Scientists@home and in the backyard: understanding the motivations of contributors to digital citizen science

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Abstract

Citizen science offers a low-cost way to both strengthen the scientific infrastructure and engage members of the public in science. Digital citizen science is based on two pillars. The first is technological: developing computer systems to manage large amounts of distributed resources. The second pillar is motivational: attracting and retaining people who would be willing to contribute their computing resources, skills, time, and effort to a scientific cause. While the technological aspect was widely studied, the motivational dimension received little attention to date. We surveyed 4376 volunteers in three citizen science projects, of varying task granularity levels, and found that collective and intrinsic motives are the most salient motivational factors, whereas reward motives seem to be less relevant to citizen scientists. In addition, we found that most motivational factors are susceptible to differences in the contribution's task granularity. Implications for research and practice are discussed.

Keywords: citizen science, motivations, crowdsourcing, volunteer computing, distributed computing, crowd computing

Many aspects of scientific research, such as observation, classification and analysis, are labor-intensive, time-consuming, and as a result, costly (Maxwell et al., 2009; Rose, 2009). *Citizen science* offers a new approach for conducting scientific research, following the crowdsourcing model, whereby volunteers participate in scientific research by contributing to data collection and analysis (Raddick et al, 2009). In times of research budget cuts (Clery, 2010) and increasing cost of doing science (Bonetta, 2008; Sarewitz, 2008), citizen science represents a low-cost way to both strengthen the scientific infrastructure and engage members of the public in science. According to Haym Hirsh, director of the NSF's Information and Intelligent Systems Division, it is "a natural solution to many of the problems that scientists are dealing with that involve massive amounts of data" (Young, 2010).

In *digital citizen science* projects (sometimes referred to as *citizen cyberscience*) (Hand, 2010), participation takes place - at least in part - online. Some examples include: volunteer computing projects, such as SETI@home and Rosetta@home (where volunteers run on their computers programs that search radio telescope signals for signs of extra terrestrial intelligence in SETI@home, and help determine the three-dimensional shapes of proteins in Rosetta@home); web-based image classification projects, such as Stardust@home (where volunteers classify images from NASA's Stardust spacecraft, searching for interstellar dust particles); and weather monitoring projects, such the Citizen Weather Observer Program (CWOP) (in which volunteers provide real-time weather data to research institutions and government agencies, and receive feedback which helps to recalibrate equipment and improve data quality). The stories of Hanny van Arkel, a Dutch schoolteacher who discovered in 2007 an unusual gas cloud that scientists believe could help explain the life cycle of quasars (Lintott et al 2009), and the discovery of an unknown pulsar in August 2010 by volunteers at Einstein@home, a BOINC project which uses its volunteers computing resources to mine data from the Arecibo Observatory (Kniepsel, et al., 2010), both illustrate the potential of the participatory approach to doing science.

Scientists increasingly take advantage of citizen science (Lowman et al., 2009) and digital citizen science (Das & Baker, 2007; Hand, 2010; Raman et al., 2010). For example, the number of projects in U.C. Berkeley's BOINC - a platform for volunteer computing projects in fields such as astronomy, biology, mathematics, medicine, and physics – grew from just one in 2004 to over 40 projects and 300,000 active contributors as of June 2010. Galaxy Zoo - where volunteers classify telescope images from the Sloan Digital Sky survey - has reached 250,000 registered members in just three years since its launch in 2007.

Digital citizen science is based on two pillars. The first is technological: developing computer systems to manage, allocate, and aggregate, large amounts of distributed resources. The second pillar – which this study investigates - is motivational: attracting and retaining people who would be willing to contribute their computing resources, skills, time, and effort for a scientific cause. Yet, while the former was widely studied, the latter received little attention to date. Why do volunteers contribute their time, effort, and expertise to scientific projects? Furthermore, do the motivations for participation depend on the specific citizen science activity they perform, or do they represent a more general commitment to citizen science? Understanding the motivational aspect is crucial for the management of such projects, especially given evidence that contributors often reduce their involvement after an initial period of experimentation and that many digital citizen science projects suffer from an alarmingly high attrition rate.

The motivations underlying information and resource sharing in online settings has attracted significant attention in recent years (e.g., Lakhani & Wolf, 2005; von Hippel & von Krogh, 2003), and studies were conducted in a variety of contexts, including open source software development (e.g., Linux), collaborative authoring (e.g., Wikipedia), collaborative tagging (e.g., delicious). These studies demonstrate that while in each of the application domains participants are driven by a mix of motives, the motivational factors that are most salient differ between projects. These differences stem from a variety of sources, such the project's ideology and contributors' identification with it, the skills required for participation, or the availability of indirect monetary incentives. For example, a comparison of the motivations of open source software and Wikipedia contributors revealed that while gaining professional reputation and learning new skills are the salient motives for open source participation, the desire to help others in the community is the most important driver of participation in Wikipedia (Oreg & Nov, 2008).

There are important differences between contributions made to digital citizen science and those made to other types of community-based projects, which stress the need to investigate motivations for participation in the specific context of citizen science. First, in digital citizen science there is a clear distinction between the volunteers making the contribution and those benefiting from the aggregate effort (i.e. the scientists who run the project). This asymmetric structure differs from most other community-based projects (e.g. Wikipedia, YouTube), where the distinction is blurred. Second, it often takes a long time for the output of the scientific project to be made public, in contrast to community-based projects where the contributions are viewable immediately, which may provide instant gratification to contributors. Third, a single contribution to digital citizen science project is sometimes too small to be attributed to a specific individual, whereas in other communities the deliverables (e.g. text, code, photos) can stand on their own and are usually attributable to their contributor.

For the empirical study of citizen scientists', we adopted a theoretical framework of voluntary participation in social movements (Klandermans, 1997; Simon, 1998). This framework includes four classes of volunteers' motivations for participation: *collective motives* (the importance attributed to the project's goals); *norm-oriented* or *social motives* (expectations regarding the reactions of important others, such as friends, family or colleagues); *reward motives* (benefits such as gaining reputation, advancing one's career, or making new friends); and *collective identification* (identification with the group, and following its norms). This conceptualization was extended to include a fifth factor, *hedonistic* or *intrinsic motivation* in the study of participation in open-source software development (Hertel et al., 2003) and Wikipedia editing (Schroer & Hertel, 2009). Given the broad range of possible 'reward motives' (Hertel et al., 2003), we divided this factor to three specific motives, all of which were identified in studies of online communities: community reputation benefits, career prospects, and social interaction benefits (Butler et al., 2002; Roberts et al., 2006).

Building on job characteristics theory (Hackman & Oldham, 1980), we draw a link between the scope of the contribution task and contributors' motivations. Citizen science projects differ greatly in their "task granularity", defined as the smallest individual investment necessary to participate in a project (Benkler, 2006). Volunteers' contributions task granularity could range from low in volunteer computing projects to high in weather monitoring. As a result, the motivations required for participation are also likely to vary between projects whose contribution tasks differ in granularity. For our study, we selected three citizen science projects, representing different task levels: SETI@home (in which volunteers run on their computers a program that searches radio telescope data; low granularity), Stardust@home (where volunteers classify online images from NASA's Stardust spacecraft; medium), and the citizen weather observers program (in which volunteers set up home weather stations and provide real-time weather data to research institutions and government agencies; high). A web-based survey was administered to volunteers in these three projects in which volunteers rated the importance of the different motives on a 1-7 Likert scale. 1843 SETI@home volunteers, 143 Stardust@home volunteers, and 2390 weather observers participated in the survey, representing response rates of 22.1%, 27.9%, and 37.2% respectively. We carried out statistical analysis to verify the survey instrument reliability and validity (see supplement for details), and compared the reported levels of the various motivational factors across the three projects.

The survey results are presented in Figure 1. The differences between all motivational factors were statistically significant ($p<.05$). In all three projects, the two most salient factors were collective and intrinsic motives; identification and norm-oriented motives were shown to be of secondary importance, and reward motives factors did not seem to play an important role. We also found that for all motives other than intrinsic motives, the differences between projects were statistically significant (p<.05), and that except collective and intrinsic motives, the salience of the motives was positively related to task granularity.

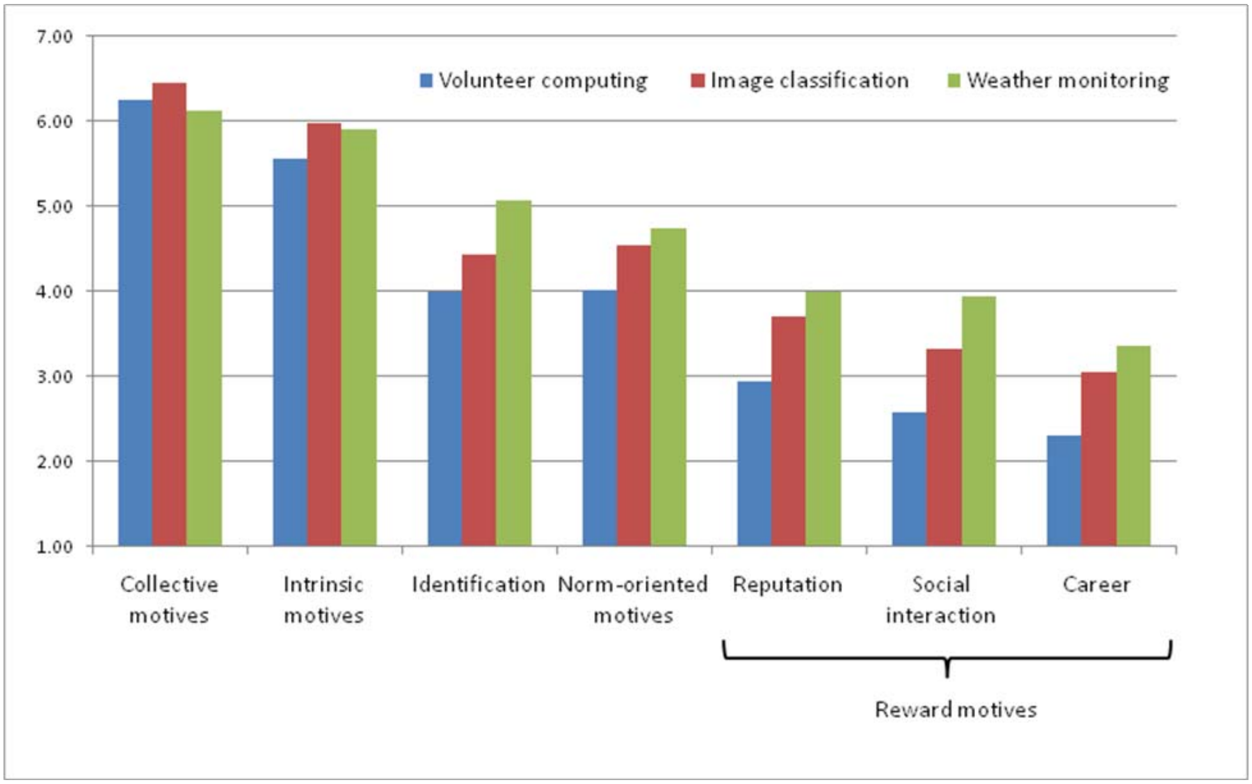

Figure 1. Results: motivational factors across projects

The findings have important implications for those administering citizen science projects. The high levels of collective motives suggest that projects should strive to increase volunteers' commitment to the project and its goals. This could possibly be done by communicating the project's mission and achievement to the volunteer-base (e.g. through social media). The salience of intrinsic motives stresses the need to develop game-like contribution channels, such as the one used in Foldit (Cooper et al., 2010), an multiplayer online game in which citizen scientists compete by folding proteins into a chemically stable configuration. The moderate levels observed for identification and norm-oriented motives suggest that - although of secondary importance – administrators should not neglect the necessity to establish a community of volunteers who share beliefs, interact regularly, and work collectively towards a common goal.

Another key insight from this study is the need to create dynamic contribution environments that allow volunteers to start contributing at lower-level granularity tasks, and gradually progress to more demanding tasks and responsibilities. Many community-based projects, such as open source software development and Wikipedia, have long realized this, and they allow interested contributors to progress in the ladder of responsibilities. This mechanism is currently absent in citizen science projects, where volunteers' tasks are usually restricted in their scope, and the governance and decision making is left in the hands of the scientists managing the projects. Adopting a more symmetric governance structure, closer to the one in community-based projects represents a major paradigm shift, even for those scientists who appreciate the potential benefits of citizen science. As digital citizen science develops, and competition for volunteers' resource increase, such a trend toward greater empowerment of volunteers may be inevitable.

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