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Human values and digital citizen science interactions

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ABSTRACT

Sustained participation is critical to the success of digital citizen-science initiatives, yet much of the current literature focuses on mapping people's motives to engage without considering the extent to which participation is sustained over time. We conducted a year-long experimental study ($n = 85$) "in-thewild" to explore the effects of human-value orientations on the use of digital citizen-science tools. Participants took part in both the co-design and use of digital citizen-science tools in Lappeenranta, Finland from 2018–2019. Our statistical analysis finds evidence of relations between value orientations, sustained participation, and the number and quality of digital interactions. Specifically, we find that value orientations are linked with different usage patterns. For instance, people with a stronger openness-to-change (OTC) values tended to use the mobile application to check others' submissions, even when they had nothing to submit, whereas people with stronger security values mostly used the application when they had something relevant to submit. Further understanding the influence of human values in digital citizen science is a promising area for future research that could contribute to a) guide the design of incentive mechanisms, b) understand user experiences in online communities, and c) inform the design and evaluation of digital citizen-science technologies.

1. Introduction

Digital citizen science has become globally popular in the last decade (Ruge, 2015) with platforms such as Safecast and eBird engaging millions of people in observing environmental and social phenomena. Digital citizen science platforms are designed to support people-driven data collection via mobile devices (Burke et al., 2006; Goldman et al., 2009; Guo et al., 2014). In the midst of the coronavirus disease (COVID-19) pandemic, for instance, two digital citizen-science platforms were on the front line of the pandemic emergency response: FoldIt[1], which has been seeking an antiviral protein to target and eradicate the disease with their community of citizen scientists, and, Ushahidi[2], a peer-to-peer crowd-mapping platform that was deployed in over 30 countries during the pandemic. Digital citizen-science platforms play increasingly important roles in scientific progress by raising public awareness, fostering informed decision making, and supporting communal data-literacy projects (Palacin-Silva et al., 2016; See et al., 2016).

However, beyond the best-known digital citizen-science projects, most medium-sized local digital citizen-science initiatives face numerous challenges in sustaining the participation of their volunteers (Foody et al., 2017; Jennett and Cox, 2018; Orchard, 2018). This has motivated many studies in two main areas: 1) investigations of people's motivations to engage in citizen-science initiatives (Curtis, 2015; Iacovides et al., 2013; Jennett and Cox, 2018; Orchard, 2018; Reed et al., 2013; Rotman et al., 2012) and 2) the design of incentive mechanisms to support people's engaged action (Jaimes et al., 2015; Restuccia et al., 2016). However, the former relies on self-reported data (e.g. surveys), thus missing the link between self-reported motives and concrete actions. The latter works on the assumption that reward-centric mechanisms (e.g. monetary incentives) may enhance participation, although the effectiveness of such mechanisms has been proven to undermine

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[1] FoldIt Solving Puzzles for Science: https://fold.it
[2] Ushahidi: https://www.ushahidi.com

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sustained participation in volunteering initiatives (Crompton, 2010; Knowles, 2013).

In this work, we use Schwartz's human values theory (2003) as a research framework that can be studied on different levels (Hanel et al., 2017; Maio, 2016). We focused on this theory for several reasons. First, values align peoples' attitudes, emotions, and behaviors and typically endure across time and situations (Schwartz, 2006). People arguably feel a sense of achievement when their actions are aligned with their most important values (Rokeach, 1973), encouraging both a conscious and unconscious pursuit of consistency between values and behavioral choices (Bardi and Schwartz, 2003; Crompton, 2010). Second, recent studies have found that human values can influence and explain online behaviors (Boyd et al., 2015; Chen et al., 2014; Esau, 2018; Hsieh et al., 2013; Mukta et al., 2016). Finally, we have limited knowledge about how social and psychological factors can affect participatory actions on digital citizen-science platforms (Foody et al., 2017; Jennett and Cox, 2018).

This work investigates the relationship between people's value orientations and their use of a citizen-science mobile application. In doing so, our work starts to address the missing link between motivation (captured through self-reported survey data) and action (captured via app usage logs) using quantitative and qualitative analyses and models. The context of this study is a year-long local initiative in Lappeenranta, Finland that co-designed and deployed digital citizen-science tools for environmental monitoring with locals, researchers, community organizations, and decision-makers. The initiative engaged 243 participants, who generated over 100 ideas concerning issues of shared interest, 28 civic tech prototypes, and 300 environmental observations.

Our results show that different values are linked with different usage patterns, demonstrating that values also influence how digital citizen science systems are used (usage patterns). For instance, participants with a greater OTC value orientation (related to independence and curiosity) interacted with the system more often (e.g., curiously browsing through others' submissions), whereas participants with a greater security value had shorter, goal-directed interactions (e.g., opening the system only to submit an observation). These findings show that further study of the role of human values in participation on digital citizen-science platforms is a promising area of research that could contribute to a) guiding the design of incentive mechanisms, b) understanding user experiences in online communities, and c) informing the design and evaluation of digital citizen-science technologies.

2. Related work

2.1. Digital citizen science

The practice of cooperation between independent researchers and regular citizens became known as "citizen science" in the twentieth century (Bonney et al., 2009; Dickinson et al., 2012; Hand, 2010; Irwin, 2002). Digital citizen-science projects combine monitoring and participatory actions and have become popular in many scientific disciplines (Rotman et al., 2014a), largely because mobile technology has become pervasive and able to capture, classify, and transmit location, image, voice, and other data autonomously (Estrin et al., 2010; Goldman et al., 2009).

Digital citizen science uses technology to help people conduct activities such as collecting, categorizing, transcribing, or analyzing scientific data on a phenomenon of interest (Bonney et al., 2014; Burke et al., 2006; Heggen, 2013). People now regularly use technologies for civic purposes, from open governance to community action and participatory science (e.g., collective city monitoring, sharing of local knowledge, and orchestration of community actions). Massive digital citizen-science platforms have emerged and engaged millions of people to observe phenomena in nature and society, some of which have already achieved outstanding results, such as the creation of the largest radiation records in history by Safecast (Safecast, 2019), large records of bird populations by Bird, (2019)) the identification of new galaxy elements by Zooniverse, (2019), and discoveries of different protein types by fold.it (FoldIt, 2019).

Public participation in digital citizen science involves various roles (Bonney et al., 2009; Palacin et al., 2019) (See Fig. 1), including collecting data on predefined issues (data provider), collaborating with authorities to monitor issues predefined by authorities (collaborator), co-creating solutions to address issues of shared concern (co-creator), ideating civic actions (ideator), and disrupting established processes by passive non-participation or negative participation (disruptor).

2.2. Motivations to participate in digital citizen science

Digital citizen-science initiatives face numerous challenges in sustaining volunteer participation (Foody et al., 2017; Jennett and Cox, 2018; Orchard, 2018). This has motivated studies to identify and report the motivations of participants from interviews and surveys (Curtis, 2015; Iacovides et al., 2013; Jennett and Cox, 2018; Orchard, 2018; Reed et al., 2013; Rotman et al., 2012), and the creation of reward-centric incentive mechanisms to increase volunteer engagement (Jaimes et al., 2015; Restuccia et al., 2016). The former relies on self-reported data (e.g., surveys), however, thus missing the link between self-reported motives and concrete actions. The latter, in contrast, assumes that reward-centric mechanisms (e.g., monetary incentives) may enhance participation, although the effectiveness of such mechanisms has been shown to undermine sustained participation in volunteering initiatives (Crompton, 2010; Knowles, 2013).

- **Self-reported motivations:** Field projects such as iSPEX (Land-Zandstra et al., 2016), Zoouniverse (Reed et al., 2013), Stardust@home (Nov et al., 2011), Happy Match (Crowston and Prestopnik, 2013), the Great Pollinator (Domroese and Johnson, 2017), and online citizen science experiments (Jackson, 2019) have reported that their participants are driven by a deep interest in contributing to science followed by curiosity (e.g., to try new devices or experiences), learning interests, enjoyment of the activities, and social engagement (e.g., a sense of community). The research of FoldIt (e.g. sense of community) (Iacovides et al., 2013), Eyewire (Curtis, 2015) and small-scale citizen science projects (Rotman et al., 2014b; 2012) have also highlighted that recognition also drive participation.

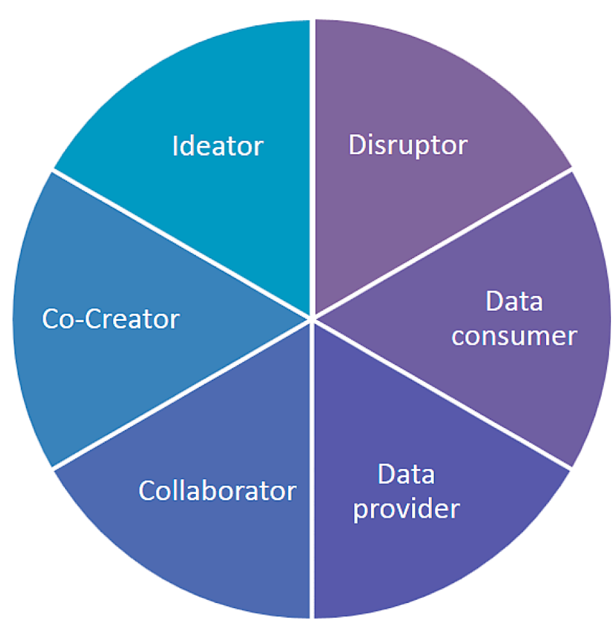


Fig. 1. Palette of participation in digital citizen science (Palacin et al., 2019).

- **Incentive mechanisms:** To support volunteers' engaged action, digital citizen-science projects may use incentive mechanisms, from remuneration (e.g., through micropayments, gamification, and reputation mechanisms) to non-monetary incentives (e.g., social rewards and hedonism-enhancing features) often aligned with economic theories or privacy-awareness principles (Jaimes et al., 2015; Khan et al., 2012; Restuccia et al., 2016).Most of these incentive mechanisms, however, focus on providing a reward to enhance participation, which may have unintended consequences, such as cultivating self-interest and consequently dampening altruistic support of volunteering activities in the longer term, as the Common Cause Report noted (Crompton, 2010, p.37).

Furthermore, recent studies in social computing have found that human values can be linked with online behaviors (Boyd et al., 2015; Chen et al., 2014; Esau, 2018; Hsieh et al., 2014; Mukta et al., 2016). But still cannot exhaustively explain the influence of human values on participation in digital citizen science (Palacin-Silva, 2018). Hence, in this article, we explore the role of human values in a digital citizen-science case by relating participant value orientations to computer-mediated interactions.

2.3. Personal human values

Every human has a set of values "Milton Rokeach (Rokeach, 1973, p.5)"

Human values are guiding principles that organize attitudes, emotions, and behaviors and typically endure across time and situations (Schwartz, 2006). Prior research has illuminated much of the relationship between people's values and their actions and behaviors (e.g., Bardi and Schwartz, 2003; Crompton, 2010; Kingston, 2016; Seddig and Davidov, 2018). People arguaby feel a sense of fulfilment when their actions are aligned with their most important values (Rokeach, 1973), encouraging a conscious and/or unconscious pursuit of consistency between values and behavioral choices (Bardi and Schwartz, 2003; Crompton, 2010).

Schwartz's theory of human values (2006) empirically maps human values and their relationships, and it has been developed and validated by surveys in 67 nations (Schwartz, 2003). It identifies ten basic human values that derive from three universal human needs: social interaction, biological needs, and the survival needs of groups. These ten basic human values map onto the following four higher-level value dimensions (see Fig. 2).

- **Openness-to-change (readiness for change)** includes two basic human values related to independence and excitement: *stimulation* (pursuing excitement, novelty, and challenge in life), and *self-direction* (pursuing independent thought and action, choosing, creating, and exploring).
- **Self-transcendence (concern for others' well-being)** includes two basic human values related to altruism: *universalism* (pursuing understanding, appreciation, tolerance, and the well-being of everyone and nature) and *benevolence* (pursuing the preservation and enhancement of the welfare of the people we know).
- **Conservation (preservation of the current status and resistance to change)** includes three basic human values related to stable practices in life: *tradition* (pursuing respect, commitment, and acceptance of traditional practices aligned with culture or religion), *conformity* (pursuing the restraint of actions, inclinations, and impulses likely to upset or harm others and violate social expectations or norms) and *security* (pursuing safety, harmony, and stability of society, of relations and of self).
- **Self-enhancement (concern for oneself)** includes three basic human values related to self-realization: *power* (pursuing social status and prestige, control, or dominance over people and resources), *achievement* (pursuing personal success by demonstrating competence according to social standards), and *hedonism* (pursuing pleasure and sensuous gratification for oneself).

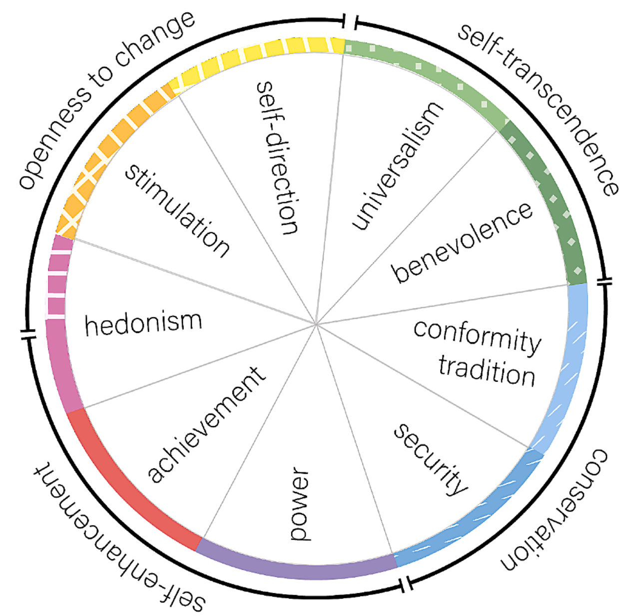


Fig. 2. Schwartz' human values circumplex (adapted from Schwartz (2003)).

Researchers have observed that people with similar values may act differently in similar situations, which is attributable to differences in contexts and personal experiences across the world (Hanel et al., 2017). Recent research has conceptualized human values as mental constructs that can be studied on three levels (Maio, 2016; Winter et al., 2018) (Fig. 3): as a system (L1) represented by a model of value relationships extensively tested by empirical research (Schwartz et al., 2012); abstractly (L2) as related to personal interpretations of each value, and as an instantiation (L3), that is, actual behaviors driven by different values.

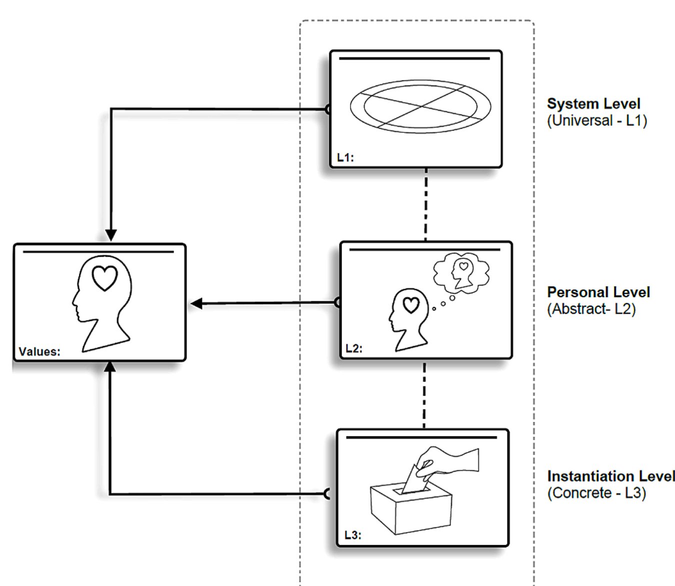


Fig. 3. Human value levels as mental representations (Winter et al., 2018).

2.4. Human values and digital participation

Traditionally, human values have been studied in several domains, including social psychology (Bilsky et al., 2011; Maio, 2016; Schwartz, 2006) and political science (Feldman, 2003). More recently, however, scholars in computing-related research areas, such as human-computer interaction and software engineering, have started centering this theory. For instance, social computing studies have found that human values can predict and explain online behaviors (Boyd et al., 2015; Chen et al., 2014; Esau, 2018; Hsieh et al., 2014; Mukta et al., 2016). These studies have shown that personal values can be identified in language narratives (Boyd et al., 2015; Esau, 2018; Palacin et al., 2020), online content (Chen et al., 2014) and digital interactions (Kalimeri et al., 2019; Mukta et al., 2016). One study showed that words used on Reddit forums were indicative of personal value orientations, for example (Chen et al., 2014); another showed how digital interactions on social media can predict the values of the interlocutors (Mukta et al., 2016). Prior work has also shown how human values can predict topical interests when reading online content (Hsieh et al., 2014).

2.5. Summary and research questions

Extant research on digital citizen science has focused on understanding motivations to nurture sustained participation. However, sustaining concrete, long-term participatory actions in citizen-science projects remains a major challenge. Given that human values can be linked with online behaviors (Boyd et al., 2015; Chen et al., 2014; Esau, 2018; Hsieh et al., 2014; Mukta et al., 2016), this article argues that advancing our understanding of the influence of human values on participation in digital citizen science could serve as a basis to guide the design of incentive mechanisms, understand user experiences in online communities, and inform the design and evaluation of digital citizen-science technologies. Hence, we asked the following:

- RQ1: What are the value orientations that underlie participation in digital citizen-science initiatives?
- RQ2: What are the effects of value orientations on digital interactions?

Answers to these questions are particularly valuable to fill the current research gap regarding the role of human values in digital participation (Esau, 2018; Palacin et al., 2020). Several scholars have called for studying the reasons underlying participation in digital citizen science to inform the design of better digital tools (Esau, 2018; Jennett and Cox, 2018; Palacin et al., 2020; Rotman et al., 2012). By relating people's interactions in a digital citizen science case with their values, this work contributes to the design and evaluation of digital citizen-science initiatives and tools.

3. Context: the SENSEI initiative

SENSEI was a community-mapping initiative during 2017–2018 in Lappeenranta, Finland that brought individuals, researchers, community organizations, and decision-makers together to understand shared challenges. The initiative sought to show how technology and participatory practices could be combined to monitor these challenges, make sense of the collected data, and solve problems collectively. A participatory action research approach (Balestrini et al., 2015; Ferrario et al., 2013) of seven stages (Fig. 4) guided the initiative. The initiative arranged ten events and workshops that generated over 100 ideas concerning issues of shared interest, 28 civic tech prototypes, and dozens of sense-making artifacts, including data interactions, analysis of datasets, and data sculptures. In addition, a digital citizen-science platform for environmental monitoring was built and deployed for three months "in the wild" (collecting a total of 300 observations).

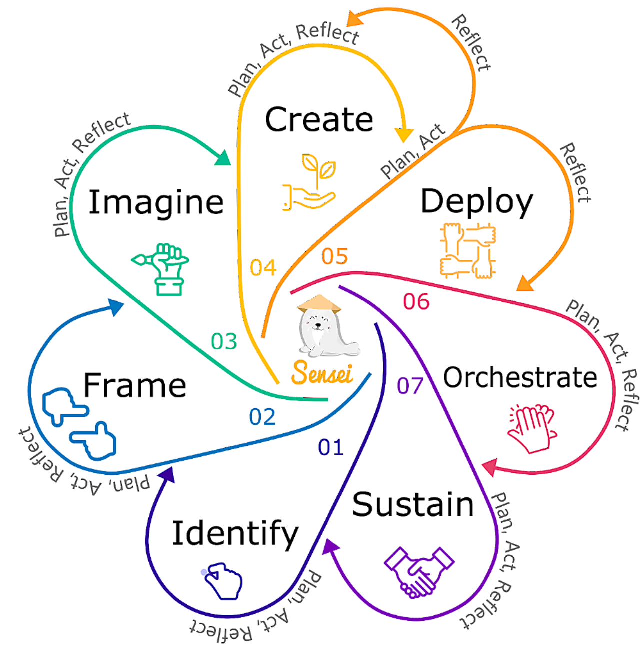


Fig. 4. SENSEI initiative stages.

3.1. Sensei initiative stages

Although participatory approaches have been employed in human-computer interaction (HCI) research for many years, the way they are used can vary significantly depending on the context in which they are applied (Duarte et al., 2018). For example, in classical user-centered design, people are understood as passive objects of study by a "knowledgeable" researcher. In participatory design, the technologist facilitates the process by which participants learn about technology and eventually take on design roles (Winschiers-Theophilus et al., 2010). In co-design, however, the users and researchers are both designers on equal footing (Muashekele et al., 2019; Stanley et al., 2015). Consequently, co-design approaches promote the use of appropriate tools, methods, and design processes over a long-term multicultural engagement between technologists and communities using participatory approaches, leading to new transcultural products (Kauhondamwa et al., 2018; Ssozi-Mugarura et al., 2017).

The overall approach of the SENSEI initiative combined two participatory frameworks: the city commons approach Balestrini et al. (2017); Woods et al. (2018) and the Speedplay framework by Ferrario et al. (2013, 2014) with an in-the-wild deployment Rogers and Marshall (2017). The city commons framework is a novel approach to orchestrate community engagement around issues of shared concern, enhancing community ownership, openness, and skill development and prompting discussions about data governance Balestrini et al. (2017). Complementarily, the Speedplay framework enables software development emphasizing social innovation in tightly constrained environments Ferrario et al. (2014). In addition, the day-to-day practices within the initiative were informed by a review of the last five years of co-design and participatory design literature in the HCI and ICT4D fields. Three core principles were extracted from that body of knowledge to guide the intervention (Fig. 5): i) *sustainable community development* practices related to the co-creation of locally appropriate solutions; ii) *fairness* practices linked to the co-creation of meaningful and fair relationships between the participants and designers; and iii) *knowledge construction*, practices related to the equitable access to production and consumption of knowledge (Blake et al., 2014; 2011; David et al., 2013; Dix, 2007; Muashekele et al., 2019; Sanders and Stappers, 2008; Smith et al., 2017; Ssozi-Mugarura et al., 2017; Stanley et al., 2015; 2016; Steinfeld and Smith, 2012; Teli et al., 2017; Winschiers-Theophilus et al., 2010;

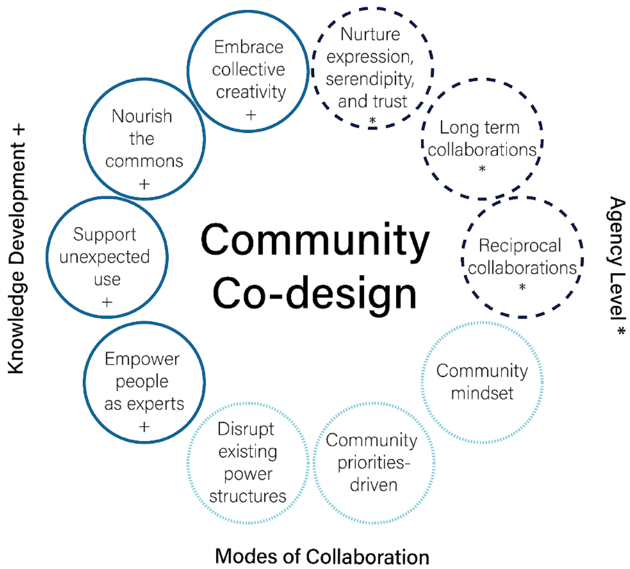


Fig. 5. Key elements of community co-design.

2013). The seven stages of the initiative are detailed below, although more detailed information about the process can be found in (Palacin et al., 2019):

- ***Stage 1:***Identify matters of shared concern and map out community stakeholders that might be interested in working together to address them. This is based on prior community stakeholder mapping Namahn and Design (2019), cross-cultural agreements Partnership (2018), and existing design kits for sensing projects with communities Woods et al. (2018), IDEO (2015).
- ***Stage 2:*** Understand matters of shared concern, map the motivations of participants to adjust the shared purpose of the initiative, and explore the appropriate uses of technology to address the matters of shared concern through a series of workshops. This is sketched upon prior studies on mapping common values Schwartz (2003) and the creation of spaces for conversation Rose et al. (2016) through co-design workshops Woods et al. (2018).
- ***Stage 3:*** Design creative experiences that allow participants to express freely in creative, unexpected ways. Participants show the ways they want to engage with the solutions through playful ideation and prototyping activities in co-creation workshops. This is sketched upon prior work on nurturing collective imagination in community settings Balestrini et al. (2017), IDEO (2019).
- ***Stage 4:*** Create appropriate tools to address the matters of concern. The tools are created in collaboration between researchers, developers, and participants following requirements set by the community through the Speedplay agile development approach Ferrario et al. (2013, 2014). The tools in this case included bicycle bells, wristbands, and sticky buttons that participants could use to report issues through a mobile or web platform. Participants were involved in critiquing and testing the prototypes through the creation stage. The creation continued through the deployment stage as participants actively sent their feedback about bugs and new feature ideas. In return, they could name the new version releases.
- ***Stage 5:*** Release the created tools into the wild Rogers and Marshall (2017), Burke et al. (2006) to address the issues of common concern. A total of 67 locals used the SENSEI tools for 13 weeks and gathered a total of 300 public observations on a) invasive plant species (51%), b) nice places (26%) and c) trash in the forest (23%);
- ***Stage 6:*** Identify possible challenges in the use of the tools and curate the data collected for public dissemination and collective sense-making Balestrini et al. (2017), Wolff et al. (2019). This was done through regular meet-ups with participants, distributing educational materials, and publicly exhibiting “urban data games” designed to familiarize people with the collected datasets.
- ***Stage 7:*** Create paths to sustain actions of the initiative by disseminating all findings and lessons learned with participants and key stakeholders through public events, social media posts, and emails and distributing certificates of “citizen scientists” to acknowledge the active participation of volunteers along with a list of next actions to get involved Woods et al. (2018).

Fig. 6. Bike bell, bracelets, and clothes for environmental monitoring.

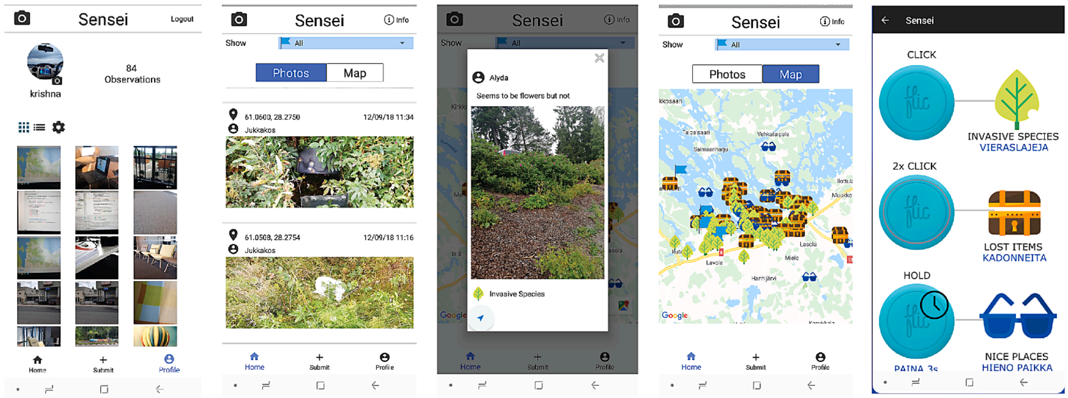
3.2. *The SENSEI platform in the wild*

The development of the SENSEI digital citizen-science tools followed a specifications document that was grounded on the key requirements gathered in stages 1–3 (Fig. 4) through the workshops. For example, the login was device-based instead of person-based to avoid linking a person to a device to ensure privacy and anonymity, a key requirement for participants. Participants were involved in critiquing and testing the prototypes prior to starting the deployment stage. Also, participants actively sent their feedback about bugs and new feature ideas. In return, they could name the new version releases. The SENSEI platform was deployed following an in-the-wild approach (Rogers and Marshall, 2017), which allowed us to understand how participants interacted with the technology in their everyday lives. The platform consisted of the following:

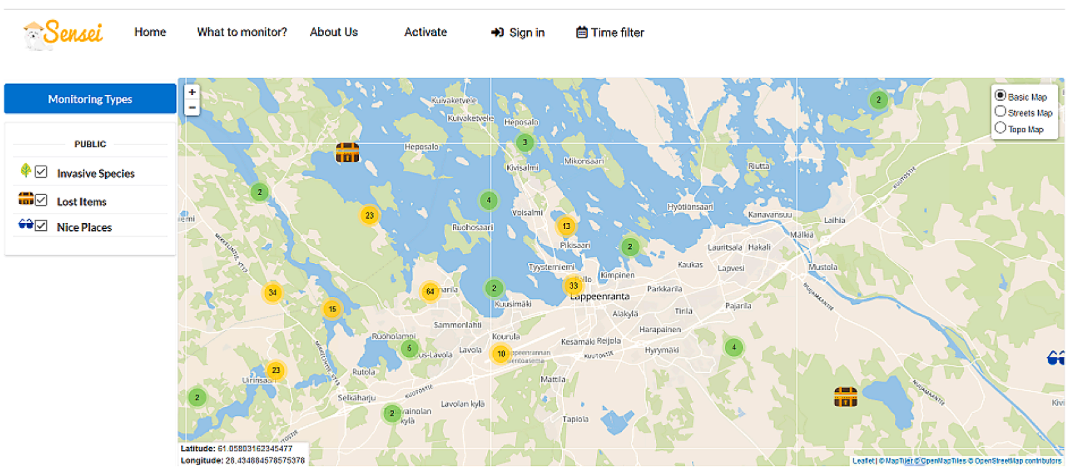
1. *Wearables* that used front-end Bluetooth devices, such as bicycle bells, wristbands, and sticky buttons (Fig. 6), that participants could use to report issues (e.g., one click = invasive plants, two clicks = nice place, and hold 3 sec = abandoned items)
2. *A mobile app* to submit photos, create private monitoring campaigns, and observe community monitoring efforts (Fig. 7(a))
3. *A web platform* to explore observations released to facilitate city actions upon the reports (Fig. 7(a)).

4. Methodology

The overall goal of this study was to understand the role of human values in a digital citizen-science case. The study was designed to explore human values at three levels: L1) universal through the use of



(a) Example of SENSEI mobile application



(b) Example of SENSEI web platform

a) an abandonned boat in the forest

b) a nice place for sunset in town

c) invasive plant species (indian balsam) in the forest

(c) Example of environmental observations collected with the SENSEI tools

Fig. 7. Screen captures from the SENSEI platform.

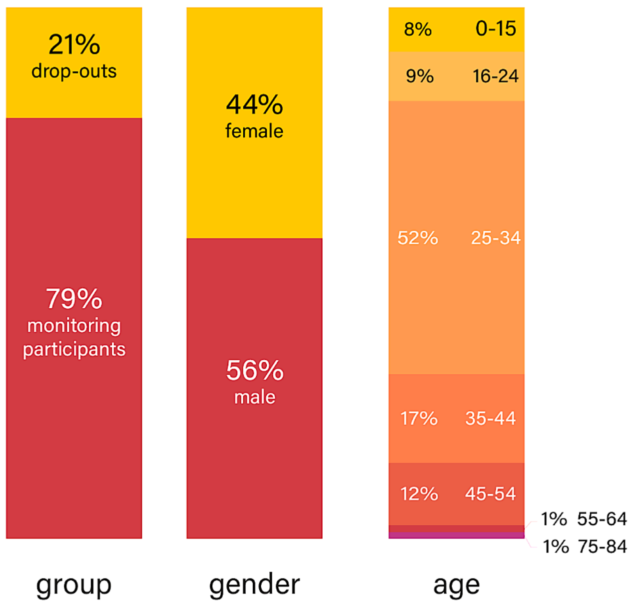


Fig. 8. Participants' demographics.

the Schwartz values instrument to map the participants' value orientations; L2) personal through the analysis of interviews, open surveys, and focus group notes; and L3) behavioral through quantitative models, such as logistic regressions[3] and negative binomial regressions[4] based on usage logs. Where the Bejamini-Hochbergh False Discovery Rate (FDR) procedure (Benjamini and Hochberg, 1995) was applied to control and correct the results from the models. In this section, participant information, data collection, analysis procedures, and instrument information are discussed in detail.

4.1. Participants

The behavior of 85 volunteers was studied. They were either full-time participants (67) or drop-outs (18) in the SENSEI initiative. Full-time participants engaged in all stages of the initiative (see Section 3 for a detailed description of the stages), whereas drop-out participants joined the project but did not interact more than two times in the activities. The participants were 7–85 years old, and they identified themselves as female (37) and male (48). Breaking this down further, 44 participants were between 25 and 34 and 14 between 35 and 44, so young adults made up most of the sample. Fig. 8 summarizes the demographics of all the participants.

4.2. Instruments for data collection

1. *The portrait values questionnaire (PVQ-21)*. This is the official instrument used in the European Social Survey (ESS-ERIC, 2020) to measure human values and contains 21 items that require responses on a 6-point Likert scale. The PVQ instrument is based on Schwartz's human values theory (Schwartz, 2003). For each item description, the participants indicate their similarity in relation to the person described on a scale from 1 (*does not look anything like me*) to 6 (*looks a lot like me*). The PVQ-21 survey was filled out by all participants ($N = 85$) during their first interaction with the initiative.

[3] The logistic regression is used to model the probability of certain event existing such as participate/dropout or pass/fail given the particular value of a predictor variable (Sommet and Morselli, 2017)

[4] *The negative binomial regression is a type of generalized linear model in which the dependent variable is a count of the number of times an event occurs* (Zwilling, 2013).

Table 1
Quantitative variables and measurements.

Data Source	Variable	Measurement
PVQ Survey	Self-transcendence	Items that measure universalism and benevolence
	Self-enhancement	Items that measure power, achievement and hedonism
	Openers-to-change	Items that measure stimulation and self-direction
	Conservation	Items that measure conformity, security and tradition
Participation Records	Participation type	Participation type (sustained participation or drop-out)
Usage logs	Platform use	Number of interactions
	Quality of use	Duration of interactions
	Use efficacy	Number of submissions

2. *Participation records.* Participants signed up for the project activities (e.g., attending a workshop or conducting environmental monitoring), and this information was used to assess sustained participation and drop-out.
3. *Usage logs.* The tools created to facilitate environmental monitoring were used for three months by the participants (stage 5). The mobile application and the website recorded some basic usage information to allow us to measure platform use, quality of use, and efficacy (Table 1).
4. *Workshop notes.* Every workshop had three to four facilitators that prepared the place, guided the activities, and made observations about each activity. These observations were used to reflect on the design of the workshops and iterate them and to inform design decisions when designing the digital citizen-science platform.
5. *Online surveys.* All participants were invited to complete two online surveys during the project (stages 5 and 6). The first survey focused on gathering ideas and feedback for the activities, and the second focused on exploring the participants' user experiences with the platform.
6. *Interviews.* Semi-structured interviews were used in the development and deployment stages to gather extra feedback and experiences. When possible, these interviews were carried out in a focus group-like setting with five or more people.

Table 1 summarizes the variables measured by these quantitative instruments.

Table 2
Participants values' orientations (Pearson's correlation significance * = 0.01; ** = 0.05).

Value Dimension	Cronbach α	Mean	Std Dev	Correlation		
				2 SE	3 OTC	4 CON
1. Self-Transcendence	.730	5.04	.65	–.113	.451**	.307**
2. Self-Enhancement	.851	3.67	1.1	-	.257*	.068
3. Openness to Change	.758	4.65	.71	.257*	-	–.028
4. Conservation	.635	4.02	.72	.068	–.028	-

Notes: This table shows the significance, mean, standard deviation, and correlation of the participating volunteers' value dimensions. The correlation coefficients ranged from moderate to strong strength, while moderate standard deviations indicated a healthy spread of values across our participants. The correlations support the circumplex theory structure between values, i.e., the opposing relationship between self-transcendence and self-enhancement (corr $= -.11$) and the proximity of OTC and self-transcendence (corr $= .45$).

4.3. Data analysis

The relationships between people's value orientations and their uses of the SENSEI citizen-science mobile application was studied at three levels (Maio, 2016; Winter et al., 2018): L1) universal through the use of the Schwartz values instrument to map the participant's human values (PVQ-21, $N = 85$); L2) personal through the analysis of qualitative data from interviews, a focus group ($N = 15$), and open surveys ($N = 149$); and L3) behavioral through quantitative models based on usage logs (useLogs = 5014 and submissions = 300).

4.3.1. L1: universal level

To map the participants' value orientations, the responses to the PVQ-21 survey were analyzed ($N = 85$). Incomplete or inconsistent responses (more than 5 missing on the 21 value items and those who gave the same answer to more than 16 of the 21 value items) (Schwartz, 2016a) were removed through standard quality checks, leading to 83 valid responses. Reliability analysis (Cronbach's alpha; see Table 2) was run to evaluate the extent to which the indices measured each value dimension that underlaid all of its items. The value of tradition did not pass the Cronbach alpha cutoff (Table 2), for instance, but the value dimenssion of conservation did. To minimize the possible effect tradition may have on the other values in its dimension (security and conformity), the dimension of conservation is always presented with details of the effect of each of its values on the dependent variables.[5] The individual scale usage differences were then corrected by converting the absolute values into scores that indicated the relative importance of each value in the individual's whole value system. The centered scores were then used for the quantitative models.

4.3.2. L2: personal level

Qualitative data sources from 15 interviews (total 240 min), responses to open questions in online surveys ($N = 149$), and one focus group session were analyzed to understand the individual meanings of human values. Thematic analysis was used, a "qualitative research method for identifying, analyzing, and reporting patterns (themes) within the data" (Braun and Clarke, 2006, p.79). It begins with a row-by-row coding process and the outcome is a set of themes that describe the phenomena under study and their relationships. We analyzed responses to questions "Why did you join the environmental monitoring initiative?" and "What do you expect from this initiative?". We generated expectation- and motivation-based codes inductively and used the theory-based codes from the values theory (Schwartz, 2006).

To address threats to validity in our qualitative analysis, we used Lincoln and Guba's (1985) techniques: prolonged engagement to extract rich data from the context, referential adequacy in the transcription and coding process, peer debriefing for additional neutral viewpoints into data analysis, and member checking to discuss findings with the studied community.

4.3.3. L3: behavioral level

Quantitative methods were used to investigate the effects of the human-value dimensions on participation in the SENSEI initiative and the use of the SENSEI mobile app, illuminating the concrete representations of human values among the participants (L3). Two methods were used to explore the relationships between these variables (Fig. 9): logistic regressions to understand participation types and negative binomial regressions to understand the effects of these value dimensions on the use and interactions of the participants.

1. Logistic regression was used to analyze whether a participant stayed a part of the initiative, which is a type of generalized linear model (GLM) that assumes that the dependent variable is binary (Allison, 2009; Osborne, 2014). The dependent variable is a function of the probability that the predicted variable will be in one of the categories (coded as participation = 1 and drop-out = 0). Instead of coefficients, as in linear regression, the effect of independent variables is often reported as conditional probabilities and odds ratios. Odds ratios enable a comparison of the relative odds of the occurrence of the outcome of interest (e.g., participation) (Norton and Dowd, 2018). For example, an odds ratio of 2 would mean that for each increase of an independent variable, the dependent variable would be twice as likely to occur. Logistic regression uses the maximum likelihood estimation and is non-parametric, not requiring homoscedasticity but requiring the independence of observations and independence of errors as well as a linear relationship between the dependent and independent variables. For logistic regression, there is no simple, substantively interpreted measure of overall model fit, such as R^2 (Osborne, 2014). Instead, a chi-square test is used for the overall model significance and the Wald test for the significance of independent variables (Osborne, 2014).

   Logistic regression has four assumptions: 1) dependent variables should be measured on a dichotomous scale; 2) independent variables are continuous or categorical; 3) observations are independent, and the dependent variables should be mutually exclusive; and 4) a linear relationship exists between any continuous independent variables and the logit transformation of the dependent variable. These assumptions required for logistic regression were met. There was no evidence of multicollinearity, as assessed by tolerance values greater than 0.1 and variable inflation factor (VIF) testing. There were no studentized deleted residuals greater than $+-3$ standard deviations or values for Cook's distance above 1. There was a linear relationship between the logit of the outcome and each dependent variable.
2. Negative binomial regression was used to analyze the digital interactions. This model is a type of GLM explicitly designed to model count data (Allison, 2009). The count variable is a specific case of variables that express the number of something, such as the number of interactions or the rising number of participants. These variables are always discrete, have values of zero or above, and often have highly skewed distributions. We selected the negative binomial over the Poisson regression to counter the potential effects of over-dispersion. In addition to regression coefficients, the effect of independent variables in negative binomial regression is often reported as incidence rate ratios (IRRs), which function like odds ratios, reporting the probability of an increase to the dependent count variable. As a GLM, negative binomial regression has similar assumptions and validity testing as logistic regression.

As an additional validity measure for regression analysis, the Benjamini-Hochberg procedure (Benjamini and Hochberg, 1995) was applied to control the false discovery rate due to multiple testing, using the adjustment formula presented by Pike, (2011) and automated with the R core stats package (R Core Team, 2013). The procedure was selected due to its suitability for exploratory research (Verhoeven et al., 2005). FDR-adjusted p-values are used differently from values corrected using family-wise error rate methods such as Bonferroni — the adjusted p-value is required to pass below the specified FDR level, but significance evaluation is still performed using the original p-value (Benjamini and Hochberg, 1995; Pike, 2011).

[5] *"It is common that some of the internal reliabilities of several PVQ-21 indexes can be relatively low. Because; 1) the items in the indexes are constructed and selected to cover the different conceptual components of each value, not to be nearly redundant measures of a narrowly defined concept and, 2) each index includes only two or three items. With so few items it is virtually impossible to obtain high alphas unless the items are very similar to one another. Considering the small number of items used to measure each of the ten values and their necessary heterogeneity, even reliabilities of 0.4 are reasonable"* (Schwartz, 2016b)

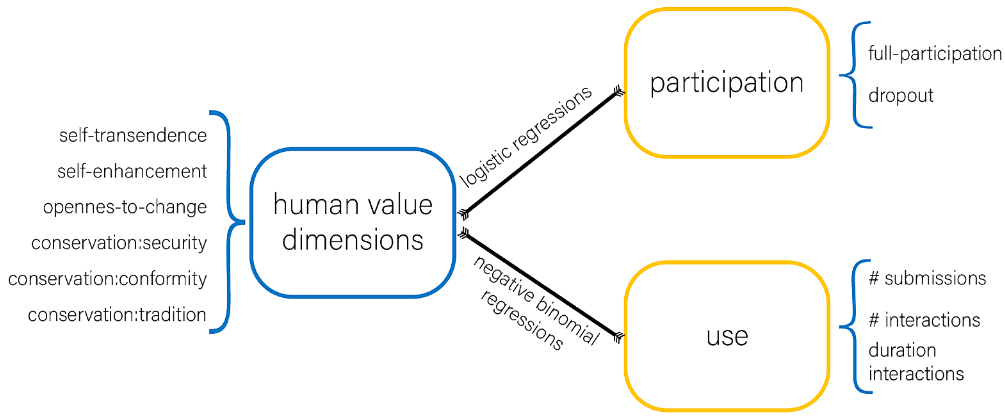


Fig. 9. Overview of quantitative methods used for data analysis.

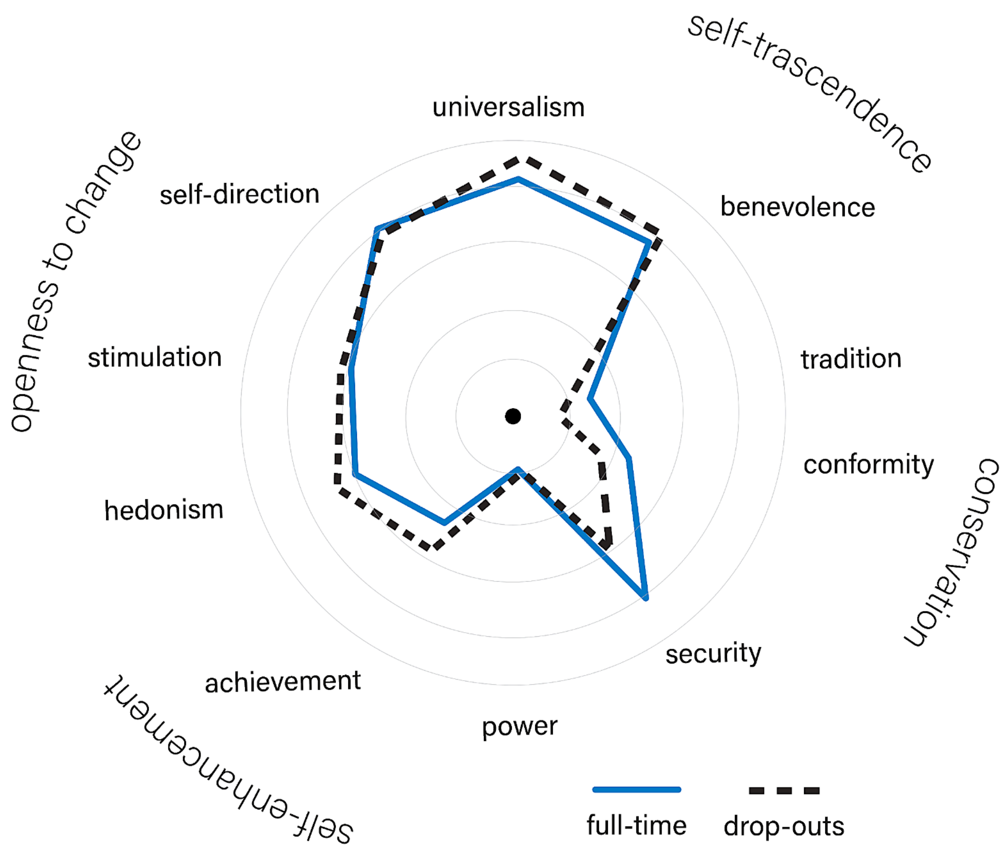


Fig. 10. Value orientations of participants in the SENSEI initative (based on the PVQ survey).

Table 3
Values ordered by centered score full-time participants and drop-outs.

Full-time Participants			Drop-outs		
Value Dimension	Value	Centered Score	Value Dimension	Value	Centered Score
ST	Universalism	0.69	ST	Universalism	0.96
OTC	Self-Direction	0.64	OTC	Self-Direction	0.66
ST	Benevolence	0.50	ST	Benevolence	0.66
CON	**Security**	**0.46**	OTC/SE	Hedonism	0.25
OTC	Stimulation	0.08	OTC	Stimulation	0.22
SE/OTC	Hedonism	0.03	SE	Achievement	− 0.13
SE	Achievement	− 0.38	CON	**Security**	**− 0.13**
CON	Conformity	− 0.45	CON	Conformity	− 0.75
CON	Tradition	− 0.82	CON	Power	− 1.10
CON	Power	− 1.08	CON	Tradition	− 1.13

Table 4
Relation of participation (a dichotomous outcome drop-out/participate) with value orientations.

Dependent variable	Independent variables	χ^2	OR	Wald p-value	BH-adjusted p-value (FDR 8%)	CI (97.5%)
Participation	**Security**	**5.5**	**2.19**	**0.019***	**0.075**§	**4.4**
	Self-Transcendence	**5.0**	**0.3**	**0.025***	**0.075**§	**7.9**
	Conformity	2.2	1.34	0.14	0.21	3.5
	Openness-to-Change	2.2	0.53	0.14	0.21	1.1
	Tradition	1.2	1.34	0.27	0.324	2.3
	Self-Enhancement	0.81	0.8	0.37	0.37	1.2

Notes: Logistic regression analysis. Where: χ^2, chi square; OR, odds ratios; BH, Benjamini-Hochberg procedure; FDR, false discovery rate; CI, confidence interval. (***p <.001. **p <.01. *p <.05. · p <.1). §-(passes BH procedure)

5. Results

5.1. Self-transcendence and security were related to participation in the digital citizen-science initiative

As suggested by prior work (Esau, 2018; Hsieh et al., 2014; Verplanken and Holland, 2002), the results suggest that self-transcendence values (universalism and benevolence) and security are associated with initial participation in this case study (Fig. 10). Furthermore, the conservation value of security was a key difference between the participants who engaged in a sustained manner and the ones who dropped out of the initiative (Table 3).

Participants who valued security more were two and a half times (119%) more likely to participate in a sustained manner in the initiative. This meant that for every increase in security, the odds of participating (versus dropping out) increases by an OR factor of 2.19. The qualitative data shows that the participants' sense of security was largely positive and related to the well-being of their surroundings ("Because I like my city and like to have it in a good condition" (P62)) and their community ([I joined] "to help others and to protect the environment" (P42). Whereas those who valued self-transcendence more were less likely to sustain their participation (Table 4). Participants with higher self-transcendence values were 70% less likely to participate in a sustained manner in the initiative, as evinced by the odds ratio factor below 1 (OR = 0.30). These participants may have more competing opportunities to engage in environmental activism (e.g., joining a march or a volunteering campaign).

Associating human values with a type of participation is vital to explore the factors affecting participation. In this case study, numerous participants indeed exhibited a strong interest in the environment and their community (e.g., *"I am an environmentalist; I like good changes in the environment" (P21), "I'm a volunteer to create new things" (P8), "I like this city, and I like to volunteer in actions to help it improve" (P57), and "I wish environment should be clean; that's why I join this environmental monitoring" (P55)*). Hence, it is possible that those who dropped out did not consider digital citizen science as something aligned with their mental model of an environmental action (or they may have had higher expectations of systems). In this study, while participants with strong self-transcendence were more willing to participate, they were also less likely to remain engaged.

5.2. Security and OTC were related to different usage patterns

The results (Table 5) suggest that different value orientations are linked with different patterns of use. For instance, participants with a higher OTC value orientation — related to independence and curiosity — interacted with the system more times (e.g., browsing curiously through others' submissions) (see Table 5b). In contrast, participants with a higher value of security had shorter, goal-directed interactions (e.g., opening the system with only the goal of submitting an observation) (Table 5c). Interactions were measured with three variables: 1) the number of interactions, which represented the platform use; 2) the duration of interactions, which represented the quality of use; and 3) the number of submissions, which represented the use efficacy.

Table 5
Relation of interactions with values' orientations.

Dependent variable	Independent variables	Anova P	IRR	BH adj. P-value (FDR 8%)	CI (97.50 %)
Number of submissions	Self-Transcendence	0.12	1.97	0.42	1.53
	Openness-to- Change	0.14	1.78	0.42	1.31
	Conservation: Tradition	0.25	0.49	0.50	0.51
	Conservation: Conformity	0.43	1.29	0.55	0.84
	Self Enhancement	0.46	0.77	0.55	0.44
	Conservation: Security	0.92	0.97	0.92	0.68
(a) Number of submissions and values' orientations					
Dependent variable	Independent variables	Anova P	IRR	BH adj. P-value (FDR 8%)	CI (97.50 %)
Number of interactions	**Openness-to- Change**	**0.0025****	**1.78**	**0.015**§	**1.16**
	Conservation: Tradition	0.17	0.62	0.50	0.20
	Self-Transcendence	0.25	1.97	0.50	0.91
	Conservation: Security	0.49	1.20	0.72	0.69
	Self Enhancement	0.60	0.77	0.72	0.52
	Conservation: Conformity	0.84	1.04	0.84	0.44
(b) Number of interactions and values' orientations					
Dependent variable	Independent variables	Anova P	IRR	BH adj. (FDR 8%) P-value	CI (97.50 %)
Duration of interactions	**Conservation: Security**	**0.010***	**0.46**	**0.06**§	**-0.20**
	Conservation: Tradition	0.152	2.06	0.46	1.64
	Openness-to- Change	0.322	1.78	0.64	0.94
	Self Enhancement	0.521	0.77	0.78	0.58
	Conservation: Conformity	0.840	0.95	0.93	0.45
	Self-Transcendence	0.929	1.97	0.93	0.68
(c) Duration of interactions and values' orientations					

Notes: Negative binomial regression analysis. Where: IRR. incidence rate ratios; BH. Benjamini-Hochberg procedure; FDR. false discovery rate; CI. confidence interval. (***p <.001. **p <.01. *p <.05. · p <.1.| § passes BH procedure)

The OTC value dimension, which comprises values such as stimulation, self-direction, and hedonism, was associated with the number of interactions a volunteer had with the digital citizen-science platform. Participants with higher OTC values were 78% more likely to interact more with the platform (IRR = 1.78), while the value of security was associated with the time participants spent using the platform: Participants with a higher value of security were more likely to have shorter interactions with it. This meant that the duration of interactions decreased by approximately 55% with every one-unit increase in security (IRR = 0.46).

From the qualitative analysis, participants with higher OTC values used the technology to explore what others were submitting, even when they had nothing to submit (e.g., *"I am always checking the observations of others users, looking for recommendations in my area" (P37), "It was fun to use the app, learned new places near me and add my favorite places for people to use" (P33), "I sometimes used it to see what others have submitted" (P3)*), whereas participants with higher security values were opening the application mostly when there was something relevant to submit. Hence, their interactions had a clear goal and were shorter (e.g., *"as I understood it's a platform to submit observations, so whenever I go out for a walk and find something interesting then only use" (P57), "[In] the usual route to work and home, I don't have relevant things to report" (P44)*).

Prior works have found that values can predict and explain usage behaviors, such as online reading interests (Hsieh et al., 2014), forum word use (Chen et al., 2014), and energy use (Vogiatzi et al., 2018). This finding demonstrates that values also influence how digital citizen-science systems are used (usage patterns). Therefore, it may be feasible to use values to support the design of digital citizen-science tools and incentive mechanisms. Associating human values with digital interactions is important to understanding the relationship between technology design and behavior.

6. Discussion

This article explores the link between human values and user behavior in the SENSEI digital citizen-science intervention. The findings demonstrate the feasibility of using values to support the design of digital citizen-science tools and incentive mechanisms. In this section, we discuss the relationship of the findings in relation to the research questions.

6.1. RQ1: what are the value orientations that underlie participation in digital citizen-science initiatives?

To answer RQ1, we mapped the values that underlaid participation in the initiative. We observed that the volunteers who engaged with the initiative had strong self-transcendence (universalism and benevolence) and security values (Fig. 10). This finding is consistent with the initiative frame/scope, which was linked to themes such as environmental action, civic participation, and community technologies. Therefore, perhaps if we had had a different initiative frame, such as "earn money by mapping issues in the city," the profiles of the participants and their observed behavior would have been different.

Furthermore, the conservation value of security was a key difference between the participants who engaged in a sustained manner and the ones who dropped out of the initiative (Table 3). Sustained participation in the initiative and use, were both associated with a higher value of security. Our results show that the value of security was a significant factor associated with both participation and use.

What did security mean for the participants in the SENSEI initiative? The conceptual definition of security is "safety, harmony, and stability of society, of relationships and of self" (Schwartz et al., 2012, pg.664). According to the refined Schwartz human values theory, security has two subtypes: personal security (e.g., a sense of belonging, family security, clean/tidy) and societal security (e.g., national security, social order). In this context of digital citizen science, which involves protecting and conserving to sustain your own life and the lives of those around you, it is unsurprising that security emerges and that its personal meaning has a close meaning with universalism, as shown in the qualitative analyses.

The qualitative data from the first interactions between participants and the initiative show that many of them emphasized positive, altruistic reasons for their decisions to join the initiative, such as helping friends (e.g., "from [a] friend's suggestion and interest for environmental protection" (P55)), being part of a community (e.g., "Because I feel like I can give something back to the community with this initiative. Maybe people and state will care about the environment a bit more" (P13)) improving the city (e.g., "because I like my city and like to have it in a good condition" (P62)), and protecting nature (e.g., "to help others and to protect the environment" (P42)). The value of security among the participants was largely altruistic and benevolent, which may hinder a connection between this type of security (positive security) and self-transcendence pursuits.

6.2. RQ2: what are the effects of value orientations on digital interactions?

In terms of use, we find that different values are linked to different usage patterns. For instance, those with stronger security values have shorter, goal-directed interactions with the system, whereas those with stronger OTC values interact more frequently with the tools. Prior works have indeed found that values can predict and explain usage behaviors, such as online reading interests (Hsieh et al., 2014), forum word use (Chen et al., 2014), and energy use (Vogiatzi et al., 2018).

What did openness-to-change mean for the participants? The conceptual definition of OTC is "readiness for change" schwartz2012refining. The qualitative analysis shows that OTC, in this context, was linked with curiosity and experience. For many, the project was the first of its kind they participated in, and several reported that they joined to see what it would be like. "I'm interested in finding out how it feels to participate in a citizen sensing project" (P39).

It has been argued that human values play a role in digital participation (Esau, 2018; Palacin et al., 2020), yet we still have little understanding of how to connect values empirically to the design of digital participation tools (Esau, 2018). More approaches to complement the evaluation and understanding of human values in computing (ViC)-related contexts are emerging. For example, some scholars have proposed and used language to understand personal values (e.g., in online forums) (Boyd et al., 2015; Chen et al., 2014). Other initiatives, such as the ViC, have created tools that tap into the abstract (personal) and concrete (behavior) levels of value understanding among software engineers (in Computing, 2019; Winter et al., 2019). Research on the link between value orientations and behavior is promising, but more tools to understand value instantiations (beyond self-reporting) in HCI are needed (Williams et al., 2017). The contributions of this article advance our understanding regarding the influence of human values on participation in digital citizen science and could serve as a basis to guide the design of incentive mechanisms, understand user experiences in online communities, and inform the design and evaluation of digital citizen-science technologies.

6.3. Limitations

- This study addresses the critiques of self-reported measures by following a systematic approach that analyses values on different levels: systemic, individual and concrete actions. Through this multilevel approach, we examined how the self-reported level matches concrete actions manifested by interactions with digital citizen-science tools. We also unpacked the different interpretations of values by participants in this context.
- The participatory approach of this study may have affected the way people participated in the initiative. Other projects (e.g., top-down

ones) with different participation approaches may have observed different behaviors.

- This study is also limited to the use of the Schwartz human values survey used in the ESS. Schwartz has a more recent survey that captures more granular differences between values, but it is significantly longer; given the time restrictions of public workshops, we opted for the ESS version of the instrument. Also, these observations reflect a Nordic mindset.
- Participants trusted the initiative (which included decision-makers and researchers) to do good with the reported data about issues they cared about. Nordic countries rank very high in political trust in national institutions (Listhaug and Ringdal, 2008). This may be different in other countries (e.g., places where people seek to hide sensitive information from political institutions due to mistrust). In those cases, the approach would have to be adapted, and a stage focused on nurturing trust and positive security through careful reflection, actions, and commitments would have to be designed.
- We were not studying how to encourage people to make submissions but to understand their motivation to be involved. These results show that participants' motivations were legible in the number and duration of their interactions with the community technologies but not in the number of submissions. A submission was done when a participant would find something relevant in relation to the initiative. Hence, there may have been cases where people wanted to submit but found nothing interesting to submit or were disallowed from doing so due to their lifestyles. Some people are simply going to be better positioned to make submissions than others, such as people who live in areas with invasive species.
- This article is exploratory in nature and does not aim to prove causality. When reporting the results of this study, validity tests and validity corrections (the Bejamini-Hochbergh FDR procedure) were employed to reduce threats to validity.

7. Conclusions

The overall goal of this study was to understand the relationship between human values and participation in digital citizen science. The questions we sought to answer within this context were the following: What are the value orientations that underlie participation in digital citizen-science initiatives? What are the effects of value orientations on digital interactions? In this article, we introduced a case study of a digital citizen-science initiative to investigate the relationship between value orientations (captured via self-reported survey data) and actions (captured via usage logs). The results show that self-transcendence, security, and OTC values influence the participation and use of digital citizen-science tools. The contributions detailed here advance our understanding of the influence of human values on participation in digital citizen science and could serve as a basis to guide the design of incentive mechanisms, understand user experiences in online communities, and inform the design and evaluation of digital citizen science technologies.

This study builds on prior work by demonstrating that values also influence the way digital citizen-science systems are used (usage patterns). We found that different values are linked with different usage patterns. Those with stronger positive security have shorter, goal-directed interactions with the system, whereas those with stronger OTC interact more times with the tools.

Security was an important value associated with participation and use in the initiative. Major digital citizen-science initiatives have indeed peaked in popularity during emergency situations, such as Safecast during the Fukushima disaster in 2011 and FoldIt during the COVID-19 pandemic in 2020. Further understanding the influence of human values, such as security, on participation in digital citizen-science platforms is currently needed in the field.

CRediT authorship contribution statement

Victoria Palacin: Conceptualization, Data curation, Formal analysis, Writing - original draft, Writing - review & editing. **Maria Angela Ferrario:** Conceptualization, Data curation, Formal analysis, Supervision. **Gary Hsieh:** Data curation, Investigation. **Antti Knutas:** Validation, Data curation, Formal analysis, Writing - original draft, Writing - review & editing. **Annika Wolff:** Formal analysis, Writing - original draft, Writing - review & editing. **Jari Porras:** Supervision, Validation, Writing - original draft, Writing - review & editing.

Declaration of Competing Interest

The authors would like to highlight that one of the authors Annika Wolff is on the editorial board. Other than that, the authors have no conflict of interest to declare.

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