Motivations and Patterns of Engagement of CosmoQuest Participants

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Keywords
motivations, engagement, online, citizen science

Citizen science in astronomy involves the exchange of volunteer effort for scientific data or data analysis needed by researchers. In order to maximize the effectiveness of citizen science projects, the motivations of these volunteers should be understood as they initially draw volunteers into the project and encourage continued engagement. Through detailed interviews with 30 participants in an online astronomy citizen science project, we categorise initial motivating factors into intrinsic and extrinsic factors and reasons for ending participation into external and internal factors. We find that volunteers with more frequent engagement in citizen science tasks are more intrinsically motivated than those who participate less frequently. Our findings that infrequent visitors, who as a whole make a significant contribution to citizen science projects, are often extrinsically motivated reveals a need for both intrinsic and extrinsic motivating factors to be built into a project and project communications in order to diversify the pool of volunteers and to maximise participation. In addition, we report on factors that led to citizen scientists stopping their engagement with a project over the short and long term.

Introduction

Citizen science, a form of public participation in scientific research, continues to provide opportunities for lay participants to work with professional scientists in data collection and analysis, engaging volunteers in various aspects of science *(Shirk et al., 2012)*. Participation in online citizen science is increasing with the proliferation of online platforms and tools, giving participants with access to the Internet a wide range of projects and tasks from which to choose, such as classifying and/or interpreting videos, pictures, and sounds, running simulations, and playing computer games *(Bonney et al., 2014; Curtis 2015a)*. Within the field of astronomy, there has been a steady increase in the number and types of citizen science projects available over the past decade, as well as an increase in the number of participants, and this trend is expected to continue to increase *(Marshall, Lintott, & Fletcher, 2015)*. Many of these are online projects, involving large datasets and providing an online forum to facilitate participant communication (e.g., Moon Mappers, GalaxyZoo, Ice Investigators, PlanetHunters).

Researchers can make the most of the citizen science process by centring and understanding the experience of the participants. One way to understand this is by exploring what motivates citizen scientists to start, continue and end their engagement with projects. This can also give citizen science project managers insight into what kinds of messaging and incentives to build into the project and include in recruiting new participants. Citizen science has a "long tail" of participants that engage casually, infrequently, and/or over a short period of time. Although this long tail does not, as a whole, contribute the majority of data collection or analysis to the project itself *(Eveleigh et al. 2014)*, wide participation fulfils another primary goal of citizen science, that of using it as a science communication tool. Specifically, citizen science projects give participants unique insight on the processes of science, a lesson that is often difficult to achieve otherwise in formal or informal education *(Bonney et al., 2015)*.

Several groups of researchers have studied the participants involved in online astronomy citizen science, looking at their motivations, types and patterns of engagement, and learning *(see Gugliucci, Gay, & Bracey, 2014; Prather et al., 2013; Raddick et al., 2010, 2013; Reed et al., 2013)*. Much of the motivation research has been conducted with the purpose of improving participant recruitment and retention, seeking to understand who participates

and what can lead to a better experience for the public and the scientists. However, much citizen science research investigates motivations for projects related to ecology and conservation which offer participants a connection to their specific location and involvement in a problem of immediate ecological importance *(e.g. He et al. 2019)*. Also, many of these studies have not gone beyond classifying participants' motivations at a surface level and do not look more deeply at the underlying motivational constructs. *Curtis (2015b)* went beyond the initial motivation to explore motivation for sustained participation for one such astronomy project, Planet Hunters, and two non-astronomy projects. As online citizen science has expanded to include many popular projects outside of astronomy, so has the research into participant motivations.

We set out to do a deeper exploration of how and why participants in an online astronomy citizen science project begin, continue and end their engagement. Building on results from an initial large survey study, we investigated online astronomy citizen scientists' motivations for participating in these projects. We interviewed participants engaged in CosmoQuest (cosmoquest.org), a collection of online astronomy citizen science projects, to gain a greater understanding of participants' rationale behind participating in citizen science and to learn if participants' original reasons for participating changed over time. Understanding why participants originally engage in citizen science and what drives continued engagement, as well as correlations with frequency of engagement, can ultimately help to understand and improve online citizen science projects' connection to and communication with their participants. In this paper, we present the findings from our thematic analysis of the interviews. Our study expands on previous work by allowing free responses to questions of motivation and categorization of these responses into intrinsic and extrinsic categories. Furthermore, we look at the motivations alongside the interviewees' self-reported level of engagement with citizen science projects. Finally, we look at how motivations have changed and reasons why participants stop their engagement for the day or for good.

Motivation and Engagement in Online Citizen Science

Many citizen science projects exist entirely on the Internet. Participants access projects like Fold-it, GalaxyZoo, Old Weather and Moon Mappers through a website interface and complete their tasks online. Some projects are passive, meaning that the participant's computer is doing most or all of the work, while others require more active involvement from the participant such as identifying and marking images. Participants have the freedom and flexibility to login anytime and anywhere they have an Internet connection and spend as much or as little time as they'd like engaging in the projects *(Curtis, 2018)*. Online citizen science participants tend to be white, male, middle-aged, and scientifically/technologically literate *(Gugliucci, Gay, & Bracey, 2014; Curtis, 2018)*. Citizen science projects are looking increasingly for ways to attract a more diverse audience in order to facilitate more inclusive science communication. For example, recruiting a wide and diverse audience to citizen science has the effect of creating more "societal value" of the science as shown by *Brouwer & Hessels (2018)* who targeted specific households with invitation to participate in citizen science projects related to drinking water research. *Füchslin, Schäfer, and Metag (2019)* found that gender, education and scientific literacy were not significant predictors for potential citizen scientists in Switzerland, finding that a positive attitude towards science was a better predictor. Although this indicates that many citizen science projects are mainly reaching those already inclined towards science, it is encouraging that other measures of diversity in this sample did not appear to affect participation.

Participants usually offer several different reasons for taking part in citizen science projects, often focusing on an interest in the scientific content and in helping the scientific endeavour. For example, *Raddick et al. (2010)* explored the motivations of Galaxy Zoo users by analysing open forum responses and interviews of 22 volunteers. Using a grounded theory approach, the researchers identified 12 categories of motivation, including interest in astronomy, helping, and learning. Most participants indicated more than one motivational factor. These categories formed the basis of a larger survey by *Raddick et al. (2013)* of 11 000 users that found "contribution to science" to be the most prevalent primary motivation (39.8%) across genders, ages and educational levels. However, these motivations are only reported for a single point in time. Many participants' motivations shift over time *(Rotman et al. 2012; Iacovides et al. 2013)*, and they may leave and return to a project or leave permanently as their reasons for participation change.

Participant engagement in citizen science projects has been the subject of a growing number of studies, with some exploring how engagement intersects with motivation. *Everett & Geoghegan (2016)* examined levels of participants' engagement and enthusiasm for the scientific process, particularly those who are already engaged as traditional amateur naturalists. They note in their qualitative study of a biodiversity related project that there is no one correct approach to increasing engagement, but that a range of approaches is needed to reach a range of audiences. Astronomy has a parallel, in that many citizen science participants also self-identify as amateur astronomers *(Gugliucci, Gay, & Bracey, 2014)*.

Nov, Arazy, & Anderson (2011) used the framework of intrinsic vs. extrinsic motivators in looking at other large collaboration activities, such as Wikipedia. This study compared low granularity citizen science tasks (i.e., more passive, such as SETI@Home, where the work is done by the idle computer) vs. high granularity citizen science tasks (more active, such as Stardust@home, where the user interacts with the data). They found higher granularity correlated with higher motivational levels in general. Motivations were also correlated with intention and contribution level. These researchers stressed the importance of intrinsic motivators as driving project participation.

Citizen science project communications may offer extrinsic motivators to encourage participation, such as challenges and "gamified" aspects. *Tiago et al. (2017)* show that participants that are most engaged have high levels of intrinsic motivations such as "enjoyment" and "perceived competence." They conclude project design that encourages fostering

those intrinsic motivation after using initial extrinsic instruments.

Iacovides et al. (2013) provide a different view. They found that in an online project with gaming aspects, many individuals begin to participate due to their intrinsic interest in the topic, not the gamified aspects. However, these extrinsic motivators, the game elements and community engagement through forums, encourage further engagement with the project.

Eveleigh et al. (2014) looked at the motivations of "dabblers and drop-outs," or users who do a project for a short period of time or sporadically, also known as "the long tail" referenced earlier. Studying patterns of engagement and types of motivations in Old Weather, they found that participants with intrinsic motivators are more likely to make more varied contributions. Reasons for dropping out included boredom and lack of information from project leaders about where the project was heading.

Methods

Overview of CosmoQuest

CosmoQuest (cosmoquest.org) is a suite of online astronomy-themed citizen science projects that ask participants to explore the surfaces of solar system objects using images from several NASA missions. Citizen scientists identify and mark craters and other surface features of Mars, Mercury, the Moon, and the asteroid Vesta to help scientists create detailed maps of these worlds. CosmoQuest offers an online forum for community interaction, a project blog and support materials for use in classrooms and planetariums.

Initial survey

Between May 16 and June 12, 2013, we conducted an online survey given to visitors of CosmoQuest who were recruited during a visit to the site. The online survey was designed to understand who was participating in CosmoQuest and how CosmoQuest could improve. This survey was used to determine general demographics and initial motivations of CosmoQuest users. As reported in *Gugliucci, Gay, and Bracey (2014)*,the survey was completed by 334 respondents. Respondents were given a series of statements based on *Raddick et al. (2013)* and asked which one was their primary motivator. Respondents reported mostly participating in CosmoQuest for the learning opportunity, personal interest and to give back to science. Half of the survey participants reported their primary motivator for participating in CosmoQuest as being "I am interested in astronomy/space science" and "I am excited to contribute to original scientific research" (Table 1). After collecting the survey results, additional information was desired on why individuals were excited to contribute to scientific research in more detail and without the restrictions of a multiple-choice response.

Participant selection and consent

Participants were recruited from a community of users engaged in online astronomy citizen science projects at CosmoQuest. Selection was purposefully done from server logs to recruit users with a range of citizen science experience on the site. The individual's duration as well as the number of CosmoQuest projects the individual participated in were both considered for inclusion in the study. Participants who had been involved in CosmoQuest for less than one month were categorised as short duration participants. Participants who had participated in CosmoQuest for three months or more were considered high duration. Users who had participated in single or multiple projects on the site were also selected. This was meant to strike a balance in the types of individuals to be interviewed and allowed researchers to evaluate their motivations and activities related to time spent engaging in astronomy citizen science projects to help understand the primary driving forces for individuals' engagement.

Primary Motivation	Count	Percent
No Answer	44	13
I am excited to contribute to original scientific research.	83	24
I was looking to find ways to learn about the solar system.	15	4
It's fun to make friends from all around the world.	5	1
I find it to be a useful resource for teaching.	14	4
I enjoy looking at the beautiful images.	6	1
I have a lot of fun marking surface features.	1	0
I am amazed by the rocky worlds in our solar system.	1	0
I am happy to help.	10	2
I wanted to see how CosmoQuest worked.	8	2
I am interested in astronomy/space science.	81	24
I find science really interesting.	25	7
I like to participate in crowdsourced projects.	3	0
I want to discover something previously unknown to researchers.	13	3
I might discover something scientifically interesting.	9	2
Other	16	4

Table 1. *Primary motivation for engaging as selected by users of CosmoQuest.org.*

Data collection

The team contacted 200 individuals via email, and 60 responded. We were able to schedule interviews with 33 participants which were all who agreed to be interviewed. All 33 individuals were interviewed between May and October of 2014. All participants were read a Statement of Consent before each interview and asked to give a verbal, recorded "yes" if they wanted to continue with the interview. The statement and procedure were approved by the Institutional Review Board at Southern Illinois University Edwardsville and designated exempt from further review on 18 April 2013 with modifications and extension approved on 13 March 2014. One interview was rejected once the participant reported that they were under 18 near the end of the interview, and that participant's data were deleted as the study was not authorized for participation by minors. Two more participants did not use any citizen science projects, only participating in other parts of the site, so they were not used in the following analysis. This left 30 interviews to analyse.

Interviews were conducted by four different individuals using a structured interview protocol that was developed by looking at the results of the initial survey and literature on motivation and citizen science. Interview questions about motivation were left open-ended so as to not restrict the participants to choose from a pre-set list. Additionally, interviewers asked the participants about their initial and continuing motivations. Interviews were conducted by phone or voice-only Skype since participants were interviewed from around the world, but video calling was not available to every participant. Interviews were conducted in English as all participants were fluent in English. Interviews took approximately 30 minutes, with the shortest being 20 minutes and the longest 46 minutes. The full list of questions can be found at Appendix A[1].

Participants were interviewed about their current and previous experience with astronomy-related citizen science. Although the focus was on astronomy citizen science projects, participants were not discouraged from discussing non-astronomy-related science activities. All interviewees had been participants in the active project of CosmoQuest, and we desired to capture their answers with respect to all astronomy projects in general. Topics of further questions included involvement in science in general, participation in different citizen science projects, frequency of engagement in citizen science projects, motivation to participate in projects, and how participation in projects has changed over time. In addition to the research questions, participants were asked to answer a series of demographic questions. These questions consisted of age, gender, country, ethnicity, highest education, and income. General demographic information was asked at the very end of the interview to avoid the possibility of stereotype bias *(Danaher & Crandall, 2008)*. Each interview was audio-recorded and transcribed verbatim. Anonymised data can be made available upon request.

Analysis

Coding was completed by five members of the research team. At least two of the five researchers independently coded each individual interview transcript using a basic thematic analysis approach *(Braun & Clarke, 2006)*. The researchers focused the analysis on three main questions that specifically addressed participant motivation and engagement:

• *What were your reasons for first participating in citizen science?*

• *Do you still participate in citizen science? And if so, are your reasons the same?*

- If Yes: What typically causes you to end your engagement for the moment/day?

- If No: Why do you no longer participate?

• *How often do you engage in citizen science activities?*

One coder reviewed the entire batch of interviews and developed themes for each question. These themes related to participants' initial motivations for participating and reasons for continuing or stopping engagement. Then the interviews were split among the five coders. Each coder read the entire interview to identify answers to these three questions that may have come up earlier or later in the conversation, as sometimes participants volunteered the information sought before it was asked or clarified later on.

Each coder categorised each answer to the questions as fitting into one or more of the generated themes, or "other" if they felt that it was not covered, in a similar fashion as the analysis of interviews in *Raddick et al. (2010)*. Then, interviews were redistributed so that each was worked on by a new coder and they categorised the answer without prior knowledge of what the original coder used.

After the interviews were coded twice, a process of comparative analysis was made by the entire coding team of five researchers to determine the level of agreement. The initial level of agreement was high, over 90%. In each case that there was disagreement, the team revisited the transcripts and came to a resolution of coding. After this process of resolution, a third coder checked again for consistency in the coded responses.

At this point, the researchers identified that motivations could be grouped into intrinsic and extrinsic motivations. We adopted the extrinsic/intrinsic definitions described by *Ryan and Deci (2000)* and utilised in an examination of participant motivations in the online citizen science project Old Weather *(Eveleigh et al., 2014)*. With this definition, motivators can be broadly divided into intrinsic (those which stem from the task itself) and extrinsic (the outcomes of an activity). Examples of intrinsic factors include having an innate interest in a particular subject matter or a particular project, finding an activity enjoyable or fun, and feeling confident about successfully completing the work. Extrinsic factors include wanting to accomplish something (e.g., achieve a certain number or level of tasks, make a contribution to science) or to engage in social interaction (Table 2).

Answers to questions of continuing engagement were separated into two categories: internal factors that can be controlled, changed, or manipulated by the managers of a citizen science project, such as negative feedback or frustration at the task or interface, and external factors, which were those things that could not be helped by the design of a citizen project, such as the participant having too much to do or suffering from eye strain.

Motivational Factor	Definition	Type	Count (D, P)
General interest	Favorable attraction to the project or activity	intrinsic	11 (4, 7)
Interest in the subject	Favorable attraction to the specific topic	intrinsic	14 (5, 9)
Help out, give back	Benefit the greater good of the project	extrinsic	21 (9, 12)
Accomplish something	Accomplish a task; do something useful	extrinsic	4 (3, 1)
To learn	To increase personal knowledge	extrinsic	5 (3, 2)
To use as an educator	To use as a tool to educate others	extrinsic	2 (2, 0)
Be a part of science	Be a part of the combined efforts to make something for science	extrinsic	8 (3, 5)
Had time/ skill	When a person perceives that they have enough time to participate or skills needed to do the task	intrinsic	3 (1, 1)
Meet people, be part of a community	When a person seeks to create a collaboration, connection, or relationship with others within CS	extrinsic	1 (0, 1)
Attractive visuals	Specific interest in the images or visuals themselves	intrinsic	3 (1, 2)
Other	Significant reasons not included in original themes		3 (1, 2)

Table 2. *Motivational factors coded by the researchers from an analysis of 30 interviews, including a breakdown into "dabblers" and "persisters"*

Results

Participant Demographics

The data analyzed in this paper consisted of interviews with 30 participants from all over the world. Respondents represented a range of ages from 23 to 70 years of age. Nine participants (30%) of the respondents were between the ages of 23 and 35. Four participants were 65 or over (13%). 80% of the respondents identified as male (n=24), and six identified as female (20%). Most were well educated with over 60% with either a bachelor's or master's degree. The largest subgroup had a bachelor's degree (39%) as their highest educational attainment. Participants' careers emphasized STEM (45%) and education (16%). An additional nine participants (29%) were in trade careers that are not related to STEM. Other participants mentioned that they were no longer working, and the career field was not mentioned, so these participants were counted as unknown (10%). 90% of participants reported having a job and over 40% of participants were career professionals between the ages of 18 and 35 years old.

Over three fourths of participants were derived from the United States (n=23) and seven participants were from: Germany, United Kingdom, Canada, South Africa, Sweden, and a country in South America. Within the United States, participants were found to be from the West (n=5, 17%), South (n=4, 13%), Mid-West (n=6, 20%), and North-East (n=8, 27%).

In the participants' free time, they fulfill personal interests in science by giving back and participating in various citizen science projects. Over half of the participants (n=17, 57%) responded that their engagement in citizen science lasted for less than an hour at a time and 20% (n=6) reported spending two hours or more during a typical engagement period for online citizen science. One fourth of respondents (n=8) reported taking part in citizen science every day, 13% of participants (n=4) reported engaging twice a week and 23% reported engaging once a week (n=7).

What are participants' initial and continuing motivations to engage in citizen science? Participants were asked about their initial motivations for engaging in citizen science with the question, "What were your reasons for first participating in citizen science?" Most participants (23 out of 30) indicated more than one motivational factor, as coded using the analysis above. The number of motivational factors coded per participant ranges from one to six with a mean of 2.5. See Figure 1.

For example, one respondent replied to the question, "What were your reasons for

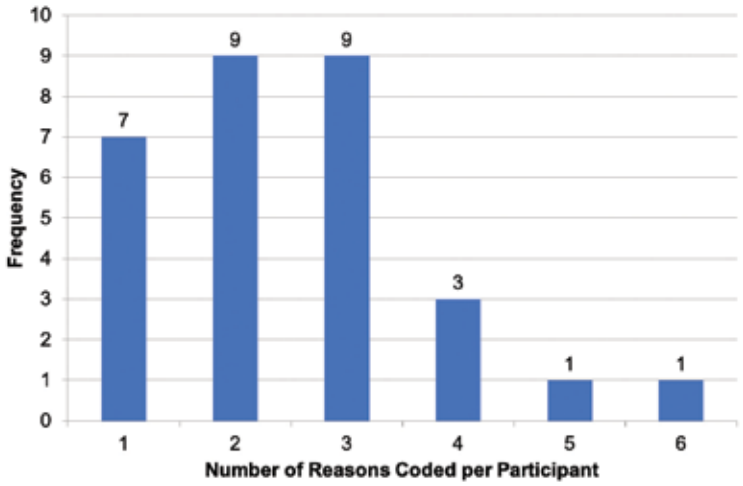

Figure 1. *Histogram of motivational reasons listed per participant. The vast majority of respondents gave more than one reason as a primary motivational factor for starting citizen science. Credit: Nicole Gugliucci*

participating in citizen science?" with the response:
"Well, I think the first participation — if you go back to SETI — was just an attitude to contribute. Then similarly with this I find it interesting and if there is truly — if what I am doing is valuable to what the researchers. Then I'm glad to contribute and the same thing for participating in this survey. I've been a grad student and I know that, you know, you try to gather data."

Since this participant specifically spoke of being interested in the CosmoQuest project in this interview, it was coded as "interest in the subject." It was also coded as "help out, give back." Table 2 lists the themes determined by the coders described in the "Analysis" section above, along with their definitions.

When respondents described why they first participated in citizen science, the three most reported reasons were to help out and give back (n=21, 70%), interest in the subject (n=14, 47%) and finding the project interesting and fun (n=11, 37%). For a smaller fraction of participants, being a part of science (n=8, 27%), learning something (n=5, 17%), and accomplishing something (n=4, 13%) were given as motivators. A few participants described other motivations such as perceiving that they had the time and skills to accomplish the tasks (n=3, 10%), using it as an educator (n=2, 7%), because the project was attractive visually (n=3, 10%), and to meet people and be part of a community (n=1, 3%).

Three "other" reasons were identified by the coders that appeared significant but did not fit into one of the previous themes. These are:

• "engage in scientific process, and advance science" which was a more specific description of "be a part of science," which was also coded for this individual;

• Be an "explorer" — although this is often a descriptor used for the scientific process, it is not solely limited to it and could not be further categorised;

• "Curiosity" — although this is often a descriptor used for the scientific process, it is not solely limited to it and could not be further categorised.

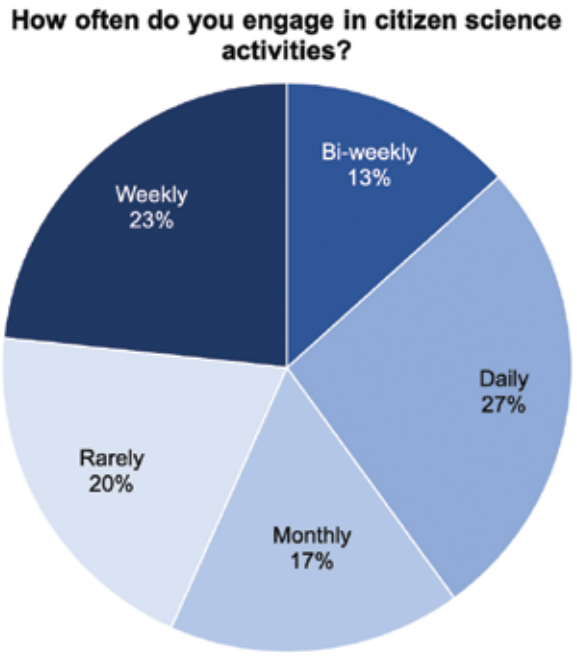

Figure 2. *Frequency of participation. Respondents were grouped by how often they participate in citizen science activities (self-reported). Credit: Nicole Gugliucci*

Excepting the three "other" responses, there were a total of 72 motivations coded among the 30 participants over the ten themes. These ten themes were divided into two main categories, intrinsic and extrinsic motivators, as described in the analysis section above. The intrinsic and extrinsic label for each of the ten categories are included in Table 2.

Half (15) of the participants indicated a mix of intrinsic and extrinsic motivational factors. Of these, 10 indicated only extrinsic factors and five indicated only intrinsic factors.

Twenty-three respondents (77%) answered that they still participate in citizen science

Theme	Definition	Type	Count
Have to do other things	Having prior obligations to attend to which stopped the participation for the time	external factor	20
Physical effects of computer time	The body feeling stiff, sore, or uncomfortable which ended the engagement in the project for the day	external factor	3
Schedule events that ends	The project was only to be for a limited duration and then ended	external factor	3
Attention span, tired	Individual's mental concentration was depleted causing the person to end their engagement	external factor	14
Computer or programme issues	Personal computer/programme was experiencing issues making connecting and engaging difficult	internal factor	1
Negative feedback from programme	Citizen science programme provide unsupportive feedback that was perceived as adverse	internal factor	1

Table 3. *Reasons for disengaging temporarily from citizen science, coded by the researchers from an analysis of 30 interviews.*

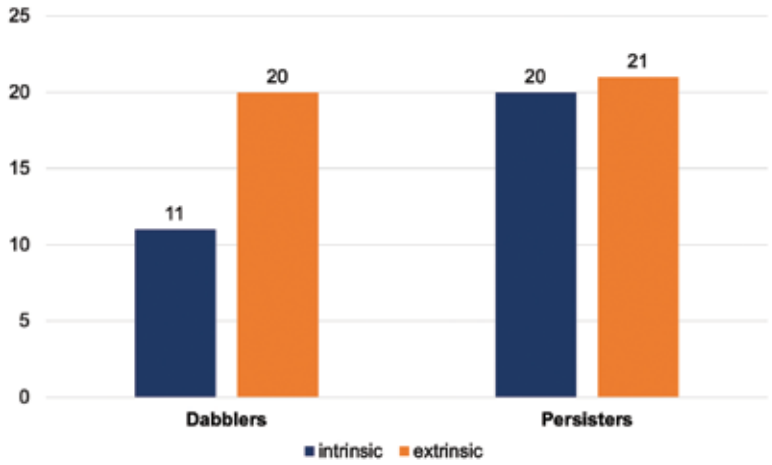

Figure 3. *Intrinsic and extrinsic motivators by frequency. Histogram of reasons coded per type for the "dabblers," those participating in citizen science on a sporadic basis, and "persisters," those participating in citizen science on a regular basis. Credit: Nicole Gugliucci*

projects. Twenty of these indicated that their reasons for participating are the same as when they began. Of the three that said their motivations changed, they now indicate making a difference or furthering the science, both extrinsic motivators, as reasons why they continue to participate.

How do participants' motivations relate to their self-reported patterns of engagement in an online citizen science project?

Participants were asked, "How often do you engage in citizen science activities?" Answers were grouped as shown in Figure 2.

Inspired by *Eveleigh et al. (2014)*, the participants were divided into two categories of self-reported behaviour. Twelve were categorised as "dabblers," or those who reported doing citizen science tasks rarely or monthly. Eighteen participants were categorised as "persisters," or those that reported doing citizen science biweekly, weekly, or daily. Users are more likely to list extrinsic motivators when they are dabblers (rarely or monthly) than if they are persisters (biweekly or more). Specifically, the dabblers, as a group, were coded with 11 intrinsic reasons and 20 extrinsic reasons. The persisters were coded with 20 intrinsic reasons and 21 extrinsic reasons. The number and type of reasons in each group is shown in Figure 3.

What factors contribute to participants ending their engagement?

Participants were asked, "What typically causes you to end your engagement for the moment or day?" Responses were grouped according to the categories in Table 3. As with motivations, some respondents recorded multiple reasons for stopping any given day's engagement. Twenty (67%) listed having to do other things as a reason for stopping for the day, and 14 (47%) noted that their attention span or tiredness were factors. Other external factors included the physical effects of time on the computer (n=3, 10%) and being part of a scheduled event until it came to an end (n=3, 10%).

Only two participants indicated factors internal to the project as reasons for ending their engagement. These reasons could be categorised as "technical issues with the computer or programme" and "negative feedback from the programme".

When asked if they still participate in citizen science, seven of the 30 participants (23%) indicated that they no longer contribute. Four of the individuals that no longer contribute cited external reasons, such as no longer having time to participate or having to give time to competing interests (work, family, school, etc.) (Table 4). Three of these cited reasons internal to the project themselves, categorised into three groups:

• Not having enough context or communication,
Example: "There is kind of a context issue. Looking at the individual small maps, since I don't know where on the Moon I am it loses part of what makes it special. When I have a close in image of a crater or feature on the Moon is that I know where to point on the Moon, 'this is where that was'"

• Perceived lack of ability due to negative feedback from the project, and
Example: "Trying real hard to make MoonMappers work and then being told that I was so far off it was pathetic. I wanted to get it right. The computer would say, 'Are you kidding me? You got so many wrong', and then I'd have to stop."

• Frustrating aspects of the project or programme.

Theme	Definition	Type	Count
No time	Lack of available time to work on the project	external factor	3
Competing distractions	Having something or someone that inhibits the ability to focus on project	external factor	3
Not enough context or communication	The project was unclear on what was wanted or how it fit into a larger picture	internal factor	2
Perceived lack of ability	User does not feel they have the ability to perform the task well	internal factor	1
Frustrating aspects of the programme	Personal computer/programme was experiencing issues or had a problematic design element, making connecting and engaging difficult	internal factor	2

Table 4. *Reasons for permanently disengaging in citizen science, coded by the researchers from an analysis of 30 interviews. Seven of the 30 interviewees indicated that they have permanently disengaged in citizen science.*

Example: "There were questions I had that I didn't know how to get answered because for me navigating a website is profoundly confusing and frustrating. If I had a question about a particular thing, for a long time I didn't even know about the chat on the side of the screen and so I would try to find a place on the forum to ask my question but then when I found the proper place in the forum I would've lost the image I had the question about."

Discussion

The results of this analysis of 30 interviews with citizen science participants reveal a complex set of motivations for starting with such a project. This may not be surprising given the open-ended nature of the questions. Most participants in this study were coded to have more than one motivational factor, and half of the participants indicated some mix of both intrinsic (relating to the task itself) and extrinsic (relating to outcomes) factors. The most prevalent factors in this analysis are indeed a mix of these as well, interest in the project or subject (25 participants), an intrinsic motivator, and helping out or giving back to science (21 participants), an extrinsic motivator (See Table 2). Although only a small number of interviewees (5 participants) indicated a motivation to learn from the citizen science project itself, an additional 7 participants indicated that "being a part of science" was a motivating factor. (One participant indicated both.) This is notable as citizen science projects are a unique way to teach about the process of science in action.

The most significant finding is a trend that emerged when study participants were sorted by reported frequency of use. We define dabblers as those who reported contributing monthly or rarely, and these tended to code with more extrinsic than intrinsic motivators. Persisters were defined as those who reported participating more frequently, and these were more evenly split between intrinsic motivators and extrinsic motivating factors. This supports the emphasis on intrinsic motivators found by *Nov, Arazy, & Anderson (2011)*.

However, while intrinsic motivation can be powerful, relying solely on this type of motivation may reduce the size of potential participant pools to those who already have an innate interest in the subject *(Prestopnik, Crowston, & Wang, 2017)*. Citizen science participant motives are often associated with participation intentions which are then related to participation efforts. External motivators can bring in new participants while also encouraging participants' commitment to the project. Projects should communicate the project's mission and results in order to foster interest in the project's collective goals *(Nov, Arazy, & Anderson 2011)*.

Although the interviews were done for a single point in time, continuing participants were asked if their motivations had changed from those they described as initial motivating factors. The overwhelming majority said that their motivations were the same or, if anything, that their motivation factors were the same, but the level of motivation increased. For the three continuing participants that said their motivations changed, they were more motivated by the opportunity to further the science or to make a difference and contribute. They added these external motivations that had not been present for them initially. To quote one participant, *"before it was I used to do it just to do it. Now, I do it because of the hopes of trying to further the science as well"*. Though a small sample, these responses further support the need for communication of the broader project goals and results to encourage sustained participation.

Although we were only able to interview 30 individuals of the thousands who have participated in this citizen science project, we were able to gain insight from these narratives that were unavailable through surveys alone as participants were free to answer without restriction from a list of choices. We were fortunate to interview several people who used to participate in these citizen science projects but no longer did. Most discussed reasons that are familiar but, ultimately, out of the control of those creating such projects, such as family obligations and work schedules. However, we were able to get useful feedback from those who indicated project-related reasons for stopping work altogether, namely, issues of communication, frustration with the programme itself, and a perceived lack of ability. The last one of these was caught early in the project and feedback prose was later rewritten to better encourage users struggling with their matching scores on randomly inserted test images. Collecting such feedback from users early in and regularly during a project can help avoid loss of engagement due to controllable factors in the long run, or "deterring the drop-outs" in the language of *Eveleigh et al. (2014)*. Issues of communicating the larger context of the project was also cited as a factor for dropping out in that study using Old Weather. Here again, we see continuing communication with citizen scientists to be a key factor in retention where, if done poorly, it can actually drive participants away.

One further observation was about the importance of passive citizen science projects. CosmoQuest projects are considered "active" as users have to engage with the image on their screen. However, participants were prompted to list all citizen science activities with which they engage, and passive projects such as SETI@home came up a number of times. In fact, this was occasionally listed as a starting point for citizen science activity, which is not surprising considering the long lifetime of that project in comparison to newer, active projects. In fact, one participant described that they received a sense of "satisfaction" from running SETI@home, especially when they did not have time to devote to more active projects.

Implications

As astronomy citizen science projects compete for attention in an ever-increasingly crowded media landscape, project designers will have to take into account the intrinsic and extrinsic motivators of their participants. These are also influenced by the project's own scientific and educational goals. Projects featuring active, but monotonous, tasks may design an interface and communication scheme that aims to pique the interest of a large audience over a short period of time or encourage referrals to bring in a steady stream of new participants. However, tiers of activity levels can be designed to further encourage persistent participation among the most highly motivated members. When pitching projects to wide and diverse audiences, project designers should consider building in extrinsic motivators that are meaningful to the communities they want to attract, e.g. integrating with fully developed lesson plans for teachers.

Future work should test the effects of these various motivators in recruiting specifically from groups that are underrepresented in astronomy citizen science efforts.

This research provides a context for recruiting and nurturing two different kinds of citizen science populations: short term dabbling and long-term persisting volunteers. Both of these groups have diverse extrinsic motivations. Put differently, we consistently find that people are motivated to participate by rewards of one form or another. By designing citizen science projects to reward users in one way or another, addressing these extrinsic needs, all populations can be satisfied. At the same time, the key population of persisters, that population which provides the greatest percentage of citizen science data, need to have the intrinsic motivations met as well.

According to *Deci & Ryan (2001)*, "When intrinsically motivated people engage in activities, it is because they find them interesting and satisfying and not because the activities lead to separable rewards or consequences". By knowing what these intrinsic motivations are, citizen science programmes can grow these key populations by design toward promoting their ability to satisfy people's personal hunger to, for instance, engage with astronomical images. If people don't know that a project will speak to their personal motivations, they will have no reason to join it. This is a design challenge for future projects. It is easy to promote extrinsic rewards through social media sharing, badging systems, and leaderboards, but promoting "you can give needed help" is harder to socially share.

This is where it can become a matter of promoting need rather than promoting reward. Citizen science is, at its core, the exchange of tasks that meet needs. Scientists need data analysed, and citizen scientists have personal needs that are met in their participation. Murray's Manifest Needs Theory *(Murray, 1938)* states that "Individuals are driven based on the object towards which the need is directed and the intensity of the particular need (e.g. educational achievement, social success)". If a project is contextualised as having a need for help, it may be more effective at attracting the necessary persisters who are driven to help.

Based on this research, we find that astronomy citizen science projects must design projects to provide the carrots that speak to extrinsic motivations. Those carrots can attract all types of participants. In order to attract persisters, projects must also promote their ability to satiate intrinsic motivations. Once these volunteers are recruited, keeping them requires providing a nurturing site that communicates the need for improvement in a gentle way and that proactively provides community members with invitations to community events and answers to common questions. Even with all the motivations fulfilled and barriers removed, it is important to note that no project can retain the typical user for a long duration because life, and its myriad of obligations, does tend to tear people away. The key is to make sure that volunteers stay as long as time and life allow and leave feeling satisfied.

Conclusions

Interviews with 30 citizen scientists recruited from CosmoQuest provide a detailed look at the motivations of these participants in conjunction with their behaviours.

The citizen scientists interviewed described a complex set of initial motivations that include both intrinsic and extrinsic motivating factors. Interest in the subject or project was the top intrinsic factor, and a desire to help out and give back with the top extrinsic motivator. The majority of respondents indicated that their motivations are the same as they were when they began.

"Persisters" who participate on a more regular basis are more likely to list intrinsic reasons for participation than "dabblers" who participate on a more sporadic basis. This highlights a potential area of improvement on the part of citizen science projects and their recruiting effort, especially in regard to attracting more diverse audiences. By expanding to and emphasising a wider range of extrinsic outcomes, such as teaching, learning, community building, or the specific impacts of the science itself, citizen science projects are more likely to sustain engagement over time.

Many factors drawing participants away from citizen science, either in the moment or for good, are outside the scope of a project's control, such as time available and family responsibilities. However, projects and communication about projects can be designed in ways that encourage "just one more" classification or a return to the project after a hiatus. Factors that can be controlled, such as communication methods, feedback, and technical issues, could be minimized through careful project testing and immediate feedback mechanisms built into the projects.

Notes

[1] You can access Appendix A here: https://drive.google.com/file/d/1cS_XZ6l5ju0sTI-mupTvq4mEjI2NSZoR/view?usp=sharing

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Acknowledgements

The authors would like to thank the citizen scientists in the CosmoQuest community for their tireless efforts to advance science, especially those 33 participants who interviewed for this research. Many thanks are due to Cory Lehan and Joseph Moore for their work in developing and maintaining the CosmoQuest site. We gratefully acknowledge Shanique Brown whose interview protocol was adapted for this work. We would also like to thank the anonymous reviewers whose comments helped strengthen and improve this manuscript.

This work was supported by NASA under award No.s NNX12AB92G, NNX16AC68A, and NNX17AD20A. Gugliucci acknowledges financial support from Saint Anselm College.

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