire cycle of mobile technology adoption in situ. From the study, we determined two factors beyond resource constraints that influenced informed decision-making about mobile technology adoption: the depth of public engagement in a campaign and staff's perspectives on technology. The results of our studies were in accordance with prior work by Grudin (1988) and others in that many expensive failures in developing and marketing software that is designed to support groups are not due to technical problems. We found that those two factors overpowered the resource constraints and lack of technical expertise (the perceived obstacle according to staff members) in the decision making process. In this regard, the last contribution is that a study of the entire creation and usage cycle of mobile solutions in volunteer data collection activities reveals the gap between perceived and actual reasons for the underuse of mobile solutions in volunteer campaigns.

## 9.2. Literature Review

### 9.2.1. Theoretical framework in IT adoption

Formulating a theoretical approach to understanding IT adoption has been an important agenda in Information Systems research (Wastell & McMaster, 2008). Among a significant body of research in information systems and human-computer interaction regarding initial acceptance and sustained usage of new systems, the most widely employed model of IT adoption is the technology acceptance model (TAM) (Davis, 1989). Recently, TAM has broadened into TAM2 to encompass social influence and cognitive instrumental processes (Venkatesh & Davis, 2000). It regards a user's "perceived ease of use" and "perceived usefulness" as major factors influencing the adoption of new technology. Perceived usefulness is "the extent to which a person believes that using a particular system will enhance the performance," and perceived ease of use is "the extent to which a person believes that using a particular system will be free of effort" (Davis, 1989, P. 320).

Another important model is Structuration Theory (ST), which accounts for technology adoption through a combination of individual acts and social forces (DeSanctis & Poole, 1994). Based on ST, research emphasized a user's individual perceptions of a technology, rather than its capabilities, as a key influencer in technology adoption. For instance, Orlikowski (2000) explained that the "appropriation of technology is strongly influenced by users' understandings of the functionalities of a technology, rather than the properties itself". Further, individual perceptions are shaped through personal prior experience and social interactions with others, which in turn shape the way people use the technology (Orlikowski, 2005). In this regard, there is a gap between what a technology is capable of doing and what people interpret a technology as capable of doing (Leonardi, 2009).

### 9.2.2. IT use in nonprofit organizations

Several studies have investigated the relationship between IT use and nonprofits' work processes. Even though IT use can enhance mission-related outcomes and organizational performance (Hackler & Saxton, 2007), few nonprofits fully leverage these technologies. A survey conducted by the Nonprofit Technology Network reported that the average technology budget was less than 5% of a nonprofit's total budget, and over 50% of small nonprofits do not plan to adopt any new technology (NTEN, 2011). As such, nonprofits have generally lagged behind for-profits in IT investment and adoption (Saeed et al., 2011). The reasons for the slow adoption of IT in nonprofits include financial and technical constraints (Rybalko & Seltzer, 2010), lack of understanding of the social context into which technologies are deployed (Carroll, 2004), organizational cost of creating and preserving the knowledge necessary to make effective use of deployed IT (Le Dantec & Edwards, 2008), imbalance between those who receive the benefit of new technologies versus those who must do the work of using them (Grudin, 1988), and diversity in the organizational structure, scope, application area and work among nonprofits (Saeed et al., 2011). Among these reasons, resource constraints were considered most salient (Hackler & Saxton, 2007), and the resources go beyond financial capacities such as the number of staff, their expertise, and time (McNutt & Boland, 1999). Finally, our recent work suggested perceived challenges beside resource constraints in the adoption of mobile technology, such as low credibility of the public-collected data and the use of mobile tools interfering with existing field experiences (Kim & Mankoff, 2014).

A number of online services provided direct technical supports, such as Center4, 4charity, BlackBaud, and Entango. However, these sites are all geared toward general IT assistance, such as building in-house infrastructure and websites. For mobile technology, a few technical tools were recently proposed to decrease technical barriers in creating mobile solutions (Aanensen et al., 2009; Hartung et al., 2010; Ramanathan et al., 2012). However, little work has been done to investigate the actual use of those tools over time.

### 9.2.3. A study of IT adoption in organizations

While little work has investigated the adoption of mobile technology in volunteer campaigns, a handful of studies conducted examinations of IT adoption in organizations. One such study is Venkatesh and Davis' (2000) four-month measurement of TAM, showing that both social influence and individual instrumental perceptions significantly influence technology adoption over time. Others investigated specific organizational environments, such as schools and hospitals, and showed that individual differences and perceptions are the primary factor to determine adoption behavior (Devaraj & Kohli, 2000; Hu et al., 2003). Extending prior studies, this work investigated the adoption of mobile technology for environmental campaigns from creation to appropriation in situ.

## 9.3. Case Selection

In our prior work, we studied local organizations and their current practices of technology use in volunteer data collection activities. Among those who participated, we selected two local organizations that currently were not using mobile tools, but were eager to adopt one to improve their work efficiency in coordinating environmental campaigns. Our main case selection criteria included:

- Coordinating regular, recurring volunteering activities
- Expressing strong needs for mobile technology use but struggling in its adoption because of resource deficiency
- Involving public participation in their campaigns

While there were a few other organizations that showed interest in participating in the study, they were excluded due to several reasons, such as lacking human resources to explore new tool adoption, and seasonal issues (*e.g.*, no ongoing campaign at the time of the study). We anonymized the official titles of the participating organizations, and instead referred to them as CleanUp org and AirQuality org. We also anonymized the official titles of the campaigns that we studied (See Table 5). In what follows, we explain each organization and their campaigns for which we investigated the adoption of mobile technology. Their made-up titles are in italics.

**Table 5. Campaigns and coordinators**

| Organization | Campaign | Coordinator | # of Interviews |
|---|---|---|---|
| CleanUp org | Watershed assessment | Outreach coordinator | 3 |
| | Stewardship campaign | Program coordinator | 12 |
| | Dumpsite reporting* | Program coordinator | 6 |
| | River cleanup | Outreach coordinator | 4 |
| AirQuality org | Bicycle air quality monitoring | Part-time Staff | 4 |
| | Air pollution reporting* | Policy and outreach coordinator | 11 |

(The campaigns marked with * are created after using Sensr.)

### 9.3.1. CleanUp Organization: Eliminating Illegal Dumping

The CleanUp org engages and empowers community members to eliminate illegal dumping. Their goal is to create healthy community, neighborhoods, and green space by cleaning and monitoring abandoned dumpsites. Illegal dumping is the improper disposal of waste at any location other than a permitted landfill or facility. Tires, large appliances, furniture, and construction waste are often illegally dumped because their proper disposal takes time and money.

The Cleanup org's two primary participatory campaigns are volunteer clean-up of dumping from the sites, *Dumpsite cleanup campaign*, and the riverbanks, *Riverbank cleanup campaign*. Two integral steps before and after cleanup events are: assessing the site to plan an event ahead of time, and monitoring the cleaned site to prevent it from becoming trashed again. While the staff members conduct the assessment of most sites, they recently launched a new campaign, aiming to engage the public in a visual assessment of a local watershed, *Watershed assessment campaign*. For monitoring the cleaned site, they ran Stewardship program. This organization expressed needs for using mobile technology in those pre- and post-cleaning steps. Lastly, they created a new campaign to allow the public to report dumpsites via mobile, the *Dumpsite reporting campaign*.

They have three full-time staff, including an executive director, a program coordinator, and an outreach coordinator, and two part-time staff. Nobody in this organization had a smart phone or a Facebook or Twitter account. All had very basic knowledge and experience in using technology, such as web surfing, documenting software, and email clients.

### 9.3.2. AirQuality Organization: Advocating for Clean Air

The AirQuality org educates the public, raises awareness, and advocates for laws and regulations regarding environmental issues with a focus on air quality. Their goal is to improve air quality to ensure human, environmental, and economic health in the region. This organization monitors whether industry facilities follow regulations, reviews legal permits and regulations, collects air quality data around the city, and organizes public hearing and volunteer activities for education and outreach.

The AirQuality org operates a few participatory campaigns, including *the bicycle air-monitoring campaign* that asks cyclists to collect urban air quality. This organization wanted to explore the possibilities of using a mobile tool for this campaign. In addition, they created a new campaign to allow citizens to report neighborhood air-quality issues, *the air-pollution reporting campaign*.

The organization has four full-time staff, including an executive director, two lawyers, a policy and outreach coordinator, and three part-time staff. All staff members owned a smart phone, and had personal Facebook or Twitter accounts. Specifically, the policy and outreach coordinator was very experienced in using advanced IT tools and basic software.

## 9.4. Method

We conducted a case study for six months to collect qualitative data of mobile technology adoption and use in environmental campaigns. In order to investigate the entire creation and usage cycle of a mobile tool, we determined the length of deployment by the stage of technology adoption cycle. Modifying Moore's general technology adoption process to account for the domain of volunteering (Moore, 1999), the stage of technology adoption cycle we defined includes:

1. System selection: Identification of system specifications and business requirements
2. System implementation: Customization to meet specific functionality required by users
3. System use
    (1) Diffusion: Disseminating the system to volunteers
    (2) Learning: Volunteer education to learn the new system
    (3) Using: Ongoing use, support and management of the new system

Because we scheduled to select and implement the system with the staff members of an organization, the expected duration for each of these stages was one week. Then, the phases in the system use stage required time for volunteers to naturally adopt and use the deployed mobile tool. After discussing with staff members about the expected duration for each stage, we allocated twenty-two weeks for the stage of system use. We projected four weeks for the diffusion of the system to volunteers, two weeks for volunteer learning, and a maximum of sixteen weeks for actual use of the system. Thus, the total duration of a case study was twenty-four weeks (See Figure 9).

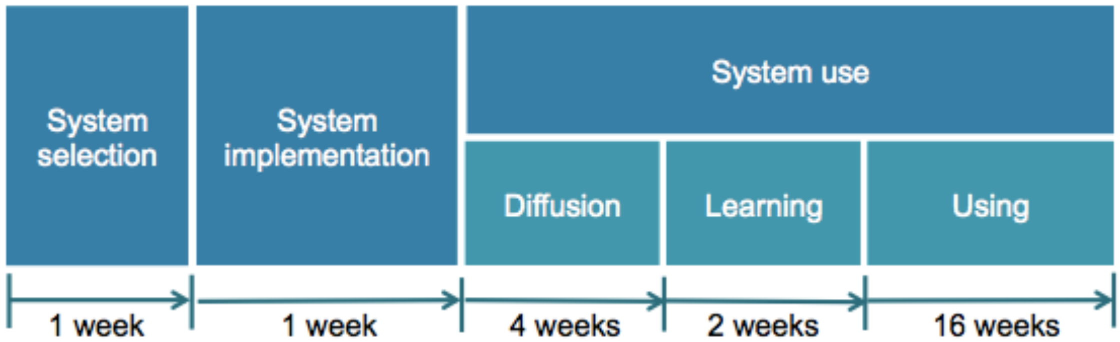



**Figure 9. The stage of technology adoption cycle**

### 9.4.1. Data collection

We visited each organization every two weeks for six months to conduct semi-structured interviews. The interview focused on how organizations determine, evaluate, and adopt or decline to use mobile technology for environmental campaigns. The first two visits were focused on understanding organizational campaigns and describing Sensr to participants. A protocol for all interviews was designed around the following areas of interest:

- Staff members' knowledge and experience in technology use, as well as technology use for their campaigns in situ
- Participatory environmental campaigns and volunteers
- The adoption and use practices of new mobile data-collection tools created via Sensr

In the CleanUp org, the program coordinator and the outreach coordinator were two primary staff that participated in the study. In the AirQuality org, the policy and outreach coordinator was the primary staff that participated in the study, and two part-time staff also periodically participated. We interviewed one staff at a time, and interviewed one or two staff about the campaigns that s/he is in charge of depending on the content. Each interview lasted 1.5 hours on average. In total, thirteen interviews were conducted with the CleanUp org, and ten interviews with the AirQuality org (Two interviews with the AirQuality org were cancelled due to holidays and their field events). All interviews were audio recorded and transcribed.

### 9.4.2. Data analysis

We analyzed our interview data using a thematic analysis to reveal patterns across data sets that are important to the description of a phenomenon and are associated with a specific research question, informed by grounded theory and other qualitative analysis methods (Strauss & Corbin, 1990). The themes became the categories for analysis.

First, we used open coding to identify and code concepts that were significant in the data as abstract representations of events, objects, happenings, actions, interactions, etc. Next, we categorized related concepts, created during open coding, into themes. A theme is a pattern that emerged within the data. Lastly, we assembled the themes into a single storyline through building relationships across themes.

## 9.5. Findings

In both organizations, one staff member was in charge of coordinating the entire process of one campaign or more independently, except the policy and outreach coordinator, who took care of all administrative and IT related tasks across different campaigns. Thus, we describe our case studies by campaign, as each campaign has its unique coordination process, protocols, and coordinator.

### 9.5.1. CleanUp Org Campaign: Watershed Assessment

The CleanUp org launched a campaign to produce segment maps of an 18-mile creek two months after participating in this study. The main idea was to teach people how to do the assessment, as well as to involve the public in the assessment process. The initial plan was that a group of one expert and several volunteers would walk through a creek to conduct a visual assessment (See Figure 10). The outreach coordinator was the primary coordinator of this campaign, and she made all comments cited in this section.

The coordinator's original plan was to use pen-and-paper with a camera to collect data: a camera to take a picture of a spot, printout section maps of the creek to determine and mark the spot, and an inventory sheet to write down a description about the spot, and a photo sheet to write down the ID number of a picture taken there. Accordingly, she planned to form a group of four or more volunteers and one expert, so that one volunteer would conduct one task.

Before launching this campaign, the outreach coordinator discussed with the interviewer about adopting technical solutions. She said that she considered the accuracy of location information most critical in the collected data, but did not fully trust the accuracy of GPS devices. Thus, she decided to use printout high-resolution section maps of the creek to determine the location, which she considered credible and handy to support her aims.

> *"We will just take pictures and record it on a map for the location, because GPS will not be accurate enough. We are looking at a very fine level accuracy. So we are just recording it on a map. We have maps that were made for us in a very small scale, so we are working on that."*

**Figure 10. Watershed assessment project**

They recorded over 250 items from the four trips in the first month – one trip a week. After completing these four field trips, she changed the data-collecting procedure, because the recording steps made the assessment process extremely slow: they completed assessing only 2 miles in a month, whereas their initial plan was to complete assessing the entire 18 miles in three months. First, they reduced the size of a group from five to two, one expert and one volunteer. Also, a photo sheet and an inventory sheet were merged into one assessment form (See Figure 12). Hence, the revised process was as such: a group of one expert and one volunteer conducts a field trip, where the volunteer takes a picture and marks its location on a printout map, and the expert fills out an assessment form.

> *"We are mostly expediting the recording process. Because we were filling it out for each thing we saw on the sheet. It's a lot of paper and a lot of actions for information."*

We discussed facilitating technical solutions again. She explored Sensr and its features for two weeks, but decided to adopt neither it nor any other technical solutions. She said it was because of the accuracy of GPS. Whenever we recommended different technologies, she said: *"How* *accurate is that?"* We asked: *"how accurate do you want?"*, and her response was *"as closest as we can"* without noting any particular accuracy.

> *"If it is not precisely accurate, then no. That's why we use this map. We can mark on the map very precisely. Because we have both copies so that we can see and mark exactly where we are. And then record it. And, it's going to be converted to GIS anyway."*


**Figure 11. Printout maps and an inventory sheets used in the watershed assessment project**

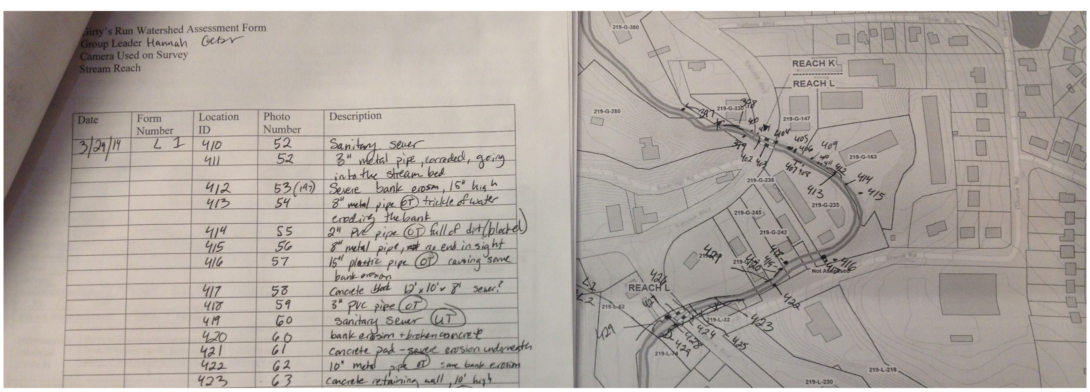



**Figure 12. An assessment sheet and a printout map with spots marked used in the watershed assessment project**

In fact, we thought that the revised data-collection process suited very well with a mobile tool to create via Sensr. However, she did not want to use it, because she was satisfied with a camera, a printout map, and an assessment sheet. While she was aware that it would take a significant amount of time to digitize the recorded data, she still wanted to use pen-and-paper. This project ended up not having any computing technologies except a camera.

### 9.5.2. CleanUp Org Campaign: Stewardship Campaign

The stewardship campaign runs volunteer stewards to monitor cleaned-up sites regularly in order to prevent it from being trashed again. A steward visits the site once a month walking around and checking whether there is new dumping, and then reports the condition to the program coordinator. She was the primary coordinator of this campaign, and she made all comments cited in this section.

At the time of this study, twenty-five stewards were enrolled in this campaign. While most reports were made through email, the coordinator sometimes had to call stewards to gather data, because stewards might forget to report back after their fieldwork. Thus, the program coordinator struggled with collecting and organizing data, and was looking for a systematic channel through which stewards could report data. After several discussions, she created a mobile tool to allow stewards to report findings on the go using Sensr. She expected that a mobile tool to report findings on the go would not only reduce her work of organizing data but also ease stewards' efforts on reporting.

> *"That will be helpful for them (stewards) to be able to do as they go through the busy day, stopping by the place to report things to us. People will not have to wait until they get back and email me."*

With this regard, the program coordinator created a mobile tool for this campaign. The tool consisted of a photo, three text fields (site name, reporter's name, general comments) and two multiple-choices (litter: minimal or extensive, dumping: yes or no) (See Figure 13).

#### *9.5.2.1. Using the tool: effects, issues, and limitations*

The immediate effect of adopting a mobile tool was on the program coordinator's feelings about the campaign. She was excited because now she could announce the campaign and its technology support. The stewardship campaign is relatively smaller and requires less effort in its operation compared to other campaigns, which often hindered her from working on it over numerous other tasks and campaigns that she coordinates. With this mobile tool, she felt more confident about the campaign itself, as well as recruiting volunteers. She repeatedly said that she felt the campaign was more official.

*"Because it's not a big item in our budget, I don't spend much time on it. And the numbers are small. So having a piece of technology all through the stewardship program makes me feel more like a program in its own right"*

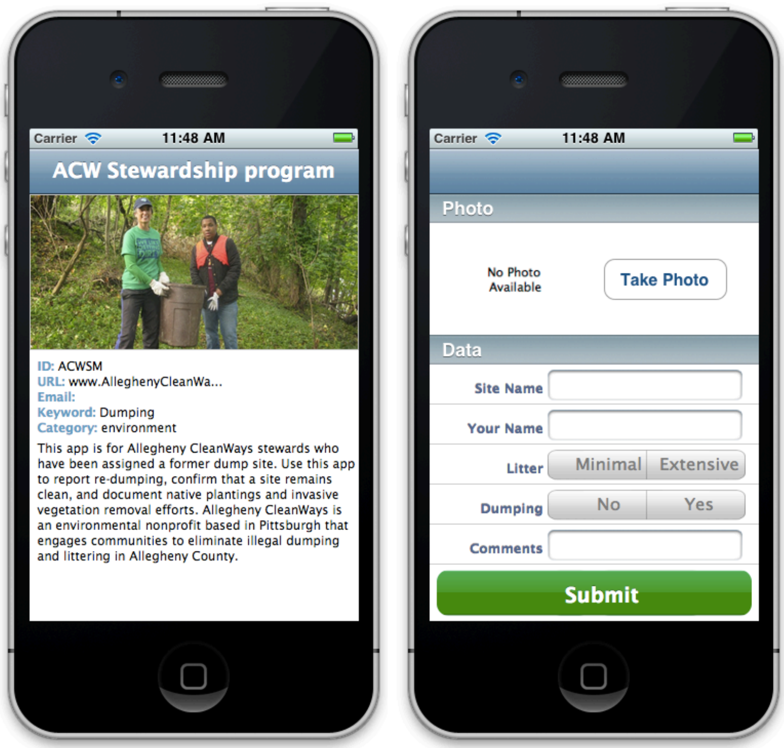



**Figure 13. Mobile stewardship project**

Because she thought that mobile technology (an app) has become standard these days, she was satisfied that her campaign now follows the social norm.

*"With the proliferation of apps for everything, not having an app is a deficit. Someone might say 'you don't have an app for that'? So, I feel like the program is more official because it has an app. It seems more official because we have some technology. I like to be able to say like 'do you want to be a steward? Now, we do have an app. We do have a way to make it easy if you have a smart phone!'"*

Also, she expected that a mobile tool would provide volunteers with a clear idea of how they are expected to do without much verbal explanation.

*"With the app, people clearly know more of what to do. 'I have this app. I am putting my data here.' Otherwise, it's like what am I doing, how am I reporting it to you?"*

The program coordinator announced this mobile campaign to volunteer students. The mobile tool was deployed for four months in this study (and is still in use). Among the twenty-five stewards, five registered to the mobile stewardship campaign, and over twenty reports were made through this tool. The most difficult problem in adopting a mobile tool stemmed from device compatibility: at the time of the study, Sensr supported iOS devices only. Among the existing stewards, only five of them owned iOS devices, whereas seven were using Android devices, and eleven were not using any smart phone. This is why only five were registered, whereas the rest of the stewards still emailed or called the program coordinator for the data report. Because the five iOS-using stewards were fully satisfied with it, she inquired about an Android version. To support other platforms beyond iOS devices, such as Android and Windows, we developed a web data-submission page where any smart phone user can access an Internet browser to submit data (See Figure 14).

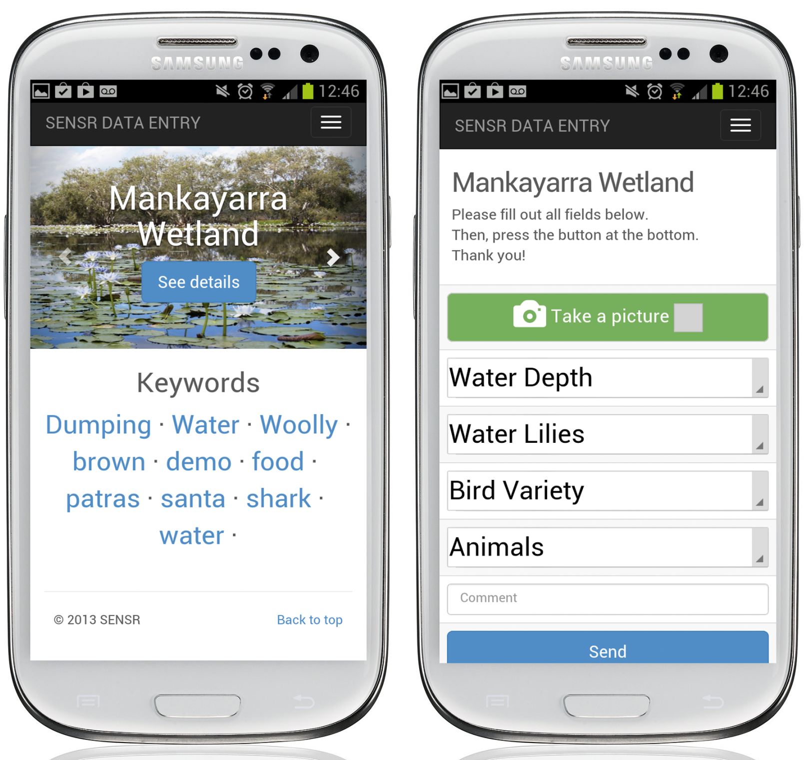



**Figure 14. Mobile stewardship project's web-submission form**

It turned out that the launch of this web data-submission page created bigger confusion. Most volunteers did not understand when they were instructed to "access the data-submission page using a mobile Internet browser to report data". Many people just assumed that the page would be where to download an application. Introducing new formats or interfaces on an already new system confused volunteers, and led to drop-off in adoption in the end. After trying to adopt the web data-submission page for two weeks, the program coordinator decided to stop using it.

> *"People are saying just like 'I don't know what's going on'. So it creates confusion, and it discourages people, and then they give up."*

> *"It was like there are two different platforms, a web-based and an iPhone app. That creates confusion for people. I have to say 'Remember to use the app, but that's not really an app but web or something. Some people just give up."*

Consequently, she had to keep the conventional ways of emailing and calling for non-iOS device users. We discussed whether operating a mobile tool would produce more work for her. She said that it still reduced her work, because it decreased the amount of work for organizing data. Also, the mobile tool allows the stewards to report their findings right away in the field, so they rarely forget to report. Lastly, the fact that the app itself does not require much work was the other reason, as the collected data are stored serially with pictures that she can access anytime.

> *"It has decreased the number of emails and reminders that I have to send out. It's more convenient for me because I am not being bombarded with separate requests and updates in my email. Also, it is nice not to have to worry as much about the data coming in, because it's all right there at one place. Especially for pictures it's really helpful, because I have a whole record right there, picture, picture, picture. It is great to have all of them in one place, rather than in an email and downloading them."*

### 9.5.3. CleanUp Org Campaign: Dumpsite Reporting

Satisfied with a mobile tool for the Stewardship campaign, the organization decided to launch another tool to enable the public to report dumpsites via mobile. In fact, this is not a new campaign, as they were receiving reports from the public about new dumpsites through email or phone occasionally. This mobile tool was also designed to be an alternative channel for people to report on the go. The program coordinator was the primary coordinator of this campaign, and made all comments cited in this section. She created a mobile tool using Sensr which consisted of a photo, four fields (city, neighborhood, nearest road, comments, email) and one multiple-choice question (tire: yes or no) (See Figure 15).

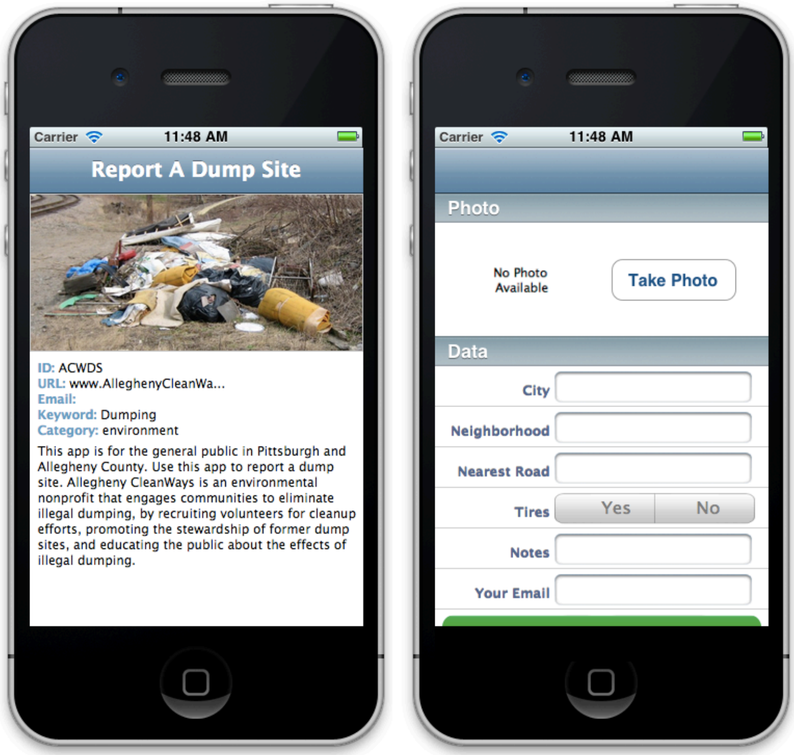



**Figure 15. A mobile stewardship project**

### *9.5.3.1. Using the tool: effects, issues, and limitations*

The program coordinator announced this mobile campaign via email, social media, and homepage. The mobile tool was deployed for two months in this study (and is still in use). During deployment, twenty-one volunteers registered to this campaign, and over thirty reports were made through this tool. In the end, the stewards who were already using a mobile tool for the stewardship campaign were the primary participants of this campaign, while the public still reported dumpsites through emails and phone calls. Because most dumpsite reporters were one-time participants, it might not be worth their time to figure out how to use a mobile tool instead of sending an email or making a phone call, she said.

> *"The difference between the convenience of the stewardship and the dumpsite app is that finding and downloading the app are not really easy if you are going to use it only once. I think the stewardship app is great because those people will be using it multiple times, and it's worth their time. But for the person that comes to me and says one dumpsite behind his house, it doesn't make much sense for that person to download it and go through the whole process. So, it looks like not as convenient for the regular people."*

Thus, the program coordinator did not expect the tool to be widely used by the public. However, she intended to keep operating it, because it does not require effort for its operation, existing stewards and active volunteers use this tool to report their concerns, and she can announce the dumpsite reporting campaign with technology support.

> *"Whenever someone does the dumpsite reporting to us, I will say like 'hey in the future you can use this app that helps you doing it easily.'"*

Lastly, we examined if having more dumpsite reports might overwhelm her, because the amount of new dumpsites may exceed their capacity, while the public might expect prompt actions about the report. She was aware of a higher expectation about follow-up activities regarding the reports, and that is why she has been expressing her appreciation to each person as soon as possible.

> *"For every singly report, I get back to its email, saying things like 'Thank you for your report. We will be working on it soon'. At the very least, we can demonstrate the magnitude of the problem."*

### 9.5.4. CleanUp Org Campaign: River Cleanup

The river cleanup campaign cleans up the city's rivers and shores. They run cleanup events twice a month from April to October, and the schedule of the events for the entire year is planned out earlier in the year. The planning includes selecting locations, preparing a boat, and recruiting volunteers. The program coordinator had coordinated this campaign, but the outreach coordinator took it over a year ago. The outreach coordinator made all comments cited in this section, except one comment that the program coordinator made (marked in parentheses).

Selecting locations is a particularly important part of the planning, as they have to determine where trash is, estimate the amount of trash in the river, and find the closest riverbank to disembark to take care of the collected trash and load/unload volunteers. The existing process was that the boat pilot drove on the river and wrote down a description of the spots. The program coordinator mentioned that they were seeking a systematic way to capture the locations on a boat using a GPS device when conducting an assessment, because logging the exact location on the river is difficult.

> *"There is no road, and the river doesn't have street names or house numbers. So, it is really hard to tell where. So, what we are doing is that we look for landmarks, and try to*

*guess and try to write down the closest from the landmark to estimate, which is not accurate." (Program coordinator)*

However, the outreach coordinator, who is currently in charge, had a different view about using technology. She did not want to use a mobile tool, because she believed that the boat pilot was experienced enough to determine the location without any technical supports. We raised the concern of difficulty in determining the exact location on the river, but she believed that the boat pilot's expertise were sufficient to achieve the goal.

*"Our boat pilot knows the river really well. He knows where the locations are. That's what we go on."*

Her attitude was the same as when she was considering a mobile tool for the watershed assessment campaign. She trusted human capabilities, and believed that pen-and-paper would be more convenient. After several discussions, she ended up not adopting any mobile tools.

**Figure 16. The riverbank cleanup project**

### 9.5.5. AirQuality Org Campaign: Bike Air Quality Monitoring

The bicycle air-quality monitoring program collects air quality data in the region from cyclists. Volunteer cyclists are recruited to attach a custom-made air quality sensor on their bikes, and to collect air quality readings while they ride around. With the data, they aimed to present a sampling of the region's air quality to illustrate location of the problem areas. Another part-time staff operated this campaign, and the policy and outreach coordinator managed the collected data. The policy and outreach coordinator made all comments cited in this section.

The policy and outreach coordinator and the part-time staff B explored leveraging mobile tools for this campaign. The idea was to enable cyclists to report things related to air pollution while riding a bike. This idea was extended to a campaign through which the public report any issues related to air pollution, as explained in the next section.

The policy and outreach coordinator was a technology expert. He managed all technical tasks in the organization, including updating a webpage, posting news on social media, and maintaining computing facilities. He mentioned that the public-collected data are mostly used as supplementary evidence for effective communication with other stakeholders, rather than to be used in house. He trusted the accuracy of the public-collected data but did not expect that the data would provide new information. This is different from the general concern about the accuracy of the novice-collected data, showing that the public-collected data has two different quality aspects, the accuracy and the novelty, to determine its quality.

### 9.5.6. AirQuality Org Campaign: Reporting Air Pollution

The AirQuality org created a new campaign that is a mobile channel through which the public can report air pollution. While the campaign itself was new, the idea was not new, as they were already receiving reports about air pollution from the public through an email or phone call occasionally. And, the mobile tool was designed as an alternative way to collect reports. Because they received a few reports via email and phone call every week, they sought a systemized channel through which the public can easily report. The policy and outreach coordinator was the primary coordinator operating this campaign, and made all comments cited in this section. He created the mobile tool using Sensr. The tool consisted of a photo, two multiple-choice questions (Pollution type: mobile or stationary, email from us: yes or no) and one field (email) (See Figure 17).

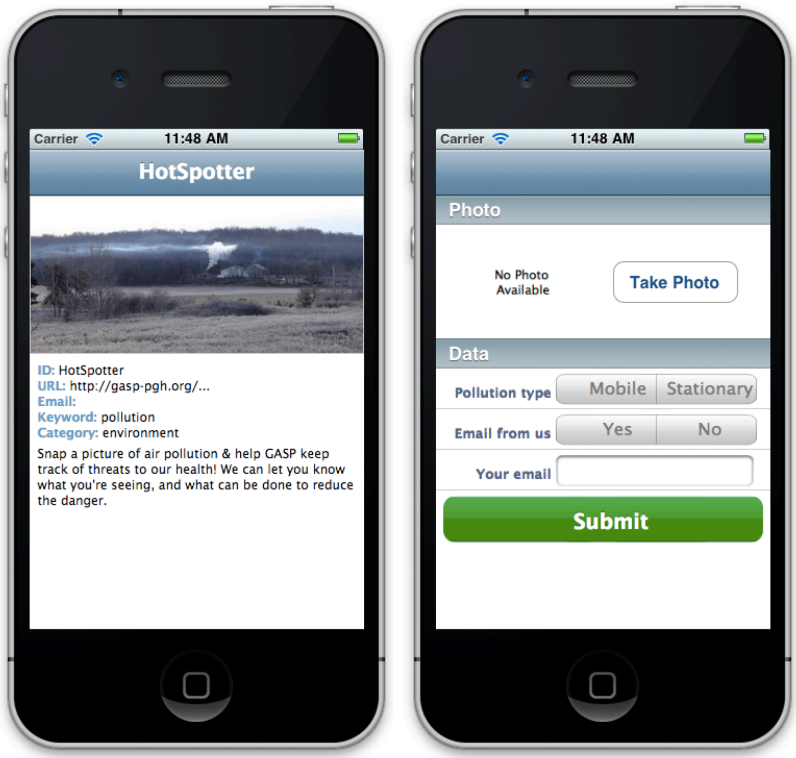



**Figure 17. Air pollution reporting project**

### *9.5.6.1. Using the tool: effects, issues and limitations*

The policy and outreach coordinator announced this mobile campaign via mailing list, social media, and its homepage. Unfortunately, there was not much use in its three-month deployment. We had several discussions with the coordinator to explore possible reasons why it was not used much. The first reason was that people might not need a special tool to report their concerns, because many of those who report air pollution are newcomers who were never involved in the organization's activity before. For them, an email or a phone would be easy enough for one-time use.

> *"They are usually people we never heard of. People don't think about air pollution until it affects them. Then, they freak out and research and find us and email or call us. Then, we give them some answer, and usually we never hear again from them."*

Those newcomers preferred sharing the entire story of their experience, rather than answering short yes-no questions. According to the policy and outreach coordinator, people want to share what happened or what they discovered with their own interpretation. Thus, an email or a phone call is simple but effective to share descriptive contents.

> *"People don't want to share a small piece of data, but want to share a whole experience about what happened and their thoughts. In this way, people feel that their actions are more meaningful than submitting a line of short sentences."*

He said that this type of information is less useful for the organization, but powerful and persuasive for community members to grow a sense of collective.

> *"We have people that look at facilities and make a report. They have their own ways to make a report, because they have been doing this for years. So, I think the people that would have been very excited to use this are already set."*

This organization has senior volunteers who have been engaged in various campaigns for a long time, reporting air pollution frequently. Unlike the volunteers in the CleanUp org, the active volunteers in this organization did not make use of the mobile tool either. They had already developed their own ways for action, and preferred their own ways rather than adopting a new tool, however easy and simple it was to use.

## 9.6. Discussion and Design Implications

When asked before starting the study, both organizations also indicated lack of technical resources as a challenge. After using Sensr, all agreed that Sensr removed their technical barriers in creating mobile solutions. However, as expected (Grudin, 1988) the increase in technical resources did not result in the increased adoption of mobile technology. A primary goal of our study was to explore the factors that lead to this outcome. We identified two factors that influenced making decisions of mobile technology adoption: (1) staff's individual perspectives on technology, and (2) the depth of public engagement in a campaign.

We found that staff's individual perspectives on technology significantly influenced its adoption. In the CleanUp org, the two staff members had completely different perspectives on mobile technology even though both were mid-twenty females with little experience in technology. One staff thought having a mobile tool was crucial not just because of its effectiveness, but also to follow a social standard of leveraging the growing cultural adoption and usage patters of mobile technology. As a result, she actively explored adopting mobile technology. Meanwhile, another staff expressed a strong distrust toward technical solutions, and did not even try using it. While data accuracy was the stated reason, there were two underlying reasons for distrust in technology: unfamiliarity with the capabilities of technology, and wanting to hold full control of tasks. In the AirQuality org, the policy and outreach coordinator, a technology expert, was not keen to adopt a mobile tool, because he did not expect to find any novel information from public-collected data.

## 9.6.1. Staff's Perspectives on Technology

We found that staff's individual perspectives on technology significantly influence its adoption. In the CleanUp org, the two staff members had completely different perspectives on mobile technology even though both were mid-twenty females with little experience in technology. As a result, she actively explored adopting mobile technology. Meanwhile, another staff expressed a strong distrust for technical solutions, and did not even try using it. While data accuracy was the stated reason, there were two underlying reasons: unfamiliar with the capabilities of technology, wanting to hold a full control of tasks. In the AirQuality org, the policy and outreach coordinator, a technology expert, was not keen to adopt a mobile tool, because he did not expect to find any novel information from public-collected data.

Personal propensity and organizational context are known to be strongly associated with the adoption of technological innovations (Tabak & Barr, 1999). Then, our finding shows that personal propensity of staff members is the most significant organizational factor that affects mobile technology adoption within the context of environmental organizations. This might be because of the size of an organization: one staff operates the entire process of a campaign so that her/his decision prevails over other factors (Hackler & Saxton, 2007). It matters little whether or not a technology is capable of performing a task unless people interpret the technology as being capable of doing so (Orlikowski, 2000).

### *9.6.1.1. Design implication*

Workers improve their interpretations of technology through social interaction with others (Leonardi, 2009). However, not much social interaction happens in this context because environmental organizations are generally small in size and one staff may control the whole. This is why individual perspectives dominate decision-making in technology adoption. Thus, fostering social interaction both internally and externally will expand the chances to benefit the capability of mobile technology.

## 9.6.2. The Depth of Public Involvement: Recurrent Participation vs. Sporadic Involvement

We found a distinct difference between the existing and new campaigns regarding the depth of public engagement that affects the adoption of mobile tools: recurrent participation or sporadic engagement. This difference affects the adoption of mobile tools through recurrent participation or sporadic engagement. We assume that this pattern is derived from a unique characteristic of volunteer campaigns: a distinction between coordinators – the creators of a mobile solution – and volunteers – the users of the solution. Whereas "perceived ease of use" and "perceived usefulness" from a coordinator's perspective are fully explored, volunteers' perspectives are rarely reflected because they are excluded from the process of mobile solutions creation, which in turn prevents its successful adoption.

### *9.6.2.1. Recurrent participation in structured campaigns*

All four existing campaigns were structured, periodic field events. Their volunteers were repeat visitors for the same event, devoting their time and effort participating in the campaign (except the Riverbank cleanup campaign as the boat pilot was considered to collect data.) We define this as recurrent participation. The depth of engagement in this type of campaigns is active, as personal resources are voluntarily allocated and spent on a campaign. And thus, people did not mind putting extra effort to learn new tools.

### *9.6.2.2. Sporadic Involvement in free-form campaigns*

Both organizations have created similar campaigns after being capable of building a mobile tool to report issues of concern. Contrary to the existing ones, new campaigns did not have particular protocols or schedules, and we define this type of public engagement as sporadic involvement. The depth of engagement is relatively passive and sporadic, as the public neither devotes to participating nor conducts a particular action until something comes to one's attention. Because organizations were already gathering public reports through other channels, they assumed that a mobile tool would facilitate public participation, as well as digitizing data instantly. However, mobile tools for these campaigns were barely used, and we reason this is because many reporters were one-time participants that had never been involved before and will hardly come back until something comes to one's attention. For them, an email or phone was just as effective for one-time use. This confirms Grudin's notion of the imbalance between those who receive the benefit of new technologies and those who must work to use them (Grudin, 1988).

Compared to the effort needed to use a tool, perceived benefits of its use in volunteers might be little.

While the staff's perspective on technology can count "perceived usefulness" and "perceived ease of use" in TAM (Davis, 1989), as well as "the privilege of an individual perceptions of a technology" (Orlikowski, 2000) from the staff's perspective, the depth of public engagement suggests extending the existing theoretical framework by integrating volunteers' stance into the model. This bespeaks the unique context of volunteer-driven environmental campaigns: a separation between the decision maker of technology adoption and creation – staff, and the decision maker of its use – volunteers (Friedman et al., 2013).

#### *9.6.2.3. Design Implication*

If people plan to use a tool more than once or even a few times, it is worth it to find better adoption rates. Meanwhile, one-time reports want to tell stories and connect directly with a person, not a database. This lends itself to design recommendations. A separate category of volunteers for one time or limited participation have a different set of needs when engaged with such organizationsm and may likely require a more natural and lightweight interface and an experience of more direct human interaction – as in an acknowledgement that their concern has been heard. Thus, when leveraging mobile technology, a deeper consideration about the form and process of digital engagement is required.

## 9.7. Conclusion and Limitations

Environmental campaigns often do not optimally benefit from mobile technology available in spite of potentials towards promoting participation in their data-collection activities. In this study, we eliminated technical barriers, the perceived major obstacle in customizing mobile solutions, and explored how campaign coordinators perceive, evaluate, adopt or decline to use mobile solutions in small organizations. Our deployment studying the entire cycle from assessment to creation to appropriation of, or failure to adopt, mobile solutions showed that the mobile tool adoption was not directly related to whether or not technical barriers existed. Instead, we identified two major constraints that significantly influenced decisions about mobile technology adoption: (1) an individual's perception of the degree of engagement in a campaign and (2) the staff's perspective on technology. Those two factors overpowered the resource constraints (the perceived obstacle) in the decision making process. This illustrates that the actual causes might be different from the perceived reasons of not using mobile solutions.

Our findings suggest a strong influence of individual perspectives both from coordinators and volunteers on the adoption and use of mobile technology. Building on the existing theories that privileged a user's individual perceptions and social interaction in technology adoption behaviors in an organizational context, this work indicates that individual values from multiple stakeholders should be taken into consideration as a whole as an iterative process of value-sensitive design, implicating different values that different stakeholders hold.

There are some limitations in this work. Because we chose to deploy our initial system on a single mobile platform (iOS), our adoption and usage results were less than if a full universal system had been deployed. With understanding in advance that this would be a concern, we deployed our single platform system to gather (even if initially limited) a set of early valuable usage and experience results around the tool and organizers. Second, because of the small volume of study participation, we do not argue that our proposed factors influencing the adoption of mobile technology are an exhaustive list. Instead, it is a starting point to explore ways to facilitate mobile technology. Lastly, as our results denote, it is crucial to incorporate volunteers' perspectives in mobile technology adoption, but this work just interpreted volunteers' perspectives through staff members indirectly. Direct studies of volunteer perspectives and interviews would provide further insights about them, opening opportunities for future research.

# 10 Discussion and conclusion

The ultimate goal of this dissertation is to develop a holistic understanding of the current state of organizational phenomena and to inform future research of mobile technology in volunteer efforts. More specifically, it is to provide design insights that further the democratization of mobile volunteer data collection systems. To leverage the ubiquity and recent advances in mobile technology, we conducted a series of field observation studies, system developments, and deployments to understand the current landscape of volunteer activities for data collection.

For our initial development, we built Creek Watch, which was designed to support citizens' activities in water quality monitoring. From this study, we demonstrated how adoption of such mobile solutions could improve the existing experiences of volunteer data collection activities. While previous research into this realm in HCI and other relevant communities has mostly focused on designing effective capture interfaces and incentive mechanisms for end users, we explored the application of HCI methods to ensure that the data itself is useful. To provide a focus for this exploration, we designed and implemented Creek Watch, which allows volunteers to report information about waterways in order to aid water management programs and agencies.

From our study, we noticed that Creek Watch's final solution could be appropriate for volunteer data collection activities in a wider scope without much modification. Its interface was simple and easy to use for novice volunteers, and the components for data collection were applicable to, and required by, a wide variety of activities. This sheds light on the potential of exploiting technical capacities of mobile technology for volunteer activities in a broad scope of domains.

However, the organizations that coordinate volunteer activities often do not fully benefit from the capabilities of advanced mobile technologies. Through a series of field studies with different methods, including an online observation, a survey and in-person interviews, we confirmed that the rate of mobile technology adoption in volunteer data collection activities has been low, and the high technical threshold was perceived as a major challenge in the customized use of mobile technology (*i.e.* building a mobile application).

In particular, our comprehensive in-depth interviews with eleven organizational leaders confirmed that information technologies were widely used to support volunteer activities. However the organizational leaders also discussed several challenges that mobile technology could easily help overcome. This study focused on deconstructing the primary elements affecting mobile technology usage within volunteer data collection tasks. Through our process of analysis, **two thematic areas** emerged in terms of volunteer participation in data collection: *environmental activism* and *community mobilization.* These thematic areas determined the perceived adoption of mobile technology. This is the technical capability of such systems to validate data accuracy in environmental activism, and the ability to scale public participation in large data collection efforts in community mobilization.

This exploration revealed **two perceived challenges** that contribute to the underutilization of mobile technology (beyond technical difficulties): *questioning the credibility of public participation*, and *mobile interaction interfering with the field experience*. While not an exhaustive list, when strategizing the adoption of mobile technologies in volunteer data collection activities, these challenges are necessary starting points.

From these studies, we identified **primary design considerations** to support technologically enhanced volunteer activities, such as:

- Avoid technological distractions that diminish the authentic field experience of environmental monitoring: The findings from the field investigation (Chapter 5) suggest that when designing a technology to improve the data collection process of an existing environmental monitoring activity, it should be carefully determined which part of the existing activity will incorporate technical solutions so that the new technical piece does not impair the authentic experience. People participate in environmental monitoring activities not just to help assess environmental conditions per se. The reason for participation can be more personal, such as enjoying the moment out in the field, conserving the neighborhood environment, and learning about nature. Therefore, technological intervention designed to enhance the process of data collection does not necessarily mean improving overall experience of volunteer participation. Rather, technology involvement may incur technological distractions, such as reading email or checking text messages in the field. Thus, technological intervention for environmental data collection should be designed in a way to avoid technological distractions to sustain the authentic field experience.

- Protect privacy and security: The findings from the Sensr pilot case study (Chapter 8) suggest that the issues relating to privacy and security are critical, but the staff members in volunteer activities seldom realize its importance due to their lack of experience with technology, and the volunteers' unfamiliarity with the system. The issues regarding privacy and security are particularly critical in digital micro-volunteerism, as the two primary types of data to collect, location and photo, might inadvertently include personally identifiable information. Since these data had already been collected through offline tools, often staff and volunteers did not realize that electronically submitted data could be publicly available. This makes it critical to systematically protect privacy issues, particularly when collecting personal identification information from volunteers, instead of letting users configure privacy and security issues themselves.
- Assure the quality of public participation: The findings from the 6-month deployment study (Chapter 9) suggest that the quality of participation is crucial for the success of volunteer data collection campaigns, but the measurement of its quality differs. In the 6-month deployment study, we determined two types of volunteer participation in data collection activities by goal, environmental monitoring and community activism, and their measure for success. Environmental monitoring activities measure the accuracy of collected data to gauge the quality of public participation, whereas community activism projects evaluate the success of public-participated projects by the volume of participation. Therefore, it is critical to first determine the measurement for quality of participation, and then incorporate the quality measurement in the design of a mobile data collection tool.
- Understand the form of volunteer participation: The findings from the 6-month deployment study (Chapter 9) suggest that the form of volunteer participation is a critical factor that affects the successful adoption of mobile solutions. In the 6-month deployment study, we determined two types of volunteer activities by their form: a structured campaign and an ad-hoc public engagement. Volunteers in a structured campaign devoted their time and efforts to turn in a set of data on a regular basis. Whereas people who engage in an activity on an ad-hoc basis do not pay attention to the issues that the activity is meant to address, unless it directly affects them. Then, once engaged, people want to share their entire personal experience on an ad-hoc basis, and they often never volunteer in the program again. Thus, we found that mobile solutions

for data collection well serve a structured volunteer campaign, but not an ad-hoc type of public engagement in neighborhood issues. Therefore it is crucial to understand the form of volunteer participation for a campaign, and determine mobile tool adoption accordingly.

Grounded in these findings, we designed, developed, and deployed an authoring environment, Sensr, which is a combination of a mobile application and a web platform to create mobile solutions for data collection. Sensr enables people without programming skills to build mobile data collection and management solutions. Through case studies, we confirmed that Sensr successfully helped people with minimal technical and financial resources author mobile solutions for data collection. The findings demonstrated that Sensr could help organizational leaders overcome technical constraints in creating mobile data collection solutions.

Finally, from a six-month investigation of how organizations evaluate, appropriate, adopt, or avoid the use of mobile solutions through deployment of Sensr, this dissertation examined factors that are associated with successful usage or non-usage of mobile technology in volunteer data collection activities. We removed the issue of technical difficulty to allow other problems to rise to the surface. Our findings revealed a significant impact of staff members' individual perspectives towards the adoption of mobile technology. Staff members with a positive perspective of mobile technology enjoyed new technical innovations available, whereas those with a negative perspective disregarded the potentials of such technology.

Literature in the field of Computer Supported Collaborative Work (CSCW) has indicated that failure in collaborative systems is rarely due to the structure of the technical systems and solutions (Ellis et al., 1991; Orlikowski, 2008). Instead, it results from not understanding the unique demands this class of software imposes on developers and users (Grudin, 1988).

There are contextual factors within the domain of nonprofit, volunteer organizations for mobile solution usage that distinguish our findings from prior works of general CSCW solutions. For instance, mobile technology no longer benefits only those who possess particular, at least in contemporary western societies. Rather, its capabilities have been democratized for personal use for multiple purposes, thanks to its affordable price and available infrastructure.

Despite the increased use of mobile technology across many economic sectors and cultural groups, custom mobile technology is not as widely adopted. There is a clear opportunity here, since mobile technology has the potential to provide information that could be of great value in community based data collection tasks. Photos, location, and other sensors could be used to enhance this, but require custom mobile applications to be effectively incorporated into data collection. This is something that non-profits have not yet invested in, for the most part.

Another contextual factor is associated with lack of mobile experience among staff members. Many staff members in nonprofit organizations have very little experience in making use of mobile solutions for their work. The result is not just lack of knowledge about the potentials, availabilities, and limitations of mobile technology, but sometimes distrust, refusal or ignorance of mobile technology. Increasing staff members' exposure to mobile technology and its usage will help diversify their view toward mobile technology, which may empower them to determine their needs and to make more informed decisions about mobile technology adoption.

Building on prior work which points to the importance of a range of social factors in technology acceptance (*i.e*., Grudin, 1988; Carroll, 2004; Le Dantec & Edwards, 2008; Saeed et al., 2011), our contribution is an analysis of the factors that should be considered in the application of custom mobile technology for data collection in small non-profits. We removed the issue of technical difficulty to allow other, more subtle, problems to rise to the surface. Our findings explore issues such as personal interpretation about, comprehension of, and propensity to accept technological interventions. This is in accordance with predominant theoretical approaches in the design of technology to include users' perspectives in the process, either directly – Participatory design – or indirectly – Value-sensitive design. Extending existing theoretical approaches to the design of technology, this dissertation suggests that we need to identify different perspectives, needs, benefits, and skills of multiple stakeholders that constitute a volunteer activity, and incorporating these into the process of novel mobile volunteering systems.

## 10.1. Summary of Contributions

This dissertation deconstructs the landscape of emerging mobile technologies and their potential to more effectively impact volunteer and data collection activities. In this regard, the first contribution of this dissertation is a better understanding of the new digital micro-volunteerism practices using mobile technology. As the resource-constrained environments were regarded by staff members as a major challenge, in both prior work as well as our own research, we eliminated the issue of technical difficulty to allow other, more subtle, problems to rise to the surface. Then, the fact emerged that complicated individual perspectives and fears towards new technology disproportionately influenced its adoption and usage. Our work revealed a new gap between the perceived and actual reasons for the underutilization of mobile technology in volunteer activities, and suggests that both the individual and the technical needs should be taken into consideration during early design phases of such technologies.

The second contribution is the development of Sensr. Sensr was designed to reduce the technical challenges surrounding the creation of mobile volunteerism applications. After several developmental iterations and pilot studies, this system has been deployed in the wild, and continues to be used by real-world users.

Lastly, from a comprehensive description of the organizational factors, and through a study of the entire creation and usage cycle of such a mobile tool, this dissertation outlines specific strategies to support an accelerated adoption of volunteer themed mobile technology. Ultimately, we hope that the work within this dissertation will broaden our knowledge of digital volunteerism and promote democratization of mobile technology within the domain of volunteering.

# AFFENDIX A – SURVEY QUESTIONS

## Survey of Nonprofit Organizations and Their Technology Use

We are a research group at Carnegie Mellon University.

As part of our research, we are conducting a survey to understand nonprofit organizations' current technology use when interacting with their volunteering members. In this survey, we will be asking about tools and methods that nonprofit organizations are using when communicating with volunteers.

Your participation is invaluable for us to proceed with our research. It will take no more than 30 minutes to complete the survey, and your organization will have a chance to win a $500 donation to your organization once you complete the survey. (Only one account from each organization will be entered for a raffle.)

If you are a technical staff, project manager, outreach coordinator, or executive director, please participate in this survey. If your role is none of these, please forward this survey to any of the staff members in your organization whose role is one of these. Participation in this research is voluntary. If you have any questions, please contact us at research.hcii@gmail.com.

Thanks!

* Required

1. **I am age 18 or older.** *
   *Mark only one oval.*
   - ( ) Yes *After the last question in this section, skip to question 4.*
   - ( ) No *After the last question in this section, skip to question 3.*

2. **I want to participate in this research and continue with the survey.** *
   *Mark only one oval.*
   - ( ) Yes *Skip to question 4.*
   - ( ) No *Skip to question 3.*

3. **Then, you are not eligible to continue this survey. Do you want to go back?** *
   *Mark only one oval.*
   - ( ) Yes, I want to restart.
   - ( ) No, I want to quit. *Skip to question 67.*

4. **What is the name of this organization?** *

   ______________________________

5. **What is the website url of this organization?**

   ______________________________

6. **Which category does this organization fall under?**
*Mark only one oval.*

- ( ) Animal Protection, Welfare and Services
- ( ) Beautification and Horticulture
- ( ) Civil Rights and Liberties
- ( ) Community Improvement
- ( ) Conservation and Environmental Education
- ( ) Health Care Facilities and Programs
- ( ) Mutual/Membership Benefit Organizations
- ( ) Philanthropy, Voluntarism, and Public Benefit
- ( ) Pollution
- ( ) Voter Education and Registration
- ( ) Zoos and Veterinary Services
- ( ) Other: ______

7. **What is the geographic coverage of this organization?**
*Mark only one oval.*

- ( ) Neighborhood community
- ( ) City-wide
- ( ) State-wide
- ( ) Nation-wide
- ( ) Other: ______

8. **Which state is this organization located?** *
*Mark only one oval.*

- ( ) AL
- ( ) AK
- ( ) AR
- ( ) AZ
- ( ) CA
- ( ) CO
- ( ) CT
- ( ) DE
- ( ) FL
- ( ) GA
- ( ) HI
- ( ) IA
- ( ) ID

9. **Which city is this organization located?**

10. **Which year was this organization established?**
Put an approximate month and day if you do not have the exact date.

*Example: December 15, 2012*

11. **How many employees are working full-time for this organization?** *
*Mark only one oval.*

- 5 or less
- 6 ~ 10
- 11 ~ 20
- 21 ~ 50
- 51 ~ 100
- 101 ~ 500
- 501 ~ 1000
- Over 1001

12. **How many divisions does this organization have?**
Enter the number of divisions

13. **What is the name of the most complicated, high-tech software that this organization is using?**

14. **Does this organization have a division related to IT management?**
*Mark only one oval.*

- Yes *Skip to question 15.*
- No *Skip to question 17.*

15. **How many staff members are working in the IT-related division?**

20. **Approximately, how many volunteers are currently enrolled in this organization?** *
*Mark only one oval.*

- under 50
- 51 ~ 100
- 101 ~ 500
- 501 ~ 1000
- 1001 ~ 5000
- Over 5001

21. **Approximately, how many among them are active volunteers?**
*Mark only one oval.*

- Under 10
- 11 ~ 20
- 21 ~ 50
- 51 ~ 100
- 101 ~ 200
- over 501

22. **Approximately, which is the most prevalent age group of the active volunteers?**
*Mark only one oval.*

- Under 20s
- 20s ~ 40s
- 40s ~ 60s
- Over 60s

23. **Do these active volunteers use mobile devices of any form for their activities?** *
*Mark only one oval.*

- Yes *Skip to question 24.*
- No *Skip to question 25.*

24. **Please specify what kinds of mobile devices they use for what reasons.**

..........................................................................................
..........................................................................................
..........................................................................................
..........................................................................................
..........................................................................................

16. **What do the staff members in this organization do if they have problems related to the IT use for work?**

..............................................................................

..............................................................................

..............................................................................

..............................................................................

..............................................................................

17. **Does this organization have volunteers to participate in organizational activities?** *
*Mark only one oval.*

- ( ) Yes *Skip to question 18.*
- ( ) No *Skip to question 42.*

18. **Select all applicable volunteer activities.**
*Check all that apply.*

- [ ] Fundraising
- [ ] General labor
- [ ] General office services
- [ ] Report incidents
- [ ] Tutor or teaching
- [ ] Other: ..............................................................................

19. **How do you recruit volunteers for the volunteer activities above? Select all applicable.**
*Check all that apply.*

- [ ] Direct mail
- [ ] Email or mailing list
- [ ] Phone call
- [ ] Public release (news paper)
- [ ] Social media (Facebook or Twitter)
- [ ] Recruiting websites
- [ ] Homepage
- [ ] Other: ..............................................................................

25. **Do these active volunteers use any special tools beside moible devices for their activities? (e.g., booklet, protocol, guideline)** *

*Mark only one oval.*

- ⬭ Yes *Skip to question 26.*
- ⬭ No *Skip to question 27.*

26. **Please specify what kinds of tools they use for what reasons.**

_______________________________________________

_______________________________________________

_______________________________________________

_______________________________________________

_______________________________________________

27. **What is the name of the most recent project that volunteers participate in?**

_______________________________________________

28. **Please briefly describe this project, including what the goal of this project, what volunteer activities are, etc.**

_______________________________________________

_______________________________________________

_______________________________________________

_______________________________________________

_______________________________________________

29. **How often does this project happen?**

*Mark only one oval.*

- ⬭ Once a week
- ⬭ Bi weekly
- ⬭ Montly
- ⬭ Bi monthly
- ⬭ Once a few months
- ⬭ Once a year
- ⬭ Other: _______________________________________________

30. **How many volunteers participate in the project on average?**
*Mark only one oval.*

- Less than 5
- 6 ~ 10
- 11 ~ 20
- 21 ~ 50
- 51 ~ 100
- Over 101

31. **What do the volunteers do for this project?**

32. **Does this organization send information to volunteers?** *
*Mark only one oval.*

- Yes *Skip to question 33.*
- No *Skip to question 36.*

33. **What kinds of information is it? Select all applicable.**
*Check all that apply.*

- Fundraising
- Volunteer recruitment
- Introducing upcoming events
- Sharing past events
- Periodical newsletter
- Communicating with individual volunteers separately
- Other:

34. **How often does this organization send out each type of information to volunteers? Select the approximate one.**
*Mark only one oval per row.*

| | More than once a day | A few times a week | A few times a month | Once a couple of months | Over once a few months |
|---|---|---|---|---|---|
| Fundraising | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Volunteer recruitment | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Introducing upcoming events | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Sharing past events | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Periodical newsletter | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Communicating with individual volunteers separately | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| Other | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |

35. **How does this organization send out information to volunteers? Select all applicable.**
*Check all that apply.*

- ☐ Direct mail
- ☐ Email
- ☐ In person
- ☐ Phone call
- ☐ Social media (Facebook or Twitter)
- ☐ Web submission form
- ☐ Other: ____________________

36. **Does this organization collect any kinds of data from volunteers?** *
*Mark only one oval.*

- ⬭ Yes *Skip to question 37.*
- ⬭ No *Skip to question 42.*

37. **What types of data is it? Select all applicable.**
*Check all that apply.*

- ☐ Observation
- ☐ Opinion
- ☐ Report
- ☐ Other: ____________________

38. **What format of data is it? Select all applicable.**
*Check all that apply.*

- [ ] Numeric
- [ ] Descriptive
- [ ] Location
- [ ] Picture
- [ ] Comment
- [ ] Other: ______________________

39. **How do volunteers turn in the data? Select all applicable.**
*Check all that apply.*

- [ ] Direct mail
- [ ] Email
- [ ] In person
- [ ] Phone call
- [ ] Social media (Facebook or Twitter)
- [ ] Web submission form
- [ ] Other: ______________________

40. **Please describe the data this organization is collecting from volunteers. (e.g., why, how, etc.)**

______________________
______________________
______________________
______________________
______________________

41. **Please describe how this organization makes use of the data collected by volunteers.**

______________________
______________________
______________________
______________________
______________________

42. **Does this organization have a Facebook page?** *
*Mark only one oval.*

- ( ) Yes *Skip to question 43.*
- ( ) No *Skip to question 45.*

43. **Approximately, how often does this organization update Facebook page?**
*Mark only one oval.*

- ◯ Once a day or more
- ◯ A couple of times a week
- ◯ Once a week
- ◯ Once a couple of weeks
- ◯ Once a month
- ◯ Over once a month

44. **What are the purposes of using a Facebook page? Select all applicable.**
*Check all that apply.*

- ☐ News updates
- ☐ Recruiting volunteers
- ☐ Fundraising
- ☐ Community engagement
- ☐ Other: ____________________

45. **Does this organization have a Twitter account?** *
*Mark only one oval.*

- ◯ Yes *Skip to question 46.*
- ◯ No *Skip to question 48.*

46. **What is the purpose of using Twitter? Select all applicable.**
*Check all that apply.*

- ☐ News updates
- ☐ Recruiting volunteers
- ☐ Fundraising
- ☐ Community engagement
- ☐ Other: ____________________

47. **Approximately, how often does this organization tweet?**
*Mark only one oval.*

- ◯ Once a day or more
- ◯ A couple of times a week
- ◯ Once a week
- ◯ Once a couple of weeks
- ◯ Once a month
- ◯ Over once a month

52. **How does this organization conduct relations with volunteers? Select all applicable.**
*Check all that apply.*

- [ ] Direct mail
- [ ] Email
- [ ] Face-to-face
- [ ] Fax
- [ ] Other IT systems
- [ ] Phone
- [ ] Social media
- [ ] Other: ______________________

53. **Please select one you use the most often among the list above.**
*Mark only one oval.*

- ( ) Direct mail
- ( ) Email
- ( ) Face-to-face
- ( ) Fax
- ( ) Other IT systems
- ( ) Phone
- ( ) Social media
- ( ) Other: ______________________

54. **Do you use a mobile computer (e.g., Smartphone, Tablet PC, etc.) for your work?**
*Mark only one oval.*

- ( ) Yes *Skip to question 55.*
- ( ) No *Skip to question 56.*

55. **What is the main purpose of using a mobile computer for work?**

______________________
______________________
______________________
______________________
______________________

56. **Which of following best describes you in this organization?** *
*Mark only one oval.*

- ( ) Executive director
- ( ) Manager
- ( ) Staff
- ( ) Intern
- ( ) Other: ____________

57. **What is your official title in this organization?**
*

____________

58. **Please describe your role or activities in this organization (e.g., what you are in charge of)**

____________
____________
____________
____________
____________

59. **How long have you been employed at this organization?** *
*Mark only one oval.*

- ( ) Less than 6 months
- ( ) 6 ~ 12 months
- ( ) 12 ~ 24 months
- ( ) 24 ~ 48 months
- ( ) Over 48 months

60. **What is your completed education level?** *
*Mark only one oval.*

- ( ) Junior/High school
- ( ) College
- ( ) University
- ( ) Graduate
- ( ) Other: ____________

48. **Does this organization use any other social media beside Facebook and Twitter?**
*Mark only one oval.*

- ◯ Yes *Skip to question 49.*
- ◯ No *Skip to question 50.*

49. **Please specify the name of other social media that this organization is using, and describe how it is used.**

..........................................................................
..........................................................................
..........................................................................
..........................................................................
..........................................................................

50. **How does this organization conduct relations with other organizations? Select all applicable.**
*Check all that apply.*

- ☐ Direct mail
- ☐ Email
- ☐ Face-to-face
- ☐ Fax
- ☐ Other IT systems
- ☐ Phone
- ☐ Other: ..........................................................................

51. **Please select one you use the most often among the list above.**
*Mark only one oval.*

- ◯ Direct mail
- ◯ Email
- ◯ Face-to-face
- ◯ Fax
- ◯ Other IT systems
- ◯ Phone
- ◯ Other: ..........................................................................

61. **How many hours do you use a computer for your work?** *
*Mark only one oval.*

- ( ) None
- ( ) Less than 2 hours
- ( ) 2 ~ 4 hours
- ( ) Over 4 hours
- ( ) Other: ____________

62. **Please select all appropriate responds from the list of software below that you are confident of using well.**
*Check all that apply.*

- [ ] Email software
- [ ] Groupware
- [ ] Spreadsheet
- [ ] Web search
- [ ] Word processor
- [ ] Web programming
- [ ] Database
- [ ] Mobile programming
- [ ] Other: ____________

63. **Can you name any software that you think you are the most technically savvy, if any?**

____________

64. **Do you own a Smartphone?**
*Mark only one oval.*

- ( ) Yes *Skip to question 65.*
- ( ) No *Skip to question 66.*

65. **Please select all that you do with your Smartphone.**
*Check all that apply.*

- [ ] Email
- [ ] Text messaging
- [ ] Social media use (Facebook, Twitter, etc.)
- [ ] Internet browsing
- [ ] Download and use mobile apps for entertainment
- [ ] Download and use mobile apps for education
- [ ] Download and use mobile apps for scheduling and work
- [ ] Other: ____________________

66. **Are you interested in follow-up interview?** *
Your participation will help us further explore the creation and adoption of mobile applications in nonprofit organizations.
*Mark only one oval.*

- ( ) Yes
- ( ) No

## Thank you!

That's all.
Thank you so much for answering all questions.

Your organization now entered the raffle to win a $500 donation. We will get back to you via the email you enter below with the raffle results soon. In the meantime, if you have any questions, please contact us at research.hcii@gmail.com.

Good luck!

67. **Please leave the contact email address to receive the raffle result.** *

____________________

# APPENDIX B – SURVEY ANSWERS

1. Which category does this organization fall under?

| | |
|---|---|
| Conservation and Environmental Education | 22 |
| Animal Protection, Welfare and Services | 4 |
| Youth development | 4 |
| Congregation | 2 |
| Foundation | 2 |
| Human services | 2 |
| Science and technology center | 2 |
| Urban Farming and Gardening | 2 |
| Aquatic invasive species management | 1 |
| Child Advocacy / Human Services | 1 |
| Education Support Services | 1 |
| Health Care Facilities and Programs | 1 |
| Preservation of Historic Structure | 1 |

2. How many employees are working full-time for this organization?

| | |
|---|---|
| 5 or less | 29 |
| 21 ~ 50 | 5 |
| 51 ~ 100 | 3 |
| 6 ~ 10 | 6 |
| 11 ~ 20 | 2 |
| 101 ~ 500 | 1 |

3. How many divisions does this organization have?

| | |
|---|---|
| 1 | 25 |
| 3 | 2 |
| 4 | 4 |
| 2 | 6 |
| 5 | 2 |
| 8 | 2 |
| 6 | 2 |

4. Does this organization have a division related to IT management?

| | |
|---|---|
| Yes | 6 |
| No | 40 |

5. Does this organization have volunteers to participate in organizational activities?

| | |
|---|---|
| Yes | 42 |
| No | 4 |

6. Select all applicable volunteer activities.

| | |
|---|---|
| Fundraising | 35 |
| General office services | 33 |
| General labor | 28 |
| Tutor or teaching | 16 |
| Report incidents | 7 |

7. How do you recruit volunteers for the volunteer activities above? Select all applicable.

| | |
|---|---|
| Social media (Facebook or Twitter) | 39 |
| Email or mailing list | 37 |
| Homepage | 30 |
| Public release (news paper) | 24 |
| Recruiting websites | 20 |
| Phone call | 16 |
| Direct mail | 15 |

8. Approximately, how many volunteers are currently enrolled in this organization?

| | |
|---|---|
| 1001 ~ 5000 | 6 |
| 101 ~ 500 | 13 |
| 501 ~ 1000 | 3 |
| 51 ~ 100 | 9 |
| Under 50 | 11 |

9. Approximately, how many among them are active volunteers?

| | |
|---|---|
| 101 ~ 200 | 6 |
| 11 ~ 20 | 8 |
| 21 ~ 50 | 14 |

| | |
|---|---|
| 51 ~ 100 | 4 |
| over 501 | 5 |
| Under 10 | 5 |

10. Approximately, which is the most prevalent age group of the active volunteers?

| | |
|---|---|
| Under 20s | 3 |
| 20s ~ 40s | 11 |
| 40s ~ 60s | 18 |
| Over 60s | 9 |

11. Do these active volunteers use mobile devices of any form for their activities?

| | |
|---|---|
| Yes | 17 |
| No | 25 |

12. Does this organization send information to volunteers?

| | |
|---|---|
| Yes | 43 |
| No | 3 |

13. What kinds of information is it? Select all applicable.

| | |
|---|---|
| Fundraising | 31 |
| Volunteer recruitment | 25 |
| Introducing upcoming events | 34 |
| Periodical newsletter | 29 |
| Sharing past events | 24 |
| Communicating with individual volunteers separately | 37 |

14. How does this organization send out information to volunteers? Select all applicable.

| | |
|---|---|
| Phone call | 31 |
| Social media (Facebook or Twitter) | 29 |
| Email | 23 |
| In person | 22 |
| Web submission form | 17 |
| Direct mail | 15 |

15. Does this organization collect any kinds of data from volunteers?

| | |
|---|---|
| Yes | 36 |

| | |
|---|---|
| No | 8 |

16. What types of data is it? Select all applicable.

| | |
|---|---|
| Observation | 22 |
| Report | 19 |
| Opinion | 13 |

17. What format of data is it? Select all applicable.

| | |
|---|---|
| Numeric | 24 |
| Descriptive | 20 |
| Location | 12 |
| Picture | 6 |
| Comment | 5 |

18. How do volunteers turn in the data? Select all applicable.

| | |
|---|---|
| Email | 23 |
| In person | 23 |
| Web submission form | 15 |
| Phone call | 14 |
| Social media (Facebook or Twitter) | 6 |

19. How does this organization conduct relations with other organizations? Select all applicable.

| | |
|---|---|
| Face-to-face | 46 |
| Phone | 35 |
| Direct mail | 21 |
| Email | 21 |
| Fax | 12 |
| Other IT systems | 6 |

20. Please select one you use the most often among the list above.

| | |
|---|---|
| Email | 41 |
| Face-to-face | 4 |
| Phone | 1 |

21. How does this organization conduct relations with volunteers? Select all applicable.

| | |
|---|---|
| Face-to-face | 40 |

| | |
|---|---|
| Phone | 37 |
| Social media | 26 |
| Direct mail | 18 |
| Email | 18 |
| Fax | 1 |
| Other IT systems | 1 |

22. Please select one you use the most often among the list above.

| | |
|---|---|
| Email | 37 |
| Social media | 3 |
| Phone | 3 |

23. Which of following best describes you in this organization?

| | |
|---|---|
| Manager | 15 |
| Executive director | 14 |
| Staff | 11 |
| Board member | 2 |
| Volunteer management | 1 |
| Officer | 1 |
| Director | 1 |
| Communications | 1 |
| Manager | 15 |
| Executive director | 14 |
| Staff | 11 |

24. What is your completed education level?

| | |
|---|---|
| Graduate | 23 |
| College | 11 |
| University | 11 |

.

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