Dynamic Changes in Motivation in Collaborative Citizen-Science Projects

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ABSTRACT

Online citizen science projects engage volunteers in collecting, analyzing, and curating scientific data. Existing projects have demonstrated the value of using volunteers to collect data, but few projects have reached the full collaborative potential of scientists and volunteers. Understanding the shared and unique motivations of these two groups can help designers establish the technical and social infrastructures needed to promote effective partnerships. We present findings from a study of the motivational factors affecting participation in ecological citizen science projects. We show that volunteers are motivated by a complex framework of factors that dynamically change throughout their cycle of work on scientific projects; this motivational framework is strongly affected by personal interests as well as external factors such as attribution and acknowledgment. Identifying the pivotal points of motivational shift and addressing them in the design of citizen-science systems will facilitate improved collaboration between scientists and volunteers.

Author Keywords

Crowdsourcing, citizen science, scientists, volunteers, motivation, collaboration, ecology.

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms

Human Factors, Design

INTRODUCTION

Citizen science, or the collaboration between scientists and volunteers, has been well documented [1-2]. Traditional scientific inquiries are conducted by individuals with scientific education and qualifications, i.e., professional scientists. Collaborative citizen-science projects, on the other hand, include citizen scientists: individuals who typically lack formal credentials and do not hold professional positions in scientific institutions or projects, who participate in scientific endeavors related to their personal interests. Distributed technologies offer new opportunities for conducting scientific inquiries on a larger scale than ever before by extending beyond geographically collocated tasks and enabling distributed collaboration. Citizen science has found success in various ways, in multiple disciplines: from documenting observations (eBird), collecting and analyzing data (Galaxy Zoo), creating content (VitalSigns Gulf preservation initiative), to curating it (Encyclopedia of Life - EOL).

Bonney et al. [3] divided citizen science projects into three major categories: (1) Contributory projects, in which volunteers contribute data to projects designed by scientists; (2) Collaborative projects, designed by scientists, but where volunteers can not only contribute data but also aid in the project design; and (3) Co-created projects, where both scientists and volunteers are involved in all parts of the project. In most cases collaboration between scientists and volunteers does not amount to co-creation or collaboration, but is maintained in the contributory phase, as data collection and in some cases partial data analysis (e.g. classification, documentation) is done by the volunteers under scientists' supervision. The data is then delivered to scientists who use it in their research.

In order to facilitate broader, sustainable, and more inclusive collaboration between scientists and volunteers we must design environments that speak to the needs of both groups. To be able to do that, we first need to understand what motivates each group and how to structure activities that leverage these unique motivations.

In this paper, we explore these motivations. We present a complex framework of motivational factors that affect participation in citizen science projects. Two pivotal points in volunteers' participation are significantly affected by motivational factors: the initial decision to participate in a project and the ensuing decision to continue this engagement once the initial task is completed.

We situate our exploration in the design of a new tool for conservation-focused collaborative citizen science, named Biotracker (www.biotrackers.net). This paper's contribution is in identifying the points at which motivational interventions are crucial, as well as identifying the types of motivations that are pertinent at each point. These findings will be used in developing the Biotracker system. We also hope to inspire other novel system designs for citizen science projects.

PREVIOUS WORK

Citizen science

Citizen science is based on a longstanding tradition of assistive participation of volunteers in scientific endeavors, which predates the Internet [1-2]. Advances in communication technology, specifically online and mobile interaction, enable citizen science to become more distributed and more widely practiced than ever before. Citizen scientists make contributions to many disciplines where the collection of large-scale field data is crucial, including biology [4], environmental studies [5], astronomy [6], but also in other fields, such as chemistry, and mathematics [7].

Collaboration between scientists and volunteers

Citizen science is not without its problems. Jonas Salk succinctly put it: "Scientists often have an aversion to what nonscientists say about science" [8]. Scientists, educated, trained and placed within the hierarchal academic world, are sometimes wary of letting others, who do not have the same credentials as they do, into their labs and research. Citizen scientists, who are volunteers without formal training or credentials, challenge this pattern. In many cases, although volunteers are allowed to take part in scientific processes, they are limited to distributed data collection and limited analysis, and are excluded from later phases of the research, in a way that prevents complete collaboration [5].

Scientific collaboration is shaped by a variety of factors, ranging from the social norms of science and the structure of disciplinary knowledge, to the specific characteristics and idiosyncrasies of existing formal and informal research networks and alliances [9-10]. The scientific work is founded upon shared vocabulary, practices, and meanings, and is dependant among other things, on mutual recognition of prestige, knowledge and competency [8]. Prestige, for example, is critical to establishing collaborations [10]. Consequently, bridging between scientists and volunteers, whose prestige in the scientific community is inherently different, is difficult.

For all these reasons, and although the contribution of volunteers to the development of science has been well documented [11-14], their participation is often considered peripheral.

Motivational framework

Bos and his colleagues [15] defined one type of scientific collaboratory that supports collaboration between distributed scientists and volunteers as “open community contribution systems”. A major issue for such communities is the need to motivate contributors while also ensuring the credibility and validity of the input data according to scientific standards. Indeed, one of the biggest challenges for community contribution systems, and communities of practice more generally, is to “allow participants at all levels to feel like full members” [16]. This is particularly challenging in boundary spanning communities where community members have different values, goals, and criteria for assessing the quality and merit of contributions.

Researchers have found a wide variety of reasons, at both the individual and group level, that explain why people participate in online collaborative activities [17]. Examples like Wikipedia, EOL, eBird and even geocaching games suggest that there are a wide variety of methods to motivate individuals to contribute to repositories [18-19], even if we do not fully understand these motivations. Social psychology theories have been harnessed to examine contributions to online repositories and recommender systems. These studies, which tested various social and technical interventions, found that emphasizing the uniqueness of an individual’s contribution and setting group goals increased participation, as did expert and peer oversight [20-21]. Others [22] emphasized the significance of facilitating small scale contributions from larger pools of participants. However, none of these studies were conducted in a scientific context.

Batson et al. [23] identified four types of motivations for social participation towards common goals: egoism, altruism, collectivism, and principlism. *Egoism* occurs when the ultimate goal is to increase one’s own welfare. *Altruism* has the goal of increasing the welfare of another individual or group of individuals. *Collectivism* has the goal of increasing the welfare of a specific group that one belongs to. *Principlism* has the goal of upholding one or more principles dear to one’s heart (e.g., justice or equality). Batson’s theory did not address collaborative science, but it is compelling in this context, as it emphasizes the role of motivation in building and sustaining community involvement, such as is needed for collaborative scientific projects. Therefore, we selected this theory as a general framework against which we will compare our findings.

METHOD

Our aim in this study was to gain an in-depth understanding of the various motivations that lead scientists and volunteers to engage in collaborative projects together. The research questions guiding this study were:

(1) What are the major motivational factors affecting volunteers and scientists engagement in citizen science projects?

(2) What are the major motivational barriers to such collaboration?

In January-April 2011 we deployed an online survey that assessed participants’ views regarding the four motivational factors outlined by Batson et al. The survey was based on a pilot study that was tested in December 2010 with 20 participants. We administered both the pilot and the survey via SurveyMonkey and on paper. Snowball recruitment was done by publicizing a link to the survey on the Encyclopedia of Life newsletter, and by directly contacting various groups interested in biodiversity, conservation, or citizen science. Social media was also utilized for this purpose, as links to the survey were published on Biotracker's Facebook page and on Twitter.

In all, we collected 142 responses. While we couldn't calculate overall response rate, completion rate for participants who began filling out the survey was 54% (for the two groups combined). We provided participants with definitions of the terms "professional scientist" and "volunteer" and asked them to self-identify with either group (scientists n=62, 44%; volunteers n=80, 56%). The majority in each group had more than one year's experience engaging in citizen science projects (75% of scientists and 56% of volunteers). The level of expertise was determined for the scientists based on their position within the academic world (e.g., doctoral student, lab technician, tenured and tenure track researchers, etc.), and for volunteers, by years of participating in citizen science projects. The male to female ratio was similar in both groups (60% of scientists were male, while 57% of volunteers were male). There was no difference in age distribution between the two groups.

For statistical analysis, comparisons of motivational factors within groups were performed using Friedman's test (the non-parametric test for differences between groups across multiple conditions); comparisons of motivational factors between groups were performed using the Mann-Whitney test (the non-parametric test for two independent samples). For both tests the level of significance was set at 0.05, Bonferroni adjustment was used in both cases to account for multiple comparisons. Data from the survey was analyzed using SPSS v.18.

The survey respondents were asked to provide contact details if they would be willing to be interviewed for the study. Of the 46 respondents we contacted, 11 were interviewed. We also recruited 7 interviewees through the same social media outlets mentioned earlier. Interviews were semi-structured, conducted by two of the research team members via telephone or Skype, and were recorded and transcribed. Interviews were between 30 minutes and an hour long. The interviewers also took notes and, where appropriate, collected additional data (e.g., personal and organizational websites, reports of scientific projects, newspaper articles). Of the interviewees, 7 were professional scientists ranging from PhD students to senior faculty, and 11 were volunteers. Volunteers' experience ranged from several months and participation in a few projects to more than 10 years' experience and deep involvement with consecutive projects. Most participants (15) had more than 3 years' experience. One participant was a professional scientist who began his career as a volunteer, thus presenting both viewpoints. Eleven interviewees were female and seven were male. Their ages ranged from early twenties to late fifties, though most were in their thirties and forties. All engaged in conservation, ecology, and natural history related projects.

The interviews were analyzed using grounded theory [24]. Grounded theory allows for themes and concepts to arise from the data itself, in a way that portrays the actual sentiments and experiences perceived by the interviewees. To achieve that, the interviews were divided into two groups (scientists and volunteers), and each interview was coded manually to reveal emergent categories (e.g., "motivational factors", "initiating collaboration" "work patterns", etc.). These categories were later bundled into themes (e.g., "cycle of collaboration"), which were axially referenced within each group and across groups, to reveal higher-level concepts. Following the analysis, most interviewees were contacted again 10 weeks later and asked to review our findings. The vast majority of interviewees concurred with the findings. Where interviewees offered further insights, we've adjusted our findings accordingly.

FINDINGS

We first discuss the survey results. We then follow with an in-depth analysis of the qualitative findings emerging from the interviews.

Survey findings

Participants were asked to rank on a Likert scale (1-5, where 1 is strongly disagree and 5 is strongly agree) statements that reflected their views regarding collaboration between scientists and volunteers. The statements were inspired by Batson et al.'s [23] framework, and were similar for both populations, with the necessary adjustments made to address each population. A sample of the statements is presented in Table 1.

Egoism:
The data volunteers provide enhance my research (scientists)

Collaboration with scientists enables me to open my horizons to new ideas and knowledge (volunteers)

***Collectivism*:**
Collaboration with volunteers can be helpful to others in the scientific community (scientists)

Collaboration between scientists and scientific volunteers is beneficial for the volunteers (volunteers)

Altruism*:*
Collaboration with volunteers helps educate them about scientific methods (scientists)

Collaboration between scientists and scientific volunteers is beneficial for scientists (volunteers)

***Principlism*:**
Collaboration with volunteers is worthwhile because I believe that all scientific knowledge should be accessible to everyone, regardless of their expertise (scientists)

Collaboration with scientists is worthwhile for making scientific knowledge accessible to the public and outside the scientific community (volunteers)

Table 1. Sample survey items; target population is noted in parenthesis.

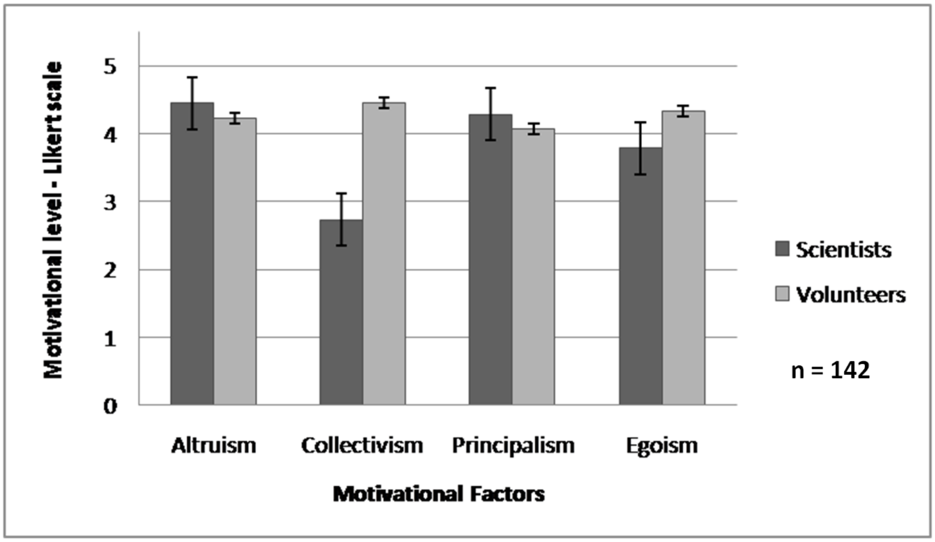

Figure 1. Scientists' and volunteers' attitudes towards motivational factors affecting their participation in scientific collaborations

Among volunteers, the average response rating to each of the categories was similar (average scores ranging between 4.08 and 4.46) (Figure 1). Scientists valued altruism (average score 4.45) and principlism similarly (4.29), but valued egoism (3.78) slightly less. Collectivism, or increasing the welfare of one's group, (2.73) was valued significantly less as a motivational factor by scientists (Friedman's test, with post hoc Wilcoxon Signed-Rank test, df=3, $p < 0.001$).

When comparing between groups (Mann-Whitney test), there was a small but statistically significant difference between scientists and volunteers in the way they valued *egoism* (mean response 3.8 for scientists vs. 4.2 for volunteers, U=250, $p < 0.001$) making egoism a slightly more salient motivator for volunteers; however, there was a marked difference in regards to another factor – *collectivism.* The mean response for scientists was lower than for volunteers (2.732 vs. 4.456, U=68.5, $p < 0.001$). The compilation of within groups and between groups differences in regards to collectivism suggests that volunteers believed collaboration with scientists would benefit the volunteer community more than scientists believed it would benefit themselves (i.e., the scientific community), but also that scientists valued collectivism less than other motivational factors. Specifically, altruism and principlism, were deemed most important by scientists, reflecting the notion that science is made to benefit the greater good. Age, gender, and level of expertise did not significantly influence the responses of volunteers or scientists (p value was found to be non-significant).

These findings were used as antecedents to the qualitative inquiry.

Qualitative interviews

In this section we discuss findings pertaining to (1) volunteers' motivations; (2) scientists' motivations; (3) motivational obstacles to collaboration.

Volunteers' motivations for collaborating with scientists

Based on the survey results, in which volunteers acknowledged the importance of four motivational factors laid out by Batson et al. as almost equal, our expectation was that volunteers will exhibit a comparable view in the interviews. A more fine-grained analysis of the interviews revealed that these motivations are not equally salient, and also do not occur at the same point in time. Volunteers by and large presented a range of egoism-related reasons as the initial and most substantial motivation for their engagement in citizen science projects. Other motivations – collectivism and altruism – were missing from the initial decision to participate in a scientific project, but surfaced at a later stage, effecting long-term engagement.

Initial interest – Volunteers' initial interest in citizen science projects stemmed from many elements, all related to egoism: (1) familiarity with- or personal curiosity about- a specific species (*"I'm one of those arachnoids geeks"*), a landscape, or environment, or a process ("*I see a lot of insects interacting with the plants and, to understand plants better, I need to know what those insects are*"); (2) previous engagement in scientific projects, in schools or as a hobby; (3) an existing hobby that is closely related to citizen science (e.g., photography); or (4) a career building step for aspiring scientists (e.g., *"[my motivation is] gaining the experience and seeing what it is, maybe having something for my resume*").

Most volunteers saw participation in scientific projects as an opportunity to extend and expend their personal knowledge of specific domains and species. The role of this motivational factor was highly dependent on scientists' attitudes towards the volunteers – when scientists acknowledged the need to educate people and not "*treat them as dumb*", as one volunteer put it, volunteers embraced the opportunity to learn more and widen their scientific horizons ("*we had a chance to sit down with a lot of the scientists who were in the field, and [we] could ask any question. You wanted to go down there with a magnet* *attached to your brain and try to absorb everything they had to say*").

Although the specific personal take on participation in scientific projects was different for each volunteer, in all cases, their initial interest originated from individual gain and personal interest, positioning **egoism** as the leading factor for initial involvement in citizen science projects. The following quotes from two different volunteers are indicative: *"I think personal interest comes first. Personal interest and personal gain, with information"; "I would be less inclined to participate in something I had little interest* [sic] *even if it was a worthy endeavor"*.

Following their initial engagement, volunteers presented secondary motivational factors, which although important, affected only their ongoing participation in citizen science projects, and not their initial decision to participate in these projects:

Recognition and attribution – all volunteers emphasized the power of being recognized for their individual contributions as a crucial motivational factor. Although volunteers clearly accepted the distinct roles of scientists and volunteers in scientific work ("*it's not always collaborative, it allows people to contribute their ideas to solve a problem, but it's usually the scientists that yank the problem and put them out there to their community*"), they nonetheless felt an intense need to be recognized and appreciated for their contributions, however big or small. Recognition happened when individual contributions were singled-out by scientists and explicit credit (through attribution) was given to the volunteers who collected, analyzed, or curated data. One volunteer articulated his expectation of attribution, which was echoed by many others, as a major motivational factor: "*I'm not really, obviously, objected to glory. I do expect attribution… I would like people to use it [the data he contributes] but I would like attribution…I would always like to be the first one to put a photo up there...it's got to count somehow*". This type of recognition was especially important where selected artifacts (e.g. photos, samples) or specific data contributed by volunteers was used by scientists in publications. For recognition purposes, volunteers did not differentiate between peer-reviewed and open-access publications, unlike scientists; both were valued uses of the data they contributed: *"if a name ends up in the acknowledgments, the name ends up in a poster, it's a measurable thing…I can show the family members and make it more of a positive experience"*.

An alternative type of recognition was mentioned by several volunteers; invitation to participate in scientific training organized by the scientists. While scientists saw training as an essential teaching process that ensured a minimal benchmark for data quality, volunteers viewed training as an opportunity to be initiated and accepted into the scientific world, and be recognized for the value of their contribution: "*from a volunteer standpoint there is a pretty big hurdle in getting through volunteer training… you have to go through all this extensive training. But, to be honest, I like it more than [another volunteer project] I looked into… because [the other project is] a lot less thorough and to me that makes it a lot less scientific… because people going through the thorough training feel like they're contributing a lot more because… I think they understand what the [scientists] are doing*". Repetitive training, such as annual reaccreditation, or seasonal meetings, was also seen as a ritual reinstating their commitment to the scientific project. Rigorous training needed for some projects was noted as more prestigious than "come as you wish" volunteer projects: *"our training is very extensive. It's a 2-3 years commitment, because of our short season. I haven't gotten certified yet but I went through partial training and so I'm proud to say I'm recognized by the local chapter of the [zoological] trust"*.

Feedback – feedback differed from recognition in that it was not associated with an individual contributor and particular contributions, but rather addressed the overall contribution of a volunteer, a group of volunteers, or the outcome of the entire project. Feedback mechanisms were expected to create a communication route between scientists and volunteers, but they also became prominent motivational factors. Volunteers sought feedback and were appreciative of those scientists and projects that have taken proactive steps to facilitate this: "*it's not about spending time or money. It's more about the constant feedback to the volunteers that what we're doing is useful and being used*". When scientists were not cognizant of providing periodic feedback to their volunteers, volunteers felt peripheral, became de-motivated, and tended to forgo future work on those projects: "*I've done other stuff and you know you don't get feedback, like 'here is what we did with the work you did', and so you don't feel like it's being used well and you don't feel like you want to continue to contribute*"

Feedback took many forms: impromptu updates about the research and its outcomes or pre-scheduled periodic meetings with groups of volunteers, intended to provide them with updates about their work, research procedures, and the way their work affected the scientific project. Alternatively, feedback was given personally, but unlike 'recognition' it did not focus on the individual contribution but more on how volunteers as a group contributed to the research and how the data they collected was used.

Community involvement – community involvement was not mentioned as a primary motivation for participation in scientific projects, even when the project had a substantial effect on the volunteer's local community. However, once volunteers were already involved in citizen science projects, the impact of their work on their local community became an influential motivating factor: "*it's the combination of being an effective citizen scientist and seeing the community thrive… people really care about their natural resources here*". Some volunteers stressed their continued commitment to scientific projects that were taking place in their area because of their potential effect on their community. One such example was a water contamination monitoring project, where citizens collected samples from streams and rivers which were previously deemed not fit for commercial harvesting. When the contamination level lowered and these areas reopened for commercial fishing, they boosted the local economy. Following that, participation in related citizen science projects rose steadily. Another aspect of community involvement was a social one, both within collocated communities - *"I've started conversations with people locally who are just very knowledgeable, it seems to easily slide into a community [involvement], though by community I mean more 'neighborhood'";* and distant ones - *"I think it's the social support as well. I've got a lot of friends who are in various mammal groups across the country, and we give each other a lot of mutual support".*

Advocacy – advocacy was seen as a collectivist motivation (unlike education, which emphasizes the personal gains volunteers get from their participation in citizen science projects). Advocacy was a motivational factor that did not influence the initial decision to participate in these projects, but became important as volunteers considered their ongoing participation. Most volunteers embraced the opportunity to understand better the issues pertaining to environmental policy that affected them and their communities through their participation in citizen science projects: *"I want to be kind of a liaison between the scientific field ... and the common person who has the questions and doesn't know how to ask"*. They saw this newfound understanding as an educational benefit from which they not only personally gained, but also an asset that they can later bring to their local or distributed communities. As one volunteer who worked at a nature center said: "*it's the perfect opportunity to help people understand their environment ... [I] hope that something that you say will make [a] dent and make them more curious and they'll go home and pick up a book or they'll call you back…it gives them a touch of what belongs to their environment*". A special emphasis was placed on children's learning: *"[small mammal walks are] a really good way to get kids engaged with the natural world. [it ends] their sort of disconnection with the earth which I think personally is what drives most of us".*

However, one volunteer mentioned advocacy as being the exact opposite, or a "*big turn-off*" because "*the day we put an opinion or try to do advocacy our data becomes compromised…and that's something I think scientists need to be really careful of*".

Scientists' motivations for collaborating with volunteers

Unlike the numerous motivational factors affecting volunteers' participation, scientists exhibited a more limited motivational range. Echoing findings in previous studies [8, 25] scientists act within a well established tradition of "invisible colleges" [26] to which they are accountable. Within this tradition, scientists saw citizen science projects mainly as an opportunity to facilitate large-scale data collection. They then used the data in the common peer-reviewed publication process.

Scientists as leaders of the scientific process - according to scientists, the volunteers' role in citizen science projects ranged from data collection (e.g. photos, specimens, samples, and observations), to data analysis (e.g. classification of collected specimen, database management) and in several unique cases even included contributions to scientific or popular-science publications. However, in most cases scientists preferred to have volunteers remain within the ascribed role of field data collectors; cases where volunteers were engaged in other roles were few and exceptional: "*I see them as most helpful in making accurate observations… they are basically the field component*"; *"basic science is very under-funded, it's impossible to get out to the field these days so it [citizen science] saves a whole bunch of time and money"*. Although some scientists mentioned that if they found enough interested volunteers who would be willing to take upon themselves more complex roles that would contribute to data analysis "*that would be great and definitely useful*", they didn't "*see that as common or easily found [as field work]".* In most cases, from the data collection onward, and more pointedly in the latter stages of the research, the scientists asserted themselves as leaders of the research and the ensuing publications; they did not see a place or a role for volunteers in these later stages, as "*there's just a few of us able to do that kind of thing [work]".* Therefore the primary motivation for their collaboration with volunteers was to maximize the useful products they can gain from this collaboration; thus limiting it to what one of them termed "*valuable but limited*" volunteer contribution.

Education and policy – a secondary motivation was scientists' altruistic notion of contributing to the common good through educating the public. This finding was salient both in the survey results and in our interviews, as well as in previous studies of scientific culture [8]. Scientists not only wanted to introduce volunteers to their specific domains: "*I think that they are really learning about these specific pollinators… it's a small piece of information they can really use"; "I want to increase climate literacy*", but also wanted to educate them about the scientific method as a whole. For example, they commented: "*for volunteers in the field… even though they weren't doing the lab work… I wanted them to learn the entire process so that they understood how critical it is every step of the way to have a set technique*". Another educational aspect was engaging educated citizens in influencing the public's thinking about science, relevant fund appropriation, policy decision-making, and making them understand better the role of science for the greater good. One scientist voiced a sentiment echoed by several others: "*I don't think people can make good decisions, be it policy or environmental or anything else, unless they understand how things work. This provides the opportunity to educate people through a valid citizen science program. So when they go to the polls they* *can become active in their communities about something that they care about*".

Education had a flip side as well: by working with people coming from a different knowledge base the scientists gained a different perspective about their work: "*a lot of master gardeners know more than I do about certain aspects of plant phenology. I know pieces of it better than they do, but I can learn from them, too*"; and "*it is nicer to work with people in a different atmosphere than the research community…just getting out of the little bubble that we're in*".

Obstacles to collaboration

The findings from our interviews also pointed to de-motivating factors affecting collaboration. These factors were especially potent at two decision points: the entry point, or the decision to participate in a project, and the ensuing decision to participate in more tasks or continue participating in the project for an extended period of time after the initial task was completed. Both groups mentioned similar obstacles, coming from different perspectives:

Mutual apprehension and trust – some of the sentiments shared by most of the volunteers were: "*scientists are intimidating*", "*scientists speak a different jargon*", "*scientists have a reputation of being arrogant*", *"they are just so unfriendly"*. Volunteers' initial hesitancy was grounded in the existing power balance between scientists and volunteers. While volunteers were eager to aid scientists they were also in awe of them, recognizing the fact that scientists were trained professionals, upholding rigid standards, and advancing the research for their own purposes as well as for the greater good. Overcoming this initial awe was difficult. Some volunteers felt that bringing their own ideas to the research table would not be positively accepted by scientists, but the few who reported that they have indeed broached the subject and offered input were pleasantly surprised when the scientists were cordial and even excited about these ideas.

From their perspective, scientists were wary of the volunteers' level of commitment and quality of work. In general they held positive views regarding collaboration, but the technicalities of obtaining high-quality data from volunteers was a reason for concern. "*Quality assurance*" and "*quality control*" were two of the most recurrent themes in scientists' accounts. They stressed the need to get as much information as possible about the volunteers' expertise, participation in previous projects, level of training, and level of commitment, as preliminary requirements in order to deflect unwanted volunteers from joining their projects. This was also their way of ensuring that only "good" data will be delivered by volunteers. Some scientists had mechanisms to support that, by requiring paid-for training, assuming that uncommitted volunteers will not bother to pay for participation; others administered online tests, assuring the knowledge base of the volunteers and predicting their success in collecting data. Others preferred to cast a wide net, but slowly "retire" volunteers who did not uphold rigid scientific standards: "*you train them, you observe them… and if they're not capable they have to get another job*"; "*you've got to go and train 100 people if you want 15 to show up on a regular basis*".

For both scientists and volunteers, creating a sustainable collaborative environment necessitated trust and credibility: "*people won't come back if there isn't that loop of credibility and things that they can see that are being accomplished as a result of the data that they are collecting*". Trust building was a long process that largely depended on both sides fulfilling each other's expectations and motivations. One problem with establishing this trust was the fact that the two groups did not always explicitly convey these expectations and motivations to each other.

Not addressing existing motivational factors – volunteers were familiar to some extent with scientists' work and motivations, but when scientists were asked about volunteers' motivations, most did not recognize volunteers' prevalent motivations. They mentioned motivations stemming from "*wanting to be outside*", "*wanting to do something meaningful*", and "*working with their friends or family [on scientific projects]",* but many scientists failed to recognize the initial interest volunteers had in scientific problems as their primary motivation. Attribution and recognition were identified as important to volunteers, but their importance was downplayed by several scientists despite the role they actually played in volunteers' engagement: "*I find that people don't want to stand out… people are put off by highlighting certain [contributions] we don't do it in a huge way… recognition can backfire*". This gap undermined the two groups' ability to reach the desired trust, and to attain a higher level of collaboration.

DISCUSSION

Community involvement motivational framework

Batson et al.'s [23] model identified four distinct factors affecting motivation to participate in activities that promote social benefit. Although this model can explain some of the motivational premises in which collaborative scientific work is grounded, our findings show that it does not translate well for collaborative citizen science projects. Such projects are inherently complex activities, spread over long periods of time, and spanning multiple tasks. In these projects motivations not only change over time, but are especially salient at particular intersections of activity and decision making.

This complexity can be seen in the way the four motivational factors identified by Batson et al. – egoism, collectivism, altruism and principlism – presented in the two groups we have studied. An in depth exploration of the motivational factors affecting participation of both groups in collaborative projects revealed that both scientists and volunteers presented egoism as the primary motivation for engagement in citizen science projects. However, they expected their goals to be different: volunteers wanted to do something that would satisfy their needs, would interest and educate them through their participation, while scientists wanted to promote their careers. Other motivational factors were less pronounced at the onset of collaboration, but appeared to have an influence on volunteers' ongoing participation. For volunteers, egoism, was satisfied through attaining attribution and recognition, particularly by scientists. Collectivism was accomplished by the scientists providing group feedback to the volunteers, and also through community involvement and advocacy, where collectivism emphasized locality. Altruism was achieved by aiding scientists in data collection (and, rarely, data analysis) processes. Scientists indicated that altruism (public education) was the second important motivational factor after egoism, which for them was tied to the need for scientific data and desire to publish. These results were also supported by survey findings. The one significant difference between the volunteers and scientists was in their perception of collectivism – volunteers saw it as being just as important as other motivational factors, while the scientists indicated that working with volunteers will not be greatly beneficial to the scientific community as a whole.

Interestingly, although in the survey both groups agreed as to the role of principlism in motivating collaborations, this factor did not come up in our interviews. One possible reason for that may be that during the interviews principlism was often "folded" into discussions of other factors such as collectivism and altruism – as one interviewee put it: *" initially, it was doing something for my own good, because I just wanted to know what those bugs were. But continued participation I would say is more a mix of that and doing something for the larger community".*

Based on these findings, we see our major contribution as highlighting the temporal nature of motivation and identifying points in time in which motivational factors affect participation in ecological citizen science projects. We present a dynamic model for the engagement cycle of volunteers, where motivations facilitate engagement and come into fruition at different stages of the collaborative process.

Figure 2 illustrates this cycle of engagement and the related motivational pivotal points. Volunteers' initial interest leads them to seek opportunities that would broaden their horizons and allow them to engage in an enjoyable activity. Their interest may be only tangential to the scientific project, as was exemplified by the case of an avid photographer who finds interest in a project documenting insects although she is not be interested in insects *per se*. At this point in time the other motivational factors Batson et al. [23] identified do not come into play. For scientists egoism reflects the need for large scale, comprehensive data collection to benefit their studies. This need leads scientists to cooperate with volunteers who provide them with data that is difficult or costly to collect otherwise. It is the synergy between the two different forms of egoism that creates the initial collaboration between the two groups. At this point in time the initial interest is enough to warrant some level of volunteer participation, especially from people who are already attuned to the idea of citizen science.

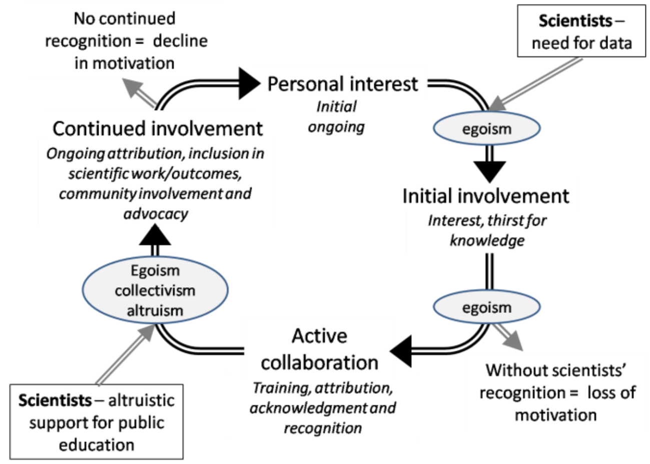

Figure 2. A process model of volunteers and scientists involvement in citizen science projects.

It is at this point that our model diverges from that presented by Batson et al [23]. Unlike their description of motivational factors as goal-directed, we propose that time has a significant effect on motivation: when volunteers' motivations are explicitly recognized they will engage further in active contribution to collaborative projects. Where these motivations are ignored (even if this is done inadvertently) volunteers' participation will decline. That is not to say that scientific projects that do not address such motivational factors will lack volunteers: if the project is interesting enough volunteers may be inclined to participate in it initially – yet, with time even avid participants will drift away,

The other formative point is at the end of a task or a project. This is when volunteers reassess their participation in the project. At this point other motivational factors - altruism and collectivism – come into play. Interestingly, what we have learned is that although this assessment is made at the end of a task or the beginning of a new one, it is mostly based on previous experiences and less on future expectations. When volunteers reflect on their previous experiences they look at the specific project, the ways in which various motivational factors were met and how they felt during the project. In this reflection an emphasis is placed on the secondary motivational factors, but also on recognition as a manifestation of egoism.

The model is cyclical, since many ecological scientific projects are lengthy and are designed in multiple stages, which can benefit from volunteer participation. In order to ensure long term, sustainable volunteer participation, their range of motivations should be repeatedly acknowledged and addressed throughout the project lifecycle. Although we highlighted the two pivotal points at which volunteers make an active decision regarding their participation, it is the ongoing appreciation and acknowledgment of volunteers that they remember and draw upon when making that decision.

As Bonney et al. [1] defined, citizen science projects can range from merely contributing data to collaborative and co-creative projects. In order to move from simple data collection to meaningful collaboration, scientists need to understand volunteers' motivations and accept them as being synergistic to theirs. This can be done through education, but it seems that an easier way would be to facilitate this change through design that will appeal to the two groups' unique motivations.

Designing for ongoing collaboration

When designing tools or communities for citizen science projects, the various motivational factors and the points in time in which they are crucial for sustaining participation should be addressed. The dynamic model we presented, allows us to suggest some implications for designing collaborative tools to support the volunteers' and scientists' participation in citizen science projects:

- *Timing* – to ensure that the proper motivational probes are emphasized at the right time, the design should enable identification of points in which participation declines (or can decline) such as the end of a task, and interject the proper motivational probes. For example, when a project is initiated, recruitment materials can emphasize the inherent interest of the topic and volunteers' chance to learn, but materials provided to recruited volunteers should emphasize opportunities for recognition, advanced training, and social engagement. Throughout the lifecycle of the project appropriate materials can accentuate volunteers' contribution to their community or to the greater good. Games, with their intrinsically rewarding mechanics, may be used to attract people who are not initially interested in a less appealing topic (i.e., bacteria; worms) or engage them further in a topic of their liking.

- *Highlighting data use* – the system needs to make available information about where, how and to what extent the data were used, in order to provide feedback to the volunteers. Collaborative citizen science projects can include an automated mechanism that tracks each time data is used and what it was used for (publication, online repositories, etc.), augmenting a notification mechanism which routinely highlights cases when volunteer-generated data is used, and notifies volunteers periodically. Similarly, attribution should be clear, accentuated and easily manageable.
- *Locality* – local interests were often mentioned as catalysts for continuous involvement. Designing tools that are grounded in the local flora and fauna, or associated with local groups, highlighting the most pressing needs for local conservation, will accentuate ways in which volunteers' contribution to their immediate community is crucial, and can help in maintaining their engagement for longer periods of time.
- *Synergy* – by setting common standards for collaborative science projects, small scale and local projects can be networked in a way that will leverage locality into mass endeavors (such as the yearly bird counts). Synergistic ties between smaller communities will enable the discovery of data, people and projects that may be of interest. Networked synergy can be created by providing open APIs to local databases, setting common standards for data entry, storage and publication.

- *Matching scientists, volunteers and tasks* – overcoming geographical barriers by creating a common infrastructure, or a "pool" for citizen science projects in various domains, where scientists can create missions, or ads, for volunteer services, based on their need for data, analysis or other services. Volunteers who will offer their services will be asked, at signup, to select their areas of interest, location, and expertise, and suggest potential roles in which they can contribute. At a later stage the system can be designed to automatically unearth secondary motivations (locality, desire to educate others) based on data derived from users and behavioral patterns that intervenes at pivotal times of participatory decline, and assign tasks appropriately.

- *Breaking tasks into smaller scale "building blocks"* – similar to locally based projects, smaller scale building blocks allow volunteers to easily find tasks that would appeal to their interest and anchor their engagement for a sustainable period of time. This approach will also aid in overcoming some of the initial awe of mass scientific projects, and enable volunteers to take control over their level of participation. For example, "Observing bugs in your backyard" may sound more feasible than "documenting the insects of the pacific north-west".

CONCLUSION

We conducted a mixed method study in which we have used an existing motivational model to examine the motivational frameworks of participants in ecological citizen science projects, with an emphasis on volunteers. We have shown that scientists and volunteers participate in scientific endeavors for different reasons. Professional scientists want to advance science and further their own professional career, while volunteers participate in scientific activities out of interest, curiosity and commitment to conservation and related educational efforts. Volunteers' motivations are temporal, dynamic and change even when the ultimate goal remains the same. Two significant points in time deserve special attention – the initial encounter between a volunteer and scientific projects and the point at which a project ends and the volunteer has to decide whether to continue contributing to other projects. It is at these points where motivational influences are most important. Identifying the right ones and nurturing them may result in stronger and more sustainable collaboration between citizens and scientists.

Our findings have important implications for designing tools to encourage volunteer participation and for facilitating collaboration between volunteers and scientists in ecological citizen science, and also for other types of citizen science projects. When building tools for citizen science projects, motivational factors have to be addressed and built into the tools, as contributors will be more inclined to participate in collaborative scientific projects when given the proper motivational impetus at the right time. Future studies that empirically evaluate design interventions, such as those we have proposed, will help to assess the usefulness of the proposed model in specific use-cases.

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