How Personal Value Orientations Influence Behaviors in Digital Citizen Science

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While much research has examined motivations for contributing to citizen science projects, few studies have considered the role of personal values in directing citizen scientists' interactions and contribution patterns. We investigated whether personal values systematically influence the behaviors of individuals who use the Zooniverse platform to select and contribute to citizen science projects. In this paper, we present the results of a research study where we launched a large-scale survey (N = 2,605) to capture personal values using Schwartz's Portrait Values Questionnaire (PVQ-21). We also extracted system log data from participant interactions on Zooniverse. Our results align with previous research suggesting intrinsic type motivators and values tend to drive specific modes of interaction, e.g., exploring projects in different disciplines. We also see that interaction in social spaces, e.g., discussion boards, is driven by values with a personal focus (e.g., self-enhancement) and social focus. Given these results, we provide several suggestions for managing these and similar projects.

CCS Concepts: • **Human-centered computing** → **Empirical studies in HCI**; **User studies**.

Additional Key Words and Phrases: citizen science, user behavior, survey, values

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1 INTRODUCTION

Digital citizen science describes a form of public participation in scientific research (PPSR) conducted over the Internet, where amateurs and professional researchers collaborate to conduct scientific research. The collaboration involves amateurs in one or many steps in the scientific process, including choosing or defining, gathering information and resources, collecting data, or discussing and reporting results [3, 4]. Over the last two decades, improvements in information and communication technologies have made it possible to researchers to collaborate with amateurs interested in contributing to science. To that end, virtual platforms like Zooniverse [54] and SciStarter [19] facilitate connections and collaboration between researchers with volunteers. Both platforms provide the technical infrastructure to facilitate the building and management of projects while providing access to a population ready to contribute to projects. Zooniverse has helped build and launch more than four hundred citizen science projects spanning diverse scientific fields, including space and climate, and its population base of approximately two million registered accounts and contributions totaling eight billion. At the time of writing, more than three thousand projects were available on SciStarter.

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Contribution in digital citizen science typically exhibits a skewed pattern of participation, with many studies finding that most participants contribute only once and in small amounts [42]. In Gravity Spy, a project hosted on Zooniverse, the average number of sessions is five, while the median is one [26]. Given the nature of participation, it is crucial to understand who the participants are and what factors influence their commitment to projects. To that end, many studies have explored the motivational drivers of participation. At a high level, we know that a variety of motivations (primarily intrinsic) drives participation [10, 36, 37] and that motivations are dynamic, potentially changing over time [39, 40]. While the findings about human motivation have substantially increased our understanding of what drives participation in digital citizen science, we propose that understanding values may help provide a more nuanced view of participation. Motivation and values are closely intertwined and influence each other in various ways. While motivation refers to the underlying reasons and desires that drive individuals to take action, values represent deeply held beliefs and principles that guide behavior and decision-making. Values are associated with motivation in expressing goals people strive to attain [38, 46].

Values have also been implicated in designing user experiences. The literature on value-sensitive design (VSD) aims to incorporate human values into the design of interactive computer systems by emphasizing value discovery, deliberation, and interventions that align with users' views [17, 52]. Studies investigating and incorporating stakeholders' values often indicate increased satisfaction and usability [53]. In that sense, highlighting the socio-technical makeup of the project we investigate may also help us understand how specific values might be activated through various social interactions and technical affordance available to participants.

This research provides insights into values and their influence on participants' levels and engagement patterns and addresses the following research question **In what ways do personal value orientations predict the contributions and participation behaviors of citizen scientists?**. We measured the value orientations of participants to projects hosted in Zooniverse. To understand and measure values, we draw on Schwartz's Theory of Basic Values [43]. Schwartz proposes a set of universally known values that can be translated into motivational constructs, articulating goals people strive to achieve and maintain. To understand and measure levels and patterns of engagement, we relied on data extracted from database logs hosted on Zooniverse servers. These digital data provide a unique opportunity to capture behaviors that accurately represent individuals' actions on computer systems.

Through our analysis of participants' values and behaviors, this paper makes several contributions to the literature on the motivation of citizen scientists. First, we demonstrate how values are crucial in guiding individuals' decision-making processes, implicating aspects of participation such as the projects they select or the level of involvement they prefer. Second, we situate our results in the broader literature on motivation, reporting the relationship between values, motivation, and behaviors. Third, we implicate various aspects of the design of Zooniverse (and other digital citizen science projects) in value alignment, suggesting processes, rules, strategies, and technical features that project organizers system designers should consider.

2 MOTIVATIONS, VALUES, AND BEHAVIORS IN OPEN COLLABORATION

2.1 Motivation in Digital Citizen Science

Over the last decade, the question of what motivates people to contribute to digital citizen science projects has received considerable attention in the academic literature. Motivation is defined as a mental construct that a volunteer uses, consciously or unconsciously, to explain their behavior, arising out of a combination of the person's mental state and properties of the situation they are in [22]. Research on participants' motivations in digital citizen science projects can

be summarized in two areas. First, a variety of motivational drivers influence participation [8, 10, 11, 35, 35–37, 39, 40]. The results in most studies indicate that intrinsic motivations are more prevalent than extrinsic ones. One of the earliest studies of the motivation of Galaxy Zoo participants revealed twelve broad categories of motivation, including contributing to a science project, learning about astronomy, enjoyment of discovery, and social engagement [36]. Similarly, in researching the motivations of Foldit participants, Curtis [10] found contribution to science, interest in science, intellectual challenge, and liking puzzles were the main motivational drivers. Reed et al. [37] indicated social interactions, desire to help, and interactions with the website as primary motivations of digital citizen scientists. In another study, Rotman et al. [39] found egoism, recognition, attribution, feedback, community involvement, advocacy, and altruism to be salient motivational drivers in ecological citizen science projects.

A second important finding highlights that motivation dynamic, changing over time [24, 40]. Research by Rotman et al. [40] found egoism was salient during early participation, while recognition and attribution were crucial for continued project engagement. Another research study by Jackson et al. [24] revealed that social interactions and learning were more influential for sustained participants, while they were less significant during the initial stages of engagement.

2.2 Motivation, Values, and Behavior

When compared to motivations, values transcend specific actions and situations; no matter the context, the same values will appear, although their relative importance may change. Values are believed to be more stable than motivations and define desired goals that motivate action and serve as guiding principles in the direction of human attitudes, beliefs, and behaviors. Values are linked to three universal requirements of humans – biological needs, social action, and group welfare and survival [45]. In HCI, some studies have explored human values, drawing on theories and survey instruments by Hofstede [20], Rokeach [38] and Schwartz [43]. In this work, we draw on theorizing and instrumentation developed through Schwartz's Theory of Basic Values which benefit our work in several ways. Unlike Hofstede, who proposes four cultural value dimensions for comparing work values across different cultures, Schwartz's Theory of Basic Values is agnostic and can be used to measure individual values in various life domains [44]. Also, the instruments were developed to account for differences in cultural values in all societies. Rokeach's covers a broader range of human values than Hofstede's but does not involve cross-cultural aspects and important value content such as tradition and power [43, 44].

2.2.1 Schwartz's value theory. Schwartz [43] defines values as desirable and trans-situational goals that vary in importance and serve as principles that guide people's lives. The theory identifies ten human values (i.e., power, achievement, hedonism, stimulation, self-direction, universalism, benevolence, tradition, conformity, and security) and four high-level values (i.e., openness to change, self-enhancement, conservation, and self-transcendence). The values can be translated into motivational constructs, articulating goals people strive to achieve and maintain. Each value and its motivational purpose are described in Table 1. For instance, motivational goals tied to stimulation emphasize excitement, novelty, and challenge in life. Thus, individuals who value stimulation will seek experiences that allow them to experience associated motivational goals.

The values also form a circular motivational continuum and are mapped onto a circumplex model (Figure 1). The circular arrangement of values in the circumplex represents a continuum of related motivations describing conflicts and compatibilities. In the circumplex model, values closer in proximity are hypothesized to express similar motivations. For example, universalism and benevolence, component values of self-transcendence, stem from a similar pursuit of goals

High-level value	Value	Defining goal
Openness to Change (readiness for change)	Self-direction	independent thought and action–choosing, creating, exploring
	Hedonism	pleasure or sensuous gratification for oneself
	Stimulation	excitement, novelty, and challenge in life
Self-enhancement (concern for oneself)	Achievement	personal success through demonstrating competence according to social standards
	Power	social status and prestige, control or dominance over people and resources
Conservation (preservation of the current status and resistance to change)	Security	safety, harmony, and stability of society, of relationships, and of self
	Conformity	restraint of actions, inclinations, and impulses likely to upset or harm others and violate social expectations or norms
	Tradition	respect, commitment, and acceptance of the customs and ideas that one's culture or religion provides
Self-transcendence (concern for others' well-being)	Benevolence	preserving and enhancing the welfare of those with whom one is in frequent personal contact (the 'in-group')
	Universalism	understanding, appreciation, tolerance, and protection for the welfare of all people and for nature

Table 1. Values as described in [47]

involving concern for the welfare and interests of others. Conversely, more distant values in the circumplex model are hypothesized to have antagonistic motivational goals. Thus, while universalism involves concern for others, power (a component value of self-enhancement) stems from opposing motivational forces related to the pursuit of self-interest. The values in the circumplex model are also theorized to be partitioned into additional conceptual distinctions related to interests that the attainment of a particular value serves Schwartz [47] - personal or social and anxiety-based or anxiety-free goals. The distinction between attaining personal and social-focused motivational goals is relevant to our research. Values on the left half of the circumplex model (e.g., self-direction) are hypothesized to be related to concern with outcomes for self. In contrast, values on the right half of the circumplex model (e.g., benevolence) are hypothesized to be related to concern with outcomes for others or established institutions.

Typically, values are measured using either the 56-item Schwartz Value Survey (SVS: Schwartz [43]) or its derivation, the 40-item Portrait Values Questionnaire (PVQ: Schwartz et al. [49] and the shorter PVQ-21). The content and structure of relations among the values have been empirically validated to define universal aspects of value content (i.e., meanings and types of ten values) and structure (i.e., conflicts and compatibility between values) through empirical tests in 20 countries, making the survey sensitive to cultural boundaries. The instruments were developed as a universal index to measure value orientations across countries and cultures [43], and research using the instruments has demonstrated that people recognized distinctive ten values within and across cultures [44, 47]. Prior research has found significant agreement regarding the priority of ten universal values in a cross-cultural study involving the values of people in 60 countries. Across most nations examined, values related to benevolence, universalism, and self-direction were consistently ranked as the most important. In contrast, values associated with power, tradition, and stimulation tend to be placed lower in the hierarchy [47, 48]. While the values appear to be stable across cultures and contexts, variations in the hierarchy can occur due to specific characteristics of each sample, such as age, occupation, religion, family size, and unique economic, social, technological, and historical experiences [48]. For example, in countries with larger typical nuclear families, self-direction values tended to have lower importance, while conformity values were more significant [47].

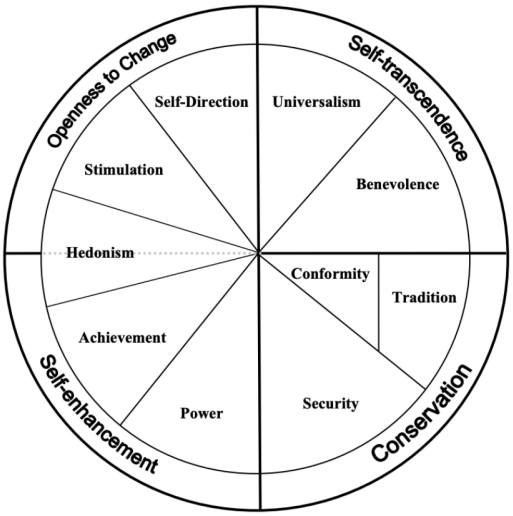


Fig. 1. Schwartz's circumplex of values and their meta categories as depicted in Davidov et al. [12]

Schwartz theorizes that values are organized into a motivational continuum that can help to explain individual decision-making, attitudes, and behavior [43]. In several articles, Schwartz offers insights into values and their influence on decision-making, attitudes, and behavior. Schwartz [45] argued that benevolence might lead to increased cooperation while power decreases it. Self-direction (creativity, choosing goals, curiosity) is hypothesized to be related to forms of intrinsic motivation. Additionally, individuals who value stimulation are often drawn to challenging jobs, while those who value security might find challenging topics less attractive [43].

The Schwartz Theory of Basic Values has been used across a variety of empirical settings to understand how values are related to voting behaviors [15], cooperative games [46], political activism [46], and organizational work [7, 18]. Glazer et al. [18] surveyed hospital nurses in four countries: Hungary, Italy, the UK, and the US, to study the relationship between their values and commitment. Although the correlations differed from country to country, it was found that openness to change type values (i.e., self-direction, hedonism, stimulation) was negatively correlated with commitment in Hungary, Italy, and the USA. Conservation-type values (i.e., conformity, tradition, and security) positively correlated with commitment (except in the UK). Cohen [7], who studied the work commitment of bank employees in Israel, found that conformity, benevolence, universalism, and power values were positively related to sustained commitment to the job. In contrast, self-direction and stimulation values were negatively correlated with commitment.

2.3 Values and Value Activation in Open Collaboration

Values have been linked to the behaviors and attitudes of users in online communities like the ones studied here [5, 6, 15, 21, 29, 31, 32]. Oreg and Nov [32] investigated the motivations and values of Open Source Software (OSS) contributors. The results showed achievement value is associated with reputation-building motivations. Since people with high achievement values focus on demonstrating their competence, they are likely to contribute to open source to establish a good reputation by showing their performances. Self-direction value was related to self-development motivations. Self-direction emphasizes learning, creating, and exploring. Mair et al. [29] examined the relationship between values and volunteers' behaviors in the R Open Source project. They found power and universalism values

to be associated with volunteers' contribution. Power was related to the number of packages (co) authored. People with high power value scores regard social power, wealth, social recognition, and authority as important. R packages are open to the public without restrictions. Therefore, people who value power are less likely to (co) author packages. Volunteers with high universalism value scores were less likely to attend R conferences.

In citizen science participants, two studies have investigated the values of participants. In Palacin et al. [34], the authors investigated the value orientations of individuals contributing to SENSEI, a citizen science project with in-person and digital components. The authors measured the relationship between value orientations and the number and quality of interactions, used Schwartz's PVQ-21 to calculate values, and collected self-report data about interactions. They found self-transcendence and security values are associated with initial participation - people who valued security were twice more likely to be sustained. On the other hand, people with high self-transcendence were less likely to be sustained. They also found that value orientations were linked to different usage patterns - people with higher security values contributed less frequently. In another study, Palacin et al. [35] interviewed participants in two digital citizen science projects. They aimed to uncover how personal values change throughout individuals' involvement in a project - finding that openness-to-change values were associated with initial participation. In contrast, a diverse range of values (excluding power) was essential in sustaining participation.

Implicated in these investigations about values is the literature on value-sensitive design (VSD) [17, 52]. VSD focuses on integrating human values into the design of interactive computer systems suggesting that tools and infrastructures embedded in these systems could reinforce or undermine specific values. For example, autonomy is promoted when the computer system designs empower users with appropriate control at the right moments. It helps individuals who value autonomy to achieve their goals more effectively through the value-supportive design [16]. While we suspect current design choices for digital citizen science projects are not necessarily the results of systematic consideration of stakeholder values, nonetheless, specific social and technological affordances might support or undermine values. For example, we suspect participants with high self-direction might be engaged in multiple projects to support independent thought and action–choosing, creating, and exploring. Conversely, individuals with high values on the social side of the value circumplex (e.g., benevolence) are more likely to seek projects and situations that allow them to realize socially focused values and goals.

3 METHODS

3.1 Setting: Zooniverse

The setting for this investigation is Zooniverse [54], an online platform for people-powered science that connects researchers with amateur volunteers. At the time of writing, Zooniverse has helped build and launch more than four hundred citizen science projects across diverse scientific areas. When people visit the Zooniverse website, they are presented with a list of projects from which to choose (Figure 2). Most Zooniverse projects involve volunteers in classifying images of existing data subjects. One well-known Zooniverse project, Galaxy Zoo, asks participants to review images of galaxies captured by telescopes, generating millions of images. Participants are shown images of galaxies and asked a series of questions about the shape of a galaxy. Like most projects hosted on Zooniverse, Galaxy Zoo relies on the "wisdom of the crowd," meaning each data object is classified by multiple participants.

In 2015, Zooniverse launched Project Builder, a free service that allows any research team to build citizen science projects and host their data on Zooniverse. Since the launch of Project Builder, Zooniverse has gone from launching a handful of projects per year to nearly one project per week [41]. The Project Builder is a template project that teams

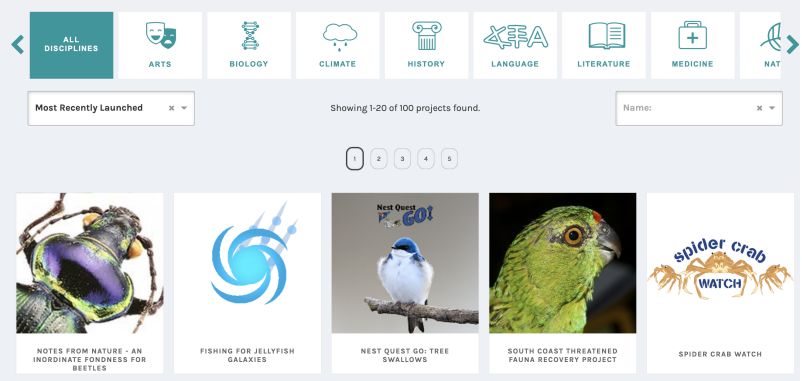


Fig. 2. The Zooniverse homepage.

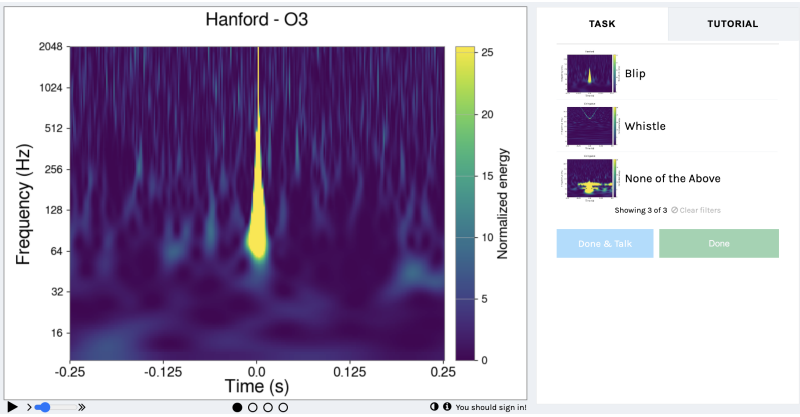


Fig. 3. The Gravity Spy classification interface.

can adapt to their needs. Much of the technical infrastructure is uniform across projects using the Project Builder, meaning the presentation and interaction with the system is relatively uniform (as shown in Figure 3) - participants are presented with data and asked to perform some analysis. In addition to classifying data, Zooniverse supports various actions, including creating & managing collections of images (similar to Pinterest), discussion boards, and private messaging. Projects do differ in some aspects. Researchers can customize different elements of their projects. For instance, researchers can customize the analysis task (i.e., the exact activity - drawing, transcribing) or produce a project with multiple tasks (e.g., workflows). The task typically depends on the goals of the researcher and the data outputs that would be most advantageous to their research. These choices can impact aspects of the user experience, which may, in turn, affect the level of interaction in a project and the quality of the data generated by the citizen scientists [55–57]. Researchers can also determine whether participants can become moderators.

In Zooniverse, although the platform was not necessarily designed with human values in mind, we expect some platform and project design decisions to help or undermine specific values. For example, self-direction (a constituent value of openness to change), which conveys independent thought and action, implicating actions such as making choices, creating, and exploring, might lead to deeper engagement on Zooniverse (i.e., operationalized as contributing

classifications in many projects). With more than hundreds of projects across seven research disciplines and various task types, participants can choose from multiple projects to support this value. Values of self-transcendence (i.e., universalism, benevolence) and conservation (i.e., tradition, conformity, security) have a social focus. Zooniverse facilitates social engagement through discussion boards where actions supporting social-focused values, e.g., self-transcendence, may be activated.

3.2 Data Collection

We used three data sources for this investigation - a large-scale participant survey, digital trace data, and information about Zooniverse projects. We describe each type of data below.

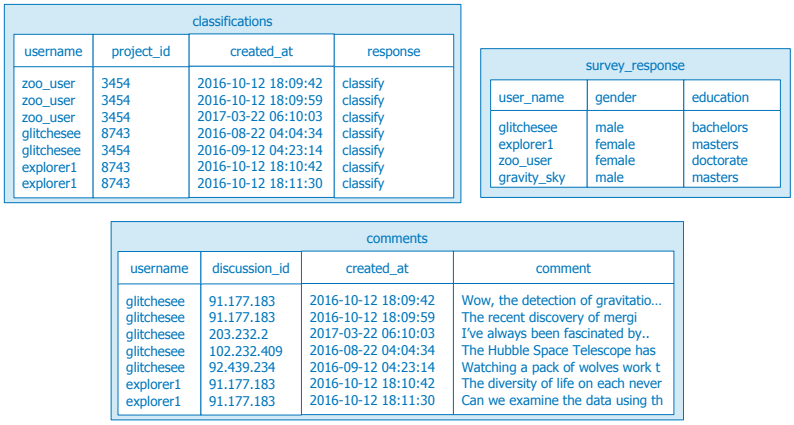
3.2.1 Participant Survey. The research team developed the questionnaire in collaboration with the Zooniverse team. We considered the Zooniverse team's desire to compare the current user population to a survey conducted in 2014. Using Qualtrics, the research team built and piloted the survey. The survey contained 44 questions in five sections:

- **Section 1. Demographics** - basic demographic information about the participant, e.g., age, gender, and income.
- **Section 2. Participation and Engagement** - questions about the volume, velocity, and variety of respondents' interactions on Zooniverse. We asked questions about the frequency of contribution to Zooniverse projects, from where they contribute (e.g., work) and how often they contribute, technology devices they use to connect to Zooniverse, their engagement with project features such as project tutorials, discussion boards, etc., and interactions with other volunteers, science teams, and Zooniverse staff.
- **Section 3 Motivations** - we used the Balanced Measure of Psychological Needs (BMPN) Sheldon and Hilpert [51] to measure three fundamental psychological needs: autonomy, competence, and relatedness. These needs are based on the Self-Determination Theory (SDT), which proposes that these three needs are essential for human motivation, well-being, and optimal functioning.
- **Section 4. Values** - to measure values, we use the shortened version of the Portrait Values Questionnaire (PVQ) [43]. The shortened version is a derivation of the original PVQ and includes 21 items that correspond to one of the ten basic values in Table 1. The 21 items are presented to respondents as "portraits" of an individual, and respondents are asked to rate, using a 6-point Likert Scale ("1 - very much like me" to "6 - not like me at all"), how similar the portrait is to them. For example, "Thinking up new ideas and being creative is important to them. They like to do things their own original way" is an example portrait intended to represent a value orientation towards self-determination. The PVQ-21 has been used in the European Social Survey [44].
- **Section 5. Community** - attitudes about Zooniverse – the platform and the community of participants. The questions in this section centered on diversity, agency, identity, and belonging.

After adjusting the questionnaire based on feedback we received during pilot testing, we recruited survey respondents through the announcements@lists.zooniverse.org listserv. Most communication between Zooniverse and its volunteers is sent through the listserv. Membership in the listserv is opt-out with the selection presented upon registering for an account and on the user profile page. A recruitment message was added to the email sent via the listserv on October 7, 2021. We included a link to the survey and offered the chance to be selected for one of five $100 gift-card raffle to incentivize participation. Upon clicking the link, respondents reviewed the informed consent. The survey was closed on October 21st, 2021. We received 7,453 responses to our survey.

3.2.2 System log files. Since we wanted to link actual (as opposed to self-reported) interactions on the platform, we used the system logs of classifications and comments to represent various aspects of engagement on the Zooniverse platform and the projects the platform hosts. At the end of the survey, we asked respondents if we could access their Zooniverse data. If the respondent answered yes, we asked them to write their Zooniverse screen name. We received permission from 3,952 respondents. The screen names were sent to the Zooniverse team, who were able to identify the screen names of 2,605 respondents.

The classification dataset contains records of each participant's annotations in each project. The comment dataset contained the submissions to a project's discussion boards. Screenshots of records in each dataset are shown in Figure 4. Each record included the participant's screen name (username), the project (N = 406) where the record originated, and the timestamp. The classification dataset included their annotation responses, and the comment dataset included the text of their posted comments.



classifications

username	project_id	created_at	response
zoo_user	3454	2016-10-12 18:09:42	classify
zoo_user	3454	2016-10-12 18:09:59	classify
zoo_user	3454	2017-03-22 06:10:03	classify
glitchesee	8743	2016-08-22 04:04:34	classify
glitchesee	3454	2016-09-12 04:23:14	classify
explorer1	8743	2016-10-12 18:10:42	classify
explorer1	8743	2016-10-12 18:11:30	classify

survey_response

user_name	gender	education
glitchesee	male	bachelors
explorer1	female	masters
zoo_user	female	doctorate
gravity_sky	male	masters

comments

username	discussion_id	created_at	comment
glitchesee	91.177.183	2016-10-12 18:09:42	Wow, the detection of gravitatio…
glitchesee	91.177.183	2016-10-12 18:09:59	The recent discovery of mergi
glitchesee	203.232.2	2017-03-22 06:10:03	I've always been fascinated by..
glitchesee	102.232.409	2016-08-22 04:04:34	The Hubble Space Telescope has
glitchesee	92.439.234	2016-09-12 04:23:14	Watching a pack of wolves work t
explorer1	91.177.183	2016-10-12 18:10:42	The diversity of life on each never
explorer1	91.177.183	2016-10-12 18:11:30	Can we examine the data using th

Fig. 4. Screenshots of the data we captured from the Zooniverse logs.

For each dataset, we computed each user's session variable and tenure variable. We sorted the datasets by users and timestamps to determine sessions and then calculated the time gap between consecutive timestamps. If the gap exceeded 30 minutes, we incremented the session variable by one, effectively identifying distinct sessions within the data. Tenure was computed as the difference between the earliest and most recent timestamps. Since we were interested in several practices related to commenting, for each comment, we extracted two variables - the number of hashtags (obtained by counting the number of "#" appearing in the text) and hyperlinks (obtained by measuring the appearance of "http" in the text). To prepare the data for analysis, we summarized our three datasets (Figure 4) - one grouped by user (N = 2,605), summarizing their contributions on the platform, and another grouped by user and project, summarizing their contributions in each project.

As noted above, we suspect aspects of individual projects might influence which values are activated. Based on the project names returned in the system logs, we captured additional information about the projects - their disciplinary focus and the task type. When building a project, the science teams can select a discipline to which the project (Biomedical, Physics & Space, Ecology & Earth Sciences, or Humanities). Additionally, when building the task, science teams choose a drawing, transcription, mixed (multiple steps), question, subtask, or survey question.

3.3 Data Analysis

Since this research is focused on the relationship between values and behaviors, we only used data from Section 1. Demographic and Section 4. Values. To ensure high-quality data, we developed several survey exclusion criteria. First, since calculating value scores is impossible with incomplete data, we removed data from respondents who did not complete the PVQ-21 questionnaire. Second, survey response time was evaluated to remove survey speeders (i.e., responses where the completion time was two standard deviations more or less than the average completion time). After implementing our quality checks, 6,089 valid survey responses remained.

Following the coding instructions in [45], we computed the value scores, linking the portrait values to high-level and basic values. The instructions also suggest different transformations of the values depending on the analysis being conducted. These transformations are required to mitigate potential biases from scale differences between individual respondents. The results include references to the transformations we used. We conducted reliability tests to measure the internal consistency of the PVQ-21 survey items. Cronbach's alpha was used to report the internal reliability of the items. The Cronbach's alpha for ten values ranged between 0.06 and 0.39. In comparison, the four higher-order values were higher, ranging between 0.41 and 0.50. Low reliability is a common issue raised by previous studies which employed PVQ. For example, one study reported that Cronbach's alpha for ten values ranged from 0.20 to 0.41 [58]. To maximize internal reliability, our analysis focuses on the four high-level dimensions, providing a more detailed examination through presentation and discussion of the basic values.

In analyzing our data, we conducted correlation analysis and mixed-effects regression analyses. The coding instructions recommend using the centered value scores for analyses of correlations [45]. The correlation analysis was used to measure the interrelationships among values and participating behaviors (e.g., number of projects, task types, classifications, sessions, comments, and duration of contribution). The study of correlations is also important for determining whether multicollinearity exists between the independent variables, which might result in their removal or separation in our regression analysis. Since the distributions in our data are non-normal, we use Spearman's rank correlation method. We report correlations for both high-level and basic values. We used mixed-effects regression models to understand the impact of values (independent variables) on participation behaviors (dependent variables) numerically measured at the user level. The coding instructions recommend using the mean value scores for regression analyses [45]. Since data are repeated measures - participants contribute to many projects, we used mixed effects regression. The logistic mixed-effects model was used to model binary outcomes, such as the likelihood of commenting. The linear model is continuous outcome variables predicting outcomes, such as the number of classifications and projects. Analyses were conducted in RStudio and used the lme4 package developed by Bates et al. [1].

4 RESULTS

We obtained responses from 2,605 participants. Respondent demographics are shown in Table 2 and align with most studies describing the population of citizen science contributors as homogeneous. The majority of respondents in our data identified as female (59%), middle-aged or older (48% were 55 and older), predominately white (85%), and educated (90% earned at least a bachelor's degree). Using the Pew Research Center income classification, half of the respondents indicated they earned 3,000 USD or less each month [1].

[1]Respondents were asked to convert monthly income to USD. Income levels were recorded as high (>= $5,000), middle ($3,000 - $4,999), and low (< $3,000) following the income classification thresholds derived from from the Pew Research Center - Covid-19 Pandemic Pinches Finances of Americas Lower and Middle-income Families

Prior research on user contribution patterns in digital citizen science indicates unequal distributions. To better understand our population, we aggregated data within and across projects to develop a profile of user contribution patterns. Our respondents were long-time contributors as the average length of tenure is 4.6 (σ = 11.83, $\tilde{x}$ = 1) years. However, users do not consistently contribute to projects. We calculated the time difference between their most recent and first activity in each project they made at least one classification. We found that most users in our sample were active in a single project for 2.5 years (σ = 2, $\tilde{x}$ = 1.85). Respondents were also engaged in many projects - contributing to an average of 16 (σ = 24, $\tilde{x}$ = 8) during their tenure in Zooniverse. We also found that respondents were active contributors, averaging 10,752 (σ = 51,663, $\tilde{x}$ = 905) classifications and 181 (σ = 1,230, $\tilde{x}$ = 1) comments across an average of 212 (σ = 775, $\tilde{x}$ = 24) sessions throughout their tenure.

Gender		**Age Group**		**Race/Ethnicity**		**Education**		**Income***	
Female	1,529 (59%)	18-24	283 (11%)	Asian	159 (6.1%)	<Bachelor	199 (8.8%)	Low	956 (50%)
Male	970 (37%)	25-34	316 (12%)	Black	11 (0.4%)	Bachelor	811 (36%)	Middle	459 (24%)
Non-binary	81 (3.1%)	35-44	330 (13%)	Hispanic	62 (2.4%)	Vocational	247 (11%)	High	514 (27%)
Non response	19 (0.7%)	45-54	430 (17%)	Multi-racial	85 (3.3%)	Master	697 (31%)		
		55-64	583 (21%)	White	2,208 (85%)	Doctoral	271 (12%)		
		65 +	702 (27%)	Other	46 (1.8%)	No Response	28 (1.2%)		
				No Response	29 (1.1%)				

Table 2. The demographics of our population.

4.1 The Value Orientations of Zooniverse participants

The average value scores for high-level and basic values are displayed as violin plots with internal box plots in Figure 5. The violin plot allows us to visualize the shape and distribution of the data. Compared to the ten basic value scores, the high-level value scores are normally distributed with slight disturbances beyond the mean scores. The shape of violin plots for basic values shows the data are volatile beyond the mean values indicating more variation among individual users concerning value orientations. This is especially true for value scores with the lowest average scores. For example, while the value score for power is lowest among the basic values (μ = 1.94), several respondents had high scores for the power value (as evidenced by outliers). The ranked value prioritization scores revealed that openness-to-change (μ = 3.34, σ = 0.77) was the highest prioritized value, followed by self-enhancement (μ = 3.09, σ = 0.64), conservation (μ = 3.06, σ = 0.65), and self-transcendence (μ = 2.98, σ = 0.68). Ranks among the basic values didn't reveal any discernible patterns. For each high-level value, the constituent basic values varied in rank (Appendix B). For example, while openness-to-change was prioritized, the component values - stimulation and self-direction ranked third and sixth, respectively.

4.2 The Relationship between Value Orientations and Volunteer Engagement

The correlation results among the value dimensions and our outcome variables are shown in Table 3. The correlation was computed using the dataset with variables aggregated by each respondent. Since the outcome variables follow a non-normal distribution, Spearman's rank was used to produce correlations. The correlations among the high-level value dimensions and the outcome variables were negligible, ranging between -0.08 and 0.07. Interestingly, however, most outcome variables were negatively correlated with self-transcendence. The correlations for basic values are presented in Appendix C, and compared to the high-level value dimensions, are more strongly (albeit still negligible)

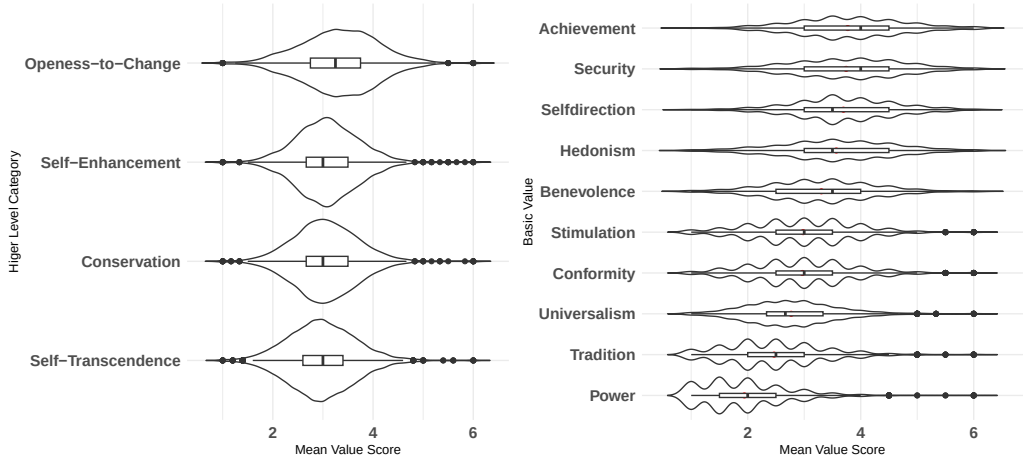


Fig. 5. The high level and basic value scores for respondents.

correlated with the outcome variables. Among the strongest correlations were the number of sessions with stimulation and self-direction.

	Tenure	*Projects*	*Class.*	*Sessions*	*Comments*	*URLs*	*Tags*	*Tasks*	*Discip.*	*Conservation*	*OTC*	*Self-Enhance.*	*Self-Trans.*
Tenure													
Projects	0.64***												
Class.	0.52***	0.72***											
Sessions	0.49***	0.69***	0.88***										
Comments	0.34***	0.44***	0.63***	0.68***									
URLs	0.20***	0.21***	0.32***	0.36***	0.49***								
Tags	0.27***	0.37***	0.53***	0.56***	0.77***	0.50***							
Tasks	0.55***	0.90***	0.60***	0.59***	0.38***	0.18***	0.31***						
Discip.	0.49***	0.79***	0.50***	0.48***	0.29***	0.16***	0.25***	0.80***					
Conservation	0.01	-0.00	0.00	-0.00	0.02	0.04	0.03	-0.01	-0.00				
OTC	0.02	0.04*	0.07***	0.07***	0.05**	-0.03	0.04	0.05*	0.01	-0.36***			
Self-Enhance.	-0.00	0.02	-0.01	0.00	-0.00	0.04*	0.02	0.02	0.05**	-0.35***	-0.31***		
Self-Trans.	-0.03	-0.05*	-0.05**	-0.07***	-0.08***	-0.06***	-0.08***	-0.06**	-0.06**	-0.40***	-0.20***	-0.25***	

Computed correlation used spearman-method with listwise-deletion.

Table 3. Correlations between values and behavior variables. Note: *p < 0.05, **p < 0.01, ***p < 0.001.

4.3 Linking values with interactions and engagement

In the subsections below, we report our mixed-effects regression models to demonstrate the relationship between value orientations and engagement behaviors in Zooniverse projects.

4.3.1 Driving exploration in Zooniverse. Given the volume of Zooniverse projects and the variety of disciplines and tasks, we wanted to identify whether value orientations could help predict how participants engage in the range of projects, task types, and disciplines available on the Zooniverse platform. Using the user-aggregated dataset, we modeled the number of projects, disciplines, and task types associated with each volunteer's tenure in Zooniverse (Table 8). Given interaction in projects is likely to be predicated by the length of involvement, we controlled for differences in time by including tenure. Again, the average respondents classified data 16.1 (σ = 23.7, $\tilde{x}$ = 8) projects. M1a reveals that higher self-transcendence scores were associated with decreased number of projects (β = -2.20, 95% CI [- 3.81 – -0.59], p = 0.01). We also computed the scores using the ten values with results in the Appendix (Table 9 - M1b). Values of benevolence (β = -1.18), hedonism (β = 1.07), and self-direction (β = 1.57) were significant predictors. For M2a, we modeled the number of unique disciplines. On average, respondents were active in 2.58 disciplines (σ = 1.37, $\tilde{x}$ = 2). We found that higher self-enhancement scores were associated with an increase in the variety of scientific fields (β = 0.20, 95% CI [0.09 – 0.30], $p < 0.01$), while self-transcendence was associated with a decrease in disciplines (β = -0.15, 95% CI [- 0.25 – -0.06], $p < 0.01$). In the expanded values model (Appendix Table 9 - M2b), only hedonism (β = 0.15) was significant. Finally, task involvement (μ = 3.99, σ = 1.92, $\tilde{x}$ = 4) was predicted by openness to change (β = 0.14, 95% CI [0.04 – 0.25], p = 0.01) and self-transcendence (β = -0.17, 95% CI [-0.30 – -0.04], p = 0.01). Again, the expended values model (M3b, Appendix Table 9) revealed hedonism (β = 0.16), power (β = -0.11), security (β = -0.11), self-direction (β = 0.17), and tradition (β = 0.09) were significant values predicting the number of unique tasks.

	Projects (M1a)			**Disciplines (M2a)**			**Tasks (M3a)**		
Predictors	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*
(Intercept)	4.26	-0.42 – 8.94	0.07	1.82	1.55 – 2.09	**<0.01**	2.51	2.14 – 2.87	**<0.01**
Conservation	-0.47	-2.06 – 1.12	0.57	-0.05	-0.14 – 0.04	0.27	-0.06	-0.19 – 0.06	0.32
Openness-to-Change	0.84	-0.53 – 2.20	0.23	0.01	-0.07 – 0.09	0.83	0.14	0.04 – 0.25	**0.01**
Self-Enhancement	1.37	-0.41 – 3.15	0.13	0.20	0.09 – 0.30	**<0.01**	0.14	-0.00 – 0.28	0.05
Self-Transcendence	-2.20	-3.81 – -0.59	**0.01**	-0.15	-0.25 – -0.06	**<0.01**	-0.17	-0.30 – -0.04	**0.01**
Tenure	0.01	0.01 – 0.02	**<0.01**	0.00	0.00 – 0.00	**<0.01**	0.00	0.00 – 0.00	**<0.01**
Observations	2605			2605			2605		
R^2 / R^2 adjusted	0.202 / 0.200			0.208 / 0.207			0.263 / 0.261		

Table 4. The results of our regression analyses with the number of unique projects (M1a), disciplines (M2a), and tasks (M3a) in which a participant contributes.

4.3.2 Varying modes of engagement. We wanted to determine the relationship between value orientations and the volume of contributions, that is, how values might affect the number of classifications (M4a), comments (M5a), and sessions (M6a). For this analysis, we used the dataset of aggregated contributions by user/project. Since the data are repeated measures, usernames and projects were included in the models as random effects. Since counts make the data uneven, we attempted to rectify this by (1) removing several influential outliers using the Cooks' distance [2] algorithm. Each outcome variable was modeled, and records identified as influential outliers were expunged for that model. We also (2) log-transformed data to ensure the normality of variance of the outcomes where appropriate.

The results models are presented in Table 5. We also modeled the outcomes using the ten basic values (Appendix Table 10). The results below reveal that conservation (β = 0.07, 95% CI [0.00 - 0.14], p = 0.05) and openness to change (β

= 0.12, 95% CI [0.06 - 0.18], $p < 0.01$) positively influence the number of classifications. The expanded model (Table 10) revealed self-direction (β = 0.12) was significant. In modeling the number of comments posted, none of the values were significant predictors, however; in the expanded model, tradition (β = 0.11) and universalism (β = -0.10) were significant predictors. The number of sessions might be a proxy for commitment to a project. M6a revealed that conservation (β = 0.07, 95% CI [0.02 - 0.11], p = 0.01) and openness to change (β = 0.08, 95% CI [0.04 - 0.12], $p < 0.01$) were significant predictors. In the expanded model, only self-direction emerged as significant (β = 0.07).

	Classifications (M4a)			**Comments (M5a)**			**Sessions (M6a)**		
Predictors	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*
(Intercept)	2.49	2.26 – 2.73	**<0.01**	0.57	0.22 – 0.92	**<0.01**	0.25	0.11 – 0.40	**<0.01**
Conservation	0.07	0.00 – 0.14	**0.05**	0.09	-0.03 – 0.20	0.14	0.07	0.02 – 0.11	**0.01**
Openness-to-Change	0.12	0.06 – 0.18	**<0.01**	0.09	-0.01 – 0.20	0.07	0.08	0.04 – 0.12	**<0.01**
Self-Enhancement	-0.05	-0.12 – 0.03	0.25	0.02	-0.11 – 0.15	0.75	0.01	-0.05 – 0.06	0.84
Self-Transcendence	0.00	-0.07 – 0.07	0.97	-0.09	-0.21 – 0.02	0.12	-0.02	-0.07 – 0.03	0.37
Tenure	0.00	0.00 – 0.00	**<0.01**	0.00	0.00 – 0.00	**<0.01**	0.00	0.00 – 0.00	**<0.01**
Random Effects									
σ^2	2.51			1.91			0.88		
τ_{00}	0.53 $_{user\_login}$			0.63 $_{user\_login}$			0.27 $_{user\_login}$		
	1.08 $_{project\_id}$			0.16 $_{project\_id}$			0.10 $_{project\_id}$		
ICC	0.39			0.29			0.30		
N	2574 $_{user\_login}$			1446 $_{user\_login}$			2580 $_{user\_login}$		
	506 $_{project\_id}$			408 $_{project\_id}$			506 $_{project\_id}$		
Observations	41471			7276			42039		
Marginal R^2 / Conditional R^2	0.150 / 0.482			0.132 / 0.387			0.275 / 0.489		

Table 5. The results of our mixed-effects regression analyses. All models include user and project as random effects.

4.3.3 Contributions beyond primary engagement. Our final task was understanding how values might affect engagement in other areas of projects. Volunteers might engage in activities that we find are often dedicated to coordinating work and curating data (using tags) or linking content like data subjects (to reference them in conversation) and posting information from external sources (e.g., videos explaining some scientific fact) using hyperlinks. We modeled the likelihood of engaging in commenting, hyperlinking, and tagging with estimates presented as odds ratios. Using the user dataset (N = 1,824), we first modeled the likelihood of making at least one comment (Table 6, M7a, and M7b in Appendix D, Table 11). Again, the data were modeled using a 70/30 training and validation split. The results in M7a reveal that holding other value scores constant, we can expect a 23% increase in the odds of commenting for each unit increase in openness-to-change. In the basic values model, self-direction and tradition were significant contributors.

Models M8a and M9a in Table 6 use the username/project dataset (and username and project as random effects) to model the likelihood of hyperlinking and tagging. We used the user:project dataset (N = 7,274) and a 70/30 test training split for these analyses. Both models performed well with R^2 = .53 and R^2 = .54 respectively. No high-level value dimension influenced hyperlinking significantly; however, the basic value model, security, self-direction, and universalism were significant. For each unit increase in security, odds increased by 30%. However, self-direction and universalism were associated with a 24% and 23% decrease in the odds, respectively. In the tagging models (M9a in

	Comment (M7a)			Hyperlink (M8a)			Tag (M9a)		
Predictors	*Odds Ratios*	*CI*	*p*	*Odds Ratios*	*CI*	*p*	*Odds Ratios*	*CI*	*p*
(Intercept)	0.20	0.11 – 0.36	**<0.01**	0.02	0.01 – 0.06	**<0.01**	0.25	0.12 – 0.52	**<0.01**
Conservation	1.16	0.96 – 1.40	0.12	1.17	0.85 – 1.60	0.33	1.15	0.91 – 1.46	0.25
Openness-to-Change	1.23	1.05 – 1.45	**0.01**	0.76	0.57 – 1.01	0.06	1.04	0.84 – 1.29	0.71
Self-Enhancement	1.15	0.93 – 1.42	0.21	1.38	0.97 – 1.97	0.07	1.09	0.83 – 1.43	0.53
Self-Transcendence	0.88	0.72 – 1.07	0.19	0.87	0.64 – 1.20	0.40	0.73	0.57 – 0.93	**0.01**
Tenure	1.00	1.00 – 1.00	**<0.01**	1.00	1.00 – 1.00	**<0.01**	1.00	1.00 – 1.00	**<0.01**
Random Effects									
σ^2				3.29			3.29		
τ_{00}				2.79 $_{\text{user\_login}}$			2.73 $_{\text{user\_login}}$		
				0.46 $_{\text{project\_id}}$			0.69 $_{\text{project\_id}}$		
ICC				0.50			0.51		
N				1446 $_{\text{user\_login}}$			1446 $_{\text{user\_login}}$		
				408 $_{\text{project\_id}}$			408 $_{\text{project\_id}}$		
Observations	1824			7274			7274		
R^2 Tjur	0.084			0.053 / 0.524			0.053 / 0.536		

Table 6. The results of logistic regression for users who post comments. The models predict the likelihood of commenting (M7a), hyperlinking (M8a), and tagging (M9a). Models M8a and M9a are mixed-effects with user and project included as random effects.

Table 6 and M9b in Appendix D, Table 10), the results of the high-value dimensions showed a 27% decrease in the odds of tagging for each unit increase in self-transcendence. Interestingly, the full set of basic values were significant predictors.

5 DISCUSSION

While existing research on motivation has contributed a great deal to our collective knowledge of why people contribute to digital citizen science, we also find evidence to consider the value orientations of contributors as well. Our results extend the work on motivation and engagement by implicating value orientations as a feature of individual contributors. In the sections below, we situate our results in the literature, and given the critical importance of values in dictating action [28], we offer suggestions on how digital citizen science projects work to emphasize prioritized values.

5.1 What values are prioritized among citizen scientists

Our findings suggest that high-level and basic values can distinguish various levels and types of engagement in citizen science. We offer several high-level insights based on our results. First, the value priorities that define participants in our results have corollaries with previous research on volunteer motivation. Openness to change, a value related to the desire for independence and new experiences, was the most important. The structure of tasks in many digital citizen science projects supports the openness to change value. In Zooniverse projects, the classification task is asynchronous and requires independent investigation. Furthermore, completing tasks involves minimal interaction with and direction from others. Citizen scientists can engage in projects when they want and have the ability to follow their intellectual curiosity. Achievement (the highest-ranked basic value) allows people to demonstrate their competence. This is supported by Oreg and Nov [32], who showed that high achievement was focused on reputation-building in OSS projects. Our

results also align with the research in Palacin et al. [34], which found security (second-ranked) was valued. The self-direction (third-ranked value) also appears to be important. Zooniverse as a platform allows individuals to choose from hundreds of projects in various disciplines—other personal-focused values such as hedonism (fourth-ranked) and security (second-ranked). Conversely, self-transcendence, defined as concern for the welfare and interest of others, was the lowest-ranked value. A possible explanation is that the goals associated with self-transcendence are more difficult to be attained since digital citizen science often relies less on collaboration among participants.

Second, for high-level value dimensions, the results demonstrate good alignment with the circumplex structure in Figure 1 that describes the congruence among value items. The structure suggests that values furthest away tended to be less related, and those in closer proximity are more closely related. Our results show that citizen scientists prioritize openness to change, self-enhancement, conservation, and self-transcendence. Openness-to-change and conservation are theorized to be opposites and while self-enhancement and self-transcendence are opposing values. Regarding the ten basic values, we find little consistency in the structure of the value ranks. At the same time, Schwartz suggests that individuals who value achievement (on the self-enhancement axis) are likely to value power (on the self-enhancement axis). Interestingly, respondents reported achievement (first-ranked) as most valued and power as least valued (tenth-ranked). This relationship was also apparent among constituent values in conservation - security (second-ranked) and tradition (ninth-ranked). While the basic value ranks are incongruent, we suspect that they may reveal specific individual participation preferences and goals inherent in the population of citizen scientists. Furthermore, these results demonstrate the need to consider high-level and basic values.

Third, related to theorizing about the circumplex structure, value prioritization is primarily associated with what Schwartz describes as regulating how one expresses personal interests and characteristics. Again, the prioritization of openness-to-change and self-enhancement emphasize (first and second-ranked) emphasize personal-focused goals, while conservation and self-transcendence tend to relate socially to others. In that sense, a reasonable assumption is that most citizen science contributors are primarily (although not exclusively) interested in pursuing activities that align with goals focused on self. These results partially align with much prior research suggesting participation in digital citizen science is primarily driven by intrinsic motivations [36, 39].

5.2 Broadening engagement in virtual citizen science

Models M1 - M3 provide insights demonstrating values that might describe goals that drive engagement and exploration on the Zooniverse platform. Several interesting findings emerged in determining the relationship between values and the number of types of projects. High-level values with a personal focus increase engagement in disciplines and tasks, while social-focused values (self-transcendence) lead to decreased engagement. The focus of Zooniverse projects might explain this finding - the primary task for most projects is the independent classification of image data. Aligned with the description of the value, self-direction, and hedonism (the openness-to-change values) were associated with more projects and experimenting with various task types. The hedonism value was also shown to lead to exploring more disciplines. Self-direction had the most significant positive effect on the values describing the outcomes in M1-M3 (1.57), while the range of other values was noticeably smaller (0.03 - 1.07). The values that significantly negatively affected the outcomes in M1-M3 were the high-level value of self-transcendence and the basic value of benevolence - two values having a social focus. In addition to self-transcendence leading to fewer projects, disciplines, and tasks, benevolence, its composite value, was associated with fewer projects. Benevolence, defined as "preserving and enhancing the welfare of those with whom one is in frequent personal contact (the in-group)," might be explained as a dedication to the group (or project) for which one has already joined. Those with high benevolence might be less likely to leave the communities

they join. This finding aligns with the previous study's findings that attest to the positive and consistent relationship between benevolence and various commitment forms in the workplace [7]. We also noted the role of hedonism (an opposing value to benevolence in the circumplex), defined as gratification for oneself, was associated with increased projects, tasks, and disciplines. This can be explained by the previous research, which finds that hedonism positively correlates with work engagement and their desire to be involved in new and challenging tasks [33]. Likewise, citizen science volunteers who value hedonism tend to contribute more work on multiple projects in various fields.

5.3 Getting Involved in Projects

M4-M6 explored how volunteers engage in projects - the number of classifications and comments and their commitment to projects measured in the number of sessions. We find support for personal and social-oriented values in explaining classification, commenting, and retention behaviors. The high-level value dimensions openness-to-change, and conservation was implicated in defining the contribution level, i.e., classifications and sessions (no high-level value was significant for commenting). Interestingly, openness-to-change and conservation appear as opposing values in the circumplex. Only self-direction was significant in the classification (M4) and session (M6) models. We rely on a similar rationale to explain this finding - the classification task, as a solitary activity, supports independent interaction. As this value is supported in projects, volunteers will contribute and return to projects they enjoy. Interestingly, while no high-level value was significant in the comment (M5) model, the basic values of tradition (i.e., respect, commitment, and acceptance of customs and ideas) and universalism (i.e., understanding, appreciation, tolerance, and protection for the welfare of people and nature) were significant. Both values are associated with a social focus. However, the direction of the effect was opposite - tradition (+0.11) and universalism (-0.10). These opposing effects might be associated with the varied participation intentions in the discussion boards (explained in the next section). These findings support the previous work suggesting that self-transcendence (e.g., universalism) and conservation (e.g., tradition) values are likely to yield affective commitment, which represents emotional attachment and involvement in the organization [18].

5.4 Social Interactions

Most digital citizen science projects do not explicitly encourage social interaction among participants; we know a small percentage of participants engage in discussion boards. Research by Jackson et al. [25] found that just 13.3% of participants posted comments in the discussion boards. Discussing can elevate citizen science projects from simple routine work (i.e., classification) to more advanced work. Examining social interactions through involvement in communicative practices (M7-M9) allows us to determine what might drive participants to this type of citizen science. According to Schwartz [47], there is a relationship between values of self-transcendence and helping and prosocial behaviors. We find, however, engagement in discussions is driven primarily by personal-focused values - for every unit increase in the openness-to-change value and self-enhancement value, the odds of commenting increase by 1.34 and 1.24. Accounting for basic values, a more nuanced view emerges, implicating opposing values in the circumplex. First, achievement (a personal-focused value) was associated with increased odds of commenting. In contrast, benevolence (a social-focused value), a value opposite achievement in the circumplex, was associated with a decrease in the odds of posting comments. Surprisingly, tradition (a social-focused value) was associated with a 1.19 increase in the odds of commenting.

We suspect that these differences may be explained by the different use cases for discussions to support both individual and community-focused goals [9, 13, 14, 23, 26, 30]. Regarding community-focused actions, Mugar et al. [30] described how newcomers to Planet Hunters, a digital citizen science project on Zooniverse, use discussion boards to

ask questions of more experienced members or receive feedback about their classifications. In that sense, participants engage in prosocial behaviors looking to involve the community of participants in their efforts. Participants might also engage in behaviors to support information sharing. Research by [14] and [13] describe the use of hyperlinks (M8) to share information. The authors describe how participants share informational resources to help other participants learn - linking to digital books, video tutorials, and discussion board posts internal to the project. Concerning M8, conformity (i.e., restraint of actions, inclinations, and impulses likely to upset or harm others and violate social expectations or norms) was associated with an increased likelihood of hyperlinking. On the other hand, self-direction (again, the value of having a personal focus) decreased the odds of engaging in the practice.

Conversely, personal values might be supported when engaging in discussions and emerge through practices such as tagging. Prior research on tagging practices has noted their importance in coordinating activity [9] and individual curation of data [23, 26]. In describing individual work practices, Jackson et al. [23] describes how participants are discovering novel phenomena in the data stream, and a common practice is using hashtags to tie similar-looking images together. The results in Appendix 11 support the multi-faceted values associated with the practice. Self-transcendence (a social-focused value) was associated with decreased odds of tagging. The basic values (Appendix D, Table 10) were uninterpretable.

6 LIMITATIONS

We wish to alert the reader to three limitations: low—reliability scores, self-selection bias, and the absence of cultural analyses. While reliability scores for the PVQ-21 items are lower than the field's rules of thumb, Schwartz notes this issue and argues that it is impossible to have high internal reliability for all ten values since PVQ-21 tries to cover the range of content of the full motivational continuum of values with a limited number of value types and items [44, 45]. Furthermore, the dimensions show higher internal reliability, which aligns with the results we gained from the reliability tests. Despite low reliability, Schwartz argues that hypothesized associations of these value scores support their validity based on the predictive power of values found from empirical research across numerous countries [50]. Each index consists of 2-4 items measuring different value aspects. In other words, low reliability is caused by an insufficient number of items to measure a value.

Second, self-selection bias is possible since we recruited users from the Zooniverse listserv. We address this in two ways. First, we report the demography and user engagement patterns in the first two paragraphs of the results. The demography of our respondents mostly matches the demographic profile of respondents in other user studies (we did find a larger percentage of women respondents). Concerning engagement profiles, our population is less similar. Our respondents are more deeply engaged in digital citizen science, contributing deeply. However, like other projects, we find the data distribution remains unequal. In most instances, standard deviations are twice as large as mean values. We argue even with self-selection bias, our results have important theoretical and methodological contributions to the field. We demonstrate the utility of Schwartz's Values Theory and how insights about users' true behaviors might be obtained from digital trace data. We also argue that our recommendations and insights remain useful in developing strategies and functionality to motivate highly engaged populations.

Third, Schwartz's Value Theory suggests value orientations may be culturally situated. Specific values may be more or less salient when culture is considered. While we collect information about each respondent's country of residence, consideration of country or cultural differences was beyond the scope of this research. We suggest integrating such user characteristics could be future research.

7 CONCLUSION AND FUTURE WORK

Researchers increasingly use citizen science to conduct scientific inquiry, and many research teams turn to digital citizen science platforms like Zooniverse to build and host their projects and recruit users dedicated to completing tasks. Much of the work required to make projects successful depends on maintaining a critical mass of participants to help analyze data. Prior research on volunteer engagement has noted several challenges, and chief among them is recruiting a critical mass of volunteers and motivating them throughout their tenure. A substantial amount of research has been conducted to understand what motivates volunteers. Our work presents a method to understand global participants' value orientations and behaviors using a universal index called Schwartz's value scale. Due to the cross-cultural aspects of this index, it can be applied to understanding international users in different contexts. We make valuable contributions to the literature on volunteer motivation by demonstrating that values are also implicated in defining patterns and levels of engagement in projects.

Future work might seek to develop a more nuanced view of values, accounting for individual participant differences. Research work by Jeong et al. [27] found that the value prioritization of citizen scientists may differ among demographic groups. Our findings might also help project organizers and developers in building infrastructure for projects to consider how various socio-technical features might align with value orientations. We suspect that additional research (e.g., interviews) on values will establish a more nuanced view of how values influence the behaviors of volunteers in citizen science and similar types of open collaboration platforms. Furthermore, our methodological approach can be applied to all citizen science projects. Zooniverse volunteers participate in diverse kinds of citizen science projects; thus, our analysis results about their values and behaviors can be extended to other types of citizen science projects besides volunteer thinking projects [13, 14].

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A SAMPLE SURVEY

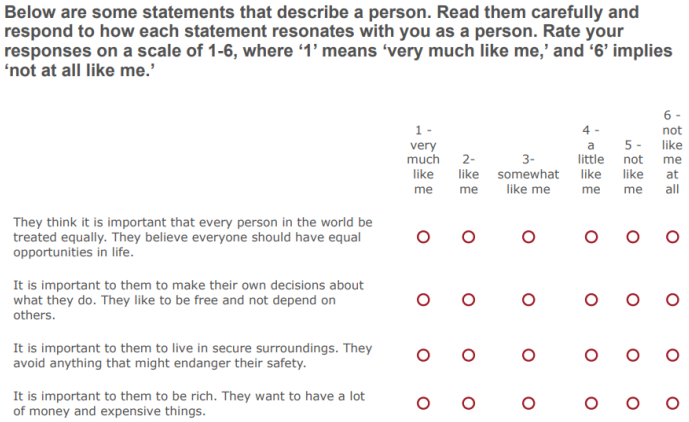

Fig. 6. An example of the portrait questions posed on the PVQ-21.

B HIGH-LEVEL AND BASIC VALUE SCORES

High-level Value Dimension	Score $\mu(\sigma)$	Value (Rank)	Score $\mu(\sigma)$
Conservation (3)	3.06 (0.65)	Conformity (7)	2.97 (0.91)
		Tradition (9)	2.47 (0.89)
		Security (2)	3.74 (0.99)
Self-enhancement (2)	3.09 (0.64)	Power (10)	1.94 (0.78)
		Achievement (1)	3.77 (0.96)
		Hedonism (4)	3.57 (1.01)
Openness to Change (1)	3.34 (0.77)	Stimulation (6)	2.98 (0.93)
		Self-Direction (3)	3.69 (0.9)
Self-transcendence (4)	2.98 (0.68)	Universalism (8)	2.77 (0.8)
		Benevolence (5)	3.57 (1.01)

Table 7. The mean value scores with ranks for high-level value dimensions and specific values.

C BASIC VALUE CORRELATIONS AMONG PREDICTOR VARIABLES

	Tenure	*Projects*	*Class.*	*Sessions*	*Comments*	*URLs*	*Tags*	*Tasks*	*Discip.*	*Achievement*	*Benevolence*	*Conformity*	*Hedonism*	*Power*	*Security*	*Self-direction*	*Stimulation*	*Tradition*	*Universalism*
Tenure																			
Projects	0.64***																		
Class.	0.52***	0.72***																	
Sessions	0.49***	0.69***	0.88***																
Comments	0.34***	0.44***	0.63***	0.68***															
URLs	0.20***	0.21***	0.32***	0.36***	0.49***														
Tags	0.27***	0.37***	0.53***	0.56***	0.77***	0.50***													
Tasks	0.55***	0.90***	0.60***	0.59***	0.38***	0.18***	0.31***												
Discip.	0.49***	0.79***	0.50***	0.48***	0.29***	0.16***	0.25***	0.80***											
Achievement	0.11***	0.04*	0.06**	0.08***	0.08***	0.06**	0.04*	0.07***	0.03										
Benevolence	0.07***	0.02	0.05**	0.07***	0.03	0.02	0.01	0.04	0.02	0.37***									
Conformity	0.09***	0.04*	0.07***	0.10***	0.05**	-0.01	0.01	0.05*	0.03	0.16***	0.23***								
Hedonism	0.09***	0.07***	0.08***	0.12***	0.08***	0.03	0.06**	0.10***	0.10***	0.26***	0.40***	0.34***							
Power	0.05*	0.01	0.04*	0.06***	0.05*	0.06**	0.05*	-0.01	0.03	0.11***	0.18***	0.15***	0.21***						
Security	0.13***	0.05*	0.09***	0.10***	0.09***	0.09***	0.07***	0.04	0.04*	0.32***	0.34***	0.34***	0.37***	0.21***					
Self-direction	0.07***	0.07***	0.13***	0.16***	0.11***	0.01	0.08***	0.09***	0.04	0.24***	0.25***	0.39***	0.33***	0.11***	0.25***				
Stimulation	0.14***	0.06**	0.10***	0.12***	0.10***	0.05**	0.06**	0.07***	0.05**	0.38***	0.30***	0.28***	0.31***	0.33***	0.32***	0.40***			
Tradition	0.06**	0.04*	0.06**	0.08***	0.10***	0.07***	0.08***	0.06**	0.04*	0.11***	0.21***	0.10***	0.22***	0.33***	0.17***	0.11***	0.17***		
Universalism	0.10***	0.02	0.04*	0.05**	0.05*	0.01	0.02	0.02	0.01	0.38***	0.25***	0.30***	0.22***	0.26***	0.27***	0.30***	0.51***	0.16***	

Computed correlation used spearman-method with listwise-deletion.

Table 8. The correlations among the predictor variables and the basic values. Since the outcome variables are non-normal, Spearman's rank correlation method was used.

D MIXED-EFFECTS REGRESSION MODELS FOR BASIC VALUES

	Projects (M1b)			**Disciplines (M2b)**			**Tasks (M3b)**		
Predictors	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*
(Intercept)	2.85	-2.02 – 7.72	0.25	1.81	1.53 – 2.09	**<0.01**	2.34	1.97 – 2.72	**<0.01**
Achievement	0.14	-0.88 – 1.16	0.79	-0.00	-0.06 – 0.06	0.99	0.03	-0.05 – 0.11	0.40
Benevolence	-1.18	-2.22 – -0.14	**0.03**	-0.06	-0.12 – 0.00	0.06	-0.04	-0.12 – 0.04	0.29
Conformity	-1.03	-2.09 – 0.03	0.06	-0.04	-0.11 – 0.02	0.15	-0.05	-0.13 – 0.04	0.27
Hedonism	1.07	0.09 – 2.06	**0.03**	0.15	0.09 – 0.21	**<0.01**	0.16	0.09 – 0.24	**<0.01**
Power	0.17	-1.03 – 1.38	0.78	0.02	-0.04 – 0.09	0.49	-0.11	-0.20 – -0.01	**0.02**
Security	-0.05	-1.04 – 0.93	0.91	-0.05	-0.11 – 0.01	0.08	-0.11	-0.18 – -0.03	**0.01**
Self-Direction	1.57	0.48 – 2.66	**<0.01**	0.04	-0.03 – 0.10	0.24	0.17	0.08 – 0.25	**<0.01**
Stimulation	-0.78	-1.95 – 0.39	0.19	-0.02	-0.09 – 0.04	0.47	-0.02	-0.11 – 0.07	0.71
Tradition	0.35	-0.66 – 1.35	0.50	0.02	-0.03 – 0.08	0.41	0.09	0.01 – 0.17	**0.03**
Universalism	-0.56	-1.85 – 0.73	0.40	-0.06	-0.14 – 0.01	0.10	-0.09	-0.19 – 0.01	0.09
Tenure	0.01	0.01 – 0.02	**<0.01**	0.00	0.00 – 0.00	**<0.01**	0.00	0.00 – 0.00	**<0.01**
Observations	2605			2605			2605		
R^2 / R^2 adjusted	0.205 / 0.202			0.214 / 0.211			0.274 / 0.271		

Table 9. The results of our logistic regression analyses predicting engagement through projects, discipline variety, and task variety.

	Classifications (M4b)			Comments (M5b)			Sessions (M6b)		
Predictors	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*
(Intercept)	2.40	2.16 – 2.65	**<0.01**	0.56	0.19 – 0.93	**<0.01**	0.20	0.05 – 0.35	**0.01**
Achievement	-0.00	-0.05 – 0.04	0.89	-0.00	-0.08 – 0.08	0.99	0.01	-0.02 – 0.04	0.51
Benevolence	0.02	-0.03 – 0.06	0.45	0.00	-0.07 – 0.08	0.90	0.01	-0.02 – 0.04	0.34
Conformity	0.00	-0.04 – 0.05	0.89	-0.07	-0.15 – 0.01	0.09	0.02	-0.01 – 0.05	0.29
Hedonism	-0.04	-0.08 – 0.01	0.09	-0.04	-0.12 – 0.03	0.24	-0.02	-0.05 – 0.01	0.17
Power	0.01	-0.04 – 0.06	0.70	0.05	-0.03 – 0.14	0.23	0.03	-0.01 – 0.06	0.14
Security	0.04	-0.01 – 0.08	0.08	0.04	-0.03 – 0.12	0.26	0.02	-0.01 – 0.05	0.14
Self-Direction	0.12	0.07 – 0.17	**<0.01**	0.07	-0.01 – 0.15	0.10	0.07	0.04 – 0.10	**<0.01**
Stimulation	0.00	-0.05 – 0.05	0.88	0.07	-0.01 – 0.15	0.10	0.01	-0.03 – 0.04	0.63
Tradition	0.02	-0.03 – 0.06	0.42	0.11	0.04 – 0.19	**<0.01**	0.02	-0.01 – 0.05	0.15
Universalism	-0.00	-0.06 – 0.05	0.93	-0.10	-0.20 – -0.01	**0.03**	-0.03	-0.07 – 0.01	0.13
Tenure	0.00	0.00 – 0.00	**<0.01**	0.00	0.00 – 0.00	**<0.01**	0.00	0.00 – 0.00	**<0.01**
Random Effects									
σ^2	2.51			1.91			0.88		
τ_{00}	0.52 $_{user\_login}$			0.62 $_{user\_login}$			0.26 $_{user\_login}$		
	1.08 $_{project\_id}$			0.16 $_{project\_id}$			0.10 $_{project\_id}$		
ICC	0.39			0.29			0.29		
N	2574 $_{user\_login}$			1446 $_{user\_login}$			2580 $_{user\_login}$		
	506 $_{project\_id}$			408 $_{project\_id}$			506 $_{project\_id}$		
Observations	41471			7276			42039		
Marginal R^2 / Conditional R^2	0.151 / 0.482			0.138 / 0.387			0.277 / 0.489		

Table 10. The results of our mixed-effect regression analyses that predict the volume of classifications, comments, and sessions.

	Comment (M7b)			Hyperlink (M8b)			Tag (M9b)		
Predictors	*Odds Ratios*	*CI*	*p*	*Odds Ratios*	*CI*	*p*	*Odds Ratios*	*CI*	*p*
(Intercept)	0.18	0.10 – 0.33	**<0.01**	0.03	0.01 – 0.07	**<0.01**	0.23	0.23 – 0.23	**<0.01**
Achievement	1.10	0.97 – 1.24	0.14	1.13	0.91 – 1.39	0.26	0.95	0.95 – 0.95	**<0.01**
Benevolence	0.93	0.82 – 1.05	0.26	1.05	0.85 – 1.29	0.67	0.93	0.92 – 0.93	**<0.01**
Conformity	1.07	0.94 – 1.22	0.29	0.80	0.64 – 1.00	0.05	0.84	0.84 – 0.84	**<0.01**
Hedonism	1.10	0.98 – 1.24	0.11	0.96	0.79 – 1.17	0.70	0.98	0.98 – 0.98	**<0.01**
Power	0.94	0.81 – 1.08	0.38	1.17	0.93 – 1.49	0.19	1.18	1.18 – 1.18	**<0.01**
Security	0.97	0.86 – 1.09	0.58	1.30	1.06 – 1.59	**0.01**	1.17	1.17 – 1.17	**<0.01**
Self-Direction	1.16	1.02 – 1.32	**0.02**	0.76	0.61 – 0.95	**0.02**	1.17	1.17 – 1.17	**<0.01**
Stimulation	1.05	0.91 – 1.21	0.47	1.09	0.87 – 1.37	0.46	0.97	0.97 – 0.97	**<0.01**
Tradition	1.14	1.01 – 1.28	**0.03**	1.17	0.96 – 1.42	0.11	1.10	1.10 – 1.10	**<0.01**
Universalism	0.95	0.81 – 1.12	0.55	0.77	0.60 – 1.00	**0.05**	0.81	0.81 – 0.81	**<0.01**
Tenure	1.00	1.00 – 1.00	**<0.01**	1.00	1.00 – 1.00	**<0.01**	1.00	1.00 – 1.00	**<0.01**
Random Effects									
σ^2				3.29			3.29		
τ_{00}				2.63 $_{user\_login}$			2.66 $_{user\_login}$		
				0.49 $_{project\_id}$			0.72 $_{project\_id}$		
ICC				0.49			0.51		
N				1446 $_{user\_login}$			1446 $_{user\_login}$		
				408 $_{project\_id}$			408 $_{project\_id}$		
Observations	1824			7274			7274		
R^2 Tjur	0.088			0.077 / 0.526			0.062 / 0.538		

Table 11. Our mixed-effects logistic regression models that predict the likelihood of posting a commenting, hyperlinking, and tagging.