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Title

Participation in citizen science: insights from the CONECT-e case study

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Abstract

Citizen Science (CS) is growing quickly given its potential to enhance knowledge co-production by diverse participants generating large and global datasets. However, uneven participation in CS is still an important concern. This work aims to understand (1) participation dynamics in CS and (2) how they are shaped by participation barriers and drivers. We do so by examining participation in CONECT-e, a CS project that uses a wiki-like platform to document traditional ecological knowledge. More precisely, we analyze quantitative data on participants' profile and activity patterns and qualitative data on barriers and drivers of participation. Our findings suggest that overcoming the education, age, and residence participation barriers is challenging, even in co-created CS projects. This is potentially due to issues of perceived self-illegitimacy and low access to information and communication technologies. Our results also point out that participants' alliance with the project's objectives and trust relationships with the project team are important drivers of participation in CS projects. Finally, we also highlight the need to think beyond participation as single actions and rather consider participation diversity in CS as functional diversity in ecosystems, with participants performing a diverse set of interconnected tasks or functions.

Keywords

Digital commons; inclusiveness; knowledge co-production; landraces; motivations; traditional ecological knowledge

INTRODUCTION

Citizen science (CS) is a rapidly growing research approach that promotes the participation of non-professional scientists in scientific research, from question design to data collection and data analysis (Wiggins and Crowston 2011). Although participation of non-scientists in scientific activities is documented since the 19th century at least (Silvertown 2009), CS is relatively new as a concept and has evolved greatly in the last three decades, leading to many different applications (Nascimento, Pereira, and Ghezzi 2014). In the context of emerging criticism of expertise and scientific legitimacy, CS is a transdisciplinary approach that levels out knowledge hierarchies and promotes the co-production of knowledge by lay people and scientists in an attempt to make science *by* and *for* the people (Alan Irwin 1995). In the context of a growing desire to improve scientific outreach and produce larger and more global datasets to answer complex scientific problems, CS is a way to increase scientific literacy while helping to crowdsource large amounts of data (e.g., observations, measurements, classifications) (Riesch and Potter 2014). While several authors have criticized the latter approach to CS for being utilitarian and top-down (Burke and Heynen 2014; Strasser et al. 2019), it remains the most commonly used (Kullenberg and Kasperowski 2016).

Different approaches to CS have led to different CS typologies, according to the level of engagement accessible to participants (Haklay 2013). Some projects are led by scientists and participants that mainly contribute through data collection (crowdsourcing or contributory CS), while other projects allow participant-led research questions and data analyses (co-created or “extreme” CS). For some authors, these different levels of engagement are an expression of participants’ interest rather than a result of systemic barriers to participation (Haklay 2013). For other authors, however, low levels of engagement are in fact driven by participants’ perceived self-legitimacy, which is influenced by knowledge hierarchies (i.e., expert scientific knowledge perceived as more legitimate than lay expertise) (Strasser et al. 2019). Moreover, differences in engagement levels can also be seen as an expression of power imbalances within projects, and generally in society, that are mediated by socio-economic and demographic factors (Dawson 2019; Schrögel and Kolleck 2019).

The growing importance of CS has led to a deep analysis of issues ranging from data reliability and quality (Kosmala et al. 2016) to the ethical and ontological implications of CS (Strasser et al. 2019; Riesch and Potter 2014). One of the most studied topics is participant motivation, retention, diversity, and inclusion, arguably because one of the most pressing issues for CS is unequal participant engagement (Haklay 2016). As CS projects struggle to maintain diverse and equitable participation (Pandya 2012), results and data that stem from them might potentially be biased and the transformative potential of CS might be challenged (Graham et al. 2014; Burke and Heynen 2014).

Participation in CS has been examined through several lines of inquiry. Some authors have focused on understanding participation dynamics by exploring participants' activity patterns in CS and similar knowledge co-production initiatives such as Volunteered Geographic Information (Seymour and Haklay 2017). Results from this line of work suggests that participation in technology mediated knowledge co-production projects follows a "90-9-1 rule" by which 90% of the participants are mostly spectators, 9% contribute occasionally, and 1% make most of the contributions (Haklay 2016). However, this so-called "rule" (which originated from the analysis of contributions to online documents) is not actually such, since several projects show variations in this pattern (Budhathoki 2010; Ponciano and Brasileiro 2014). Moreover, given the complexity of participation dynamics and engagement profiles in CS and similar initiatives, such as Online Creation Communities (OCC) where volunteers participate in the co-creation of knowledge online, some authors have questioned the notion of participation as single independent actions, proposing instead a view of participation as an ecosystem (Fuster Morell 2010). Indeed, co-dependencies, feedbacks, adaptations, and synergies can exist between the different forms and degrees of participation, such as active participation (knowledge production/contribution) or passive participation (knowledge reproduction/sharing). For instance, some authors argue that although most Wikipedia users only look at or share content, without making contributions, both types of participation are essential for knowledge co-production (Fuster Morell 2010).

Other authors have explored the barriers to participation, suggesting that socio-economic and demographic factors (e.g., gender, age, ethnicity, income, rurality, or education) shape participation in science in general and in CS in particular (Dawson 2018; Schrögel et al. 2018; Jolly 2015; Peltola and Arpin 2018). This is so because issues such as low income and lack of leisure time, low access to science education and scientific references, or low access to and use of Information and Communication Technologies (ICT) — all of which are barriers to participation in CS — are also linked to these socio-economic and demographic factors. For instance, some studies have shown that, in western contexts at least, everyday science learning activities (including some CS projects) reproduce discrimination and exclusion practices, resulting in a larger participation of "middle-upper class, white males" (Dawson 2019). Moreover, participation in technology-mediated CS is mainly dominated by urban and young participants with greater ICT access and skills (Newman et al. 2012; Graham et al. 2014).

Finally, some authors have focused on understanding the factors driving participant engagement, highlighting that participation in CS is driven by individual incentives and motivations, which results in unequal volunteer engagement (Forte and Bruckman 2008). More specifically, results from this line of work (Rotman et al. 2012) suggest that participants in online CS projects have dynamic motivations (i.e., motivations that can change over the life-time of the project) that include collectivistic (i.e., benefiting the group of participants), altruistic (i.e., benefiting the scientists or the public in general), principalistic (i.e., making scientific knowledge accessible to everyone), and egoistic motivations (i.e., participants' own benefit through interaction with the scientists and the project). Other authors have found that affiliation to a group closely related to a CS project can drive participant engagement (Nov, Anderson, and Arazy 2010). The importance of these drivers and their impact on participant activity depend on the project requirements and vary throughout the project's lifetime. For instance, Nov and colleagues (2011) found that in projects requiring a high individual investment to make a contribution, the association between collectivistic motivations and participation intention was significantly higher than in projects requiring lower investment. The same authors also concluded that although attributing importance to the project's objectives can drive people to join a project, once the participant has become an active contributor the importance and impact of this driver might change.

In this work, we combine questions related to these three lines of inquiry to understand (1) CS participation dynamics and (2) how they are shaped by participation barriers and drivers. We do so by examining quantitative data on participants' profiles and activity patterns and qualitative data on participation barriers and drivers in a specific case study: the CONECT-e project. This case study was selected because of the direct participation of the authors in it, but also because of its middle-ground position in the CS participation typologies spectrum, being initiated and hosted by a research institution but then co-created with a civil society organization with a political motivation (Calvet-Mir et al. 2018).

CASE STUDY

CONECT-e is an initiative based on a wiki-like online platform (www.conecte.es) that aims to engage non-scientists in the documentation, sharing, and protection[1] of Traditional Ecological Knowledge (TEK) in Spain. TEK is understood as the dynamic and adaptive knowledge, practices, and beliefs about the use and management of ecosystem elements such as plants and animals (Berkes, Colding, and Folke 2000). Although TEK is a key aspect of sustainable resource management and community resilience (Reyes-García 2015), socio-cultural, economic and demographic changes have led to its widespread abandonment (Gómez-Baggethun, Corbera, and Reyes-García 2013; Benyei, Calvet-Mir, et al. 2020). TEK systems are also threatened by private property rights (e.g., patents or breeder rights) that enclose TEK, limiting the ability of

[1] "Protection" is primarily used in this paper to refer to defensive protection or the compilation of traditional knowledge in searchable databases that can be used as evidence of prior art by patent examiners when assessing patent or breeder rights' applications (WIPO 2012). It is also used in the sense of maintaining it under a *commons* framework to prevent its misappropriation (Calvet-Mir et al. 2018).

communities to use and manage this knowledge (Reyes-García, Benyei, and Calvet-Mir 2019; Calvet-Mir et al. 2018; Reyes-García et al. 2018).

CONECT-e was co-designed, developed, and disseminated by a management team that included an interdisciplinary scientific team and two delegates of the Spanish seed network ("*Red de Semillas: Resembrando e Intercambiando,"* Red de Semillas hereinafter), a decentralized civil society organization defending farmers' rights and promoting community-based dynamic management of cultivated biodiversity (Red de Semillas 2015). Project design and initial results were also discussed at two general assemblies of Red de Semillas, and several Red de Semillas members were active contributors to the project and gave feedback regarding design or management.

In CONECT-e, content was structured in three sections with pages for plants, landraces, and ecosystems. Participants could contribute different type of contents (e.g., text content describing landraces' characteristics, medicinal plant use locations, or pictures of plants and landraces) related to different domains of knowledge (from traditional plant uses such as medicinal, ornamental, or symbolic uses, to traditional management practices such as collection, seed production, or commercialization). The information about traditional use and management of the plants/landraces was structured using the categories of the Spanish Inventory of Traditional Knowledge related to Biodiversity (see Pardo-de-Santayana et al. 2014).

CONECT-e also had a peer validation system in place. Although most editor permissions (i.e., the right to edit other participants' content) were granted to participants from the scientific team and Red de Semillas, these permissions were also granted to any participant who contributed meaningfully to the project. The decision to grant these permissions was taken by the management team. This meant that although most editors were closely related to the project team, not only the scientists were able to validate or eliminate content. Furthermore, although participants without editor permissions could not formally validate or eliminate entries, they could contribute to improving the overall information quality and detecting wrong information by commenting, "liking," or "rating" the information posted on the platform.

The inception of CONECT-e was motivated by more than an ethno-scientific interest in documenting TEK for academic purposes, as the project also aimed at making TEK freely available under common norms and encouraging its revitalization (Calvet-Mir et al. 2018). The content of CONECT-e was managed as a digital commons in which all participants accepted a common set of management rules, which ensured the long-term use value of the information (Calvet-Mir et al. 2018; Reyes-García, Benyei, and Calvet-Mir 2019). All participants had to abide by the terms of the copyleft creative commons license (CC BY-SA 4.0) that guarantees the free exchange and reproduction of knowledge if done without excluding other peoples' access and use of that content. Thus, CONECT-e can be considered a politically motivated project for two main reasons. First, because it targets a body of knowledge (TEK) that is key for local communities' resilience but endangered by misappropriation processes. Second, because it has been co-designed with a civil society organization in a way that allows long-term peer knowledge co-production and management (under the digital commons framework) with an empowering objective in mind. Moreover, CONECT-e could be considered as an Online Creation Community, because to some extent it was a "collective action performed by individuals that communicate, interact, and cooperate in several forms and degrees via an Internet-based platform and with the common goal of knowledge-making and sharing, resulting in a digital common" (Fuster Morell 2010, 271; Fuster Morell 2015; Calvet-Mir et al. 2018). However, CONECT-e's content was not downloadable by participants. This was not an a-priori decision, but rather a design flaw of the CONECT-e platform that reduced participants' ability to engage in data analysis and interpretation, since the database had to be requested from the management team.

To further incentivize participation, CONECT-e was disseminated through a school program and talks at academic and non-academic events (see Benyei, Aceituno-Mata, et al. 2020 and Benyei 2020 for more details). Most of these activities targeted relatively young audiences (19-23 year-old agricultural school students) because the project rationale was that younger participants could act as intermediaries between the digital platform and the normally non-ICT-skilled TEK holders (i.e., elders in rural areas).

METHODS

We used a quantitative approach to measure and analyze participants' profile and activity patterns, and a qualitative approach to explore the barriers and drivers for participation perceived by a subset of participants. We then combined results from both approaches to analyze how the barriers and drivers of participation affected participation dynamics in CONECT-e.

Quantitative methods

The profile and activity data of registered participants was saved in the platform's database. We used this database to extract our quantitative data (participants gave their free prior informed consent for scientific use of this data upon registration). In our analyses, we only examined participant actions for the plants and landrace sections of CONECT-e, since the ecosystem section was in a test phase and had not been fully disseminated to the public (see Calvet-Mir et al. 2018 for a more in-depth analyses of the platforms' content).

Analyses include data collected during CONECT-e's first year (from 02/14/2017 to 03/16/2018). We transformed information collected in different tables to create a single data set in which each row was a participant and the columns were variables capturing profile or activity information (Table 1).

For each registered participant we collected the following profile information: registration date, age, gender, education level, use of ICT, experience with CS, town of residence, and work sector. We also collected the primary motivation for participation. Participants had to choose one option from the following: participate in collective action, curiosity, gain knowledge, obtain a good school grade, share knowledge, prevent knowledge loss, and other. Finally, we collected participants' affiliation to the project and association[2] membership (see Table 1 for a description of the variables).

Table 1. Variables used in the analyses

Variables	Code	Type	Attributes
Registration date^	registration_date	numerical	yyyy-mm-dd
Age*^	user_age	numerical	years old
Gender*^	user_gender	categorical	"male" "female" "other"
Education level*^	user_education	categorical	1= no formal education 2= basic schooling 3= high school level 4= technical higher education 5= university education
Use of Information and Communication Technologies (ICT)* ^	user_ict	categorical	1=never uses ICT 2=uses ICT once per month 3=uses ICT once per week 4=uses ICT daily
Experience with CS*^	user_experience	dummy	1=has previous experience
Town of residence^	user_residence	numerical	town numeric code
Rurality of residence*^	rurality_residence	categorical	1=urban 2=intermediate 3=rural
Work sector^	user_sector	categorical	"administration" "agriculture" "animal husbandry" "education" "forestry" "industry" "tourism" "other"
Re-coded work sector*^	user_sector_rcd	categorical	"primary" "services" "industry" "other"
Motivation for participation^	user_motivation	categorical	"participate in collective action" "curiosity" "gain knowledge" "obtain a good school grade" "share knowledge" "prevent knowledge loss" "other"
Re-coded motivation*^	user_motivation_rcd	categorical	"individualistic" "collectivistic" "other"
Affiliation to the project *^	user_type	categorical	"schools" "scientific team"

[2] By association we understand a group working together in an organization for a particular purpose. These organizations were not necessarily linked to the project (e.g., a political or sports association).

			"Red de Semillas" "other" "none"
Association membership*^	user_association	dummy	1=is member of at least one association
Number of total actions*^	num_total_actions	numerical	number of actions
Diversity of action types^	num_total_action_types	categorical	0= not participating 1= only participating in one action type 2= participating in two action types 3=participating in all action types
Diversity of sections^	num_total_sections	categorical	0=not participating 1=participating only one section 2=participating in both sections
Activity binary *^	use_binary	dummy	1=participant had some activity (i.e., number of total actions different than zero)
*used in bivariate analyses ^used in descriptive analyses			

The town of residence variable was transformed into a three-level categorical variable (rurality of residence) according to the Eurostat DEGURBA classification of towns into urban, intermediate, and rural (European Commission 2014). The work sector variable was re-coded into a variable that grouped work sectors into primary ("agriculture," "animal husbandry" and "forestry"), services ("administration," "education" and "tourism"), industry, and other. Finally, the motivation for participation variable was re-coded into a variable that grouped motivations into collectivistic ("participate in collective action," "share knowledge," and "prevent knowledge loss"), individualistic ("curiosity," "gain knowledge," and "obtain a good school grade"), and other motivations.

For each registered participant, we also calculated some activity variables. "Number of total actions" measured participants' number of actions (e.g., contributing/editing text, pictures, locations or names). "Diversity of action types" measured whether the participant had engaged in none, one or all types of measurable actions (content creation, editing, and validation/elimination). "Diversity of platform sections" measured whether a participant had no activity, activity in only one platform section (e.g., plants or landraces), or activity in both examined sections. Using the number of total actions, we also created a binary variable capturing whether a participant was active or passive (i.e., registered but did no measurable action).

Data transformations were done using the *tydiverse* R package (Wickham 2017).

Qualitative methods

Two years after the project was first discussed by Red de Semillas, a participatory evaluation workshop was held at its annual meeting (October 2018). The twofold aim of this workshop was to present CONECT-e's content results (Calvet-Mir et al. 2018) and to generate a discussion about which factors were limiting or enabling participation in CONECT-e. The workshop used a World Cafe methodology (Alberich et al. 2009), in which participants (about 20 people of mixed genders and ages) rotated between three round tables and discussed a topic. The topics were (1) personal reasons for/against participation in CONECT-e; (2) strengths and weaknesses (internal factors) of CONECT-e; and (3) opportunities and threats (external factors) to CONECT-e. Platform improvement proposals were also noted. During the workshop, three members of the scientific team summarized the information discussed at each round table and created posters showing participants' inputs.

Data analysis

To analyze the quantitative data, we performed descriptive and bivariate statistical analyses. First, we ran some descriptive statistics and data visualizations on profile and activity variables using the *base* and *ggplot2* R packages (Wickham 2016; R Core Team 2018). Then we tested the statistical association between profile and activity variables. More specifically, with the binary activity variable, we ran a Wilcoxon rank sum test against age (numeric variable), and Pearson Chi-Square tests against gender, education level, use of ICT, experience with CS, rurality, work sector, motivation for participation, affiliation to the project, and association membership (categorical variables). We also performed Kruskal Wallis rank sum tests with Tukey non-parametric pairwise comparisons to analyze the differences in mean number of total actions between different participant motivation, affiliation, and association groups. These analyses were done using the wilcox.test, chisq.test, and kruskal.test functions from the *stats* and *nparcomp* R packages (R Core Team 2018; Konietschke 2015). All quantitative analyses and data transformations were done using RStudio Version 1.1.456.

To analyze the qualitative data, we first transcribed and digitized the information from the posters generated during the World Cafe, organizing participant's inputs by topic in a table. Inputs were grouped into two main categories: participation barriers (grouping personal reasons against participation, weaknesses and threats to CONECT-e), and participation drivers (grouping reasons for participation, strengths and opportunities of CONECT-e). We also coded the inputs inductively according to the types of issues they referred to, which lead to five types of inputs: data (e.g., issues with the nature of TEK as data), infrastructure (e.g., issues with the digital platform), personal (e.g., issues related to participant's time or interest), political (e.g., issues related to trust or misappropriation), and project (e.g., issues with the project design, development or management). Finally, we assigned keywords to the inputs in order to create a conceptual map. These words were chosen to describe or synthesize the input's content in a more concise and visual way.

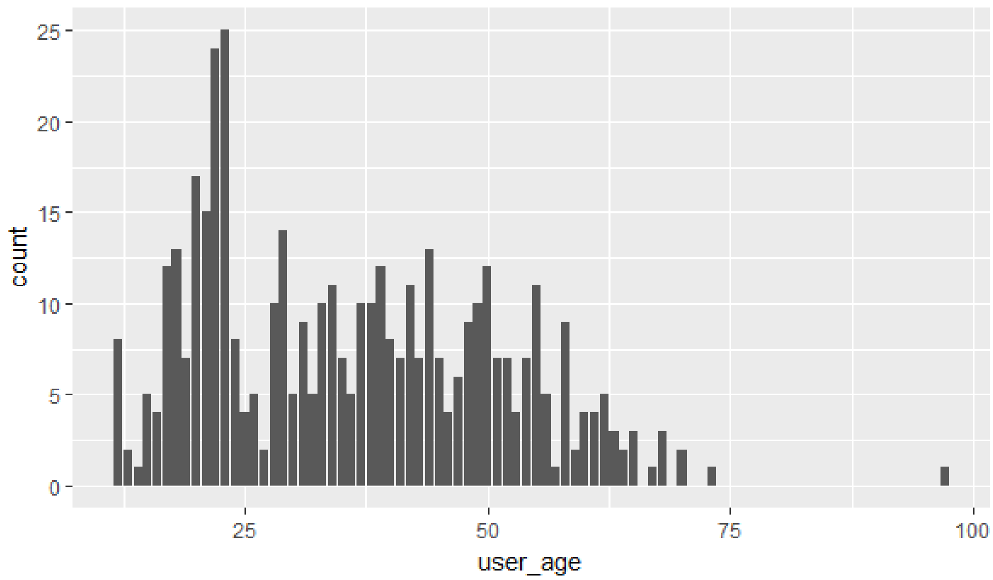
RESULTS

Participant's profile and activity patterns

During the analyzed period, 467 participants registered on CONECT-e. Most did so in the early months of the project, with a peak in registration around March 2017, when the platform was launched and several dissemination activities, including the school program, took place.

CONECT-e participants were in general highly educated (65.5% had a university degree), relatively young (median age 35 years old, see Figure 1), active ICT participants (85.2% used ICT tools daily), and new to CS (only 5.6% had previous experience with CS). CONECT-e participants were also relatively rural (50.3% lived in a rural or intermediate-rural town) and many worked in the primary sector (22.1% to agriculture, 5.6% to animal husbandry, and 10.1% to forestry). Gender was relatively balanced, with 43.9% female and 50.5% male participants. Some participants did not define themselves as either. Motivation was also balanced, with 41.1% of participants having an individualistic motivation and 40.5% of them having a collectivistic motivation. The most frequent motivations were to gain knowledge (33.6%) and to prevent knowledge loss (22.7%). Most participants (47.5%) had no affiliation to the project, but some were affiliated to one of three core groups: a partner school (21.8%), the Red de Semillas (8.6%), or the scientific team (4.7%). Finally, around one third of participants (34.1%) stated they belonged to at least one association (e.g., cultural or political associations not necessarily linked to the project).

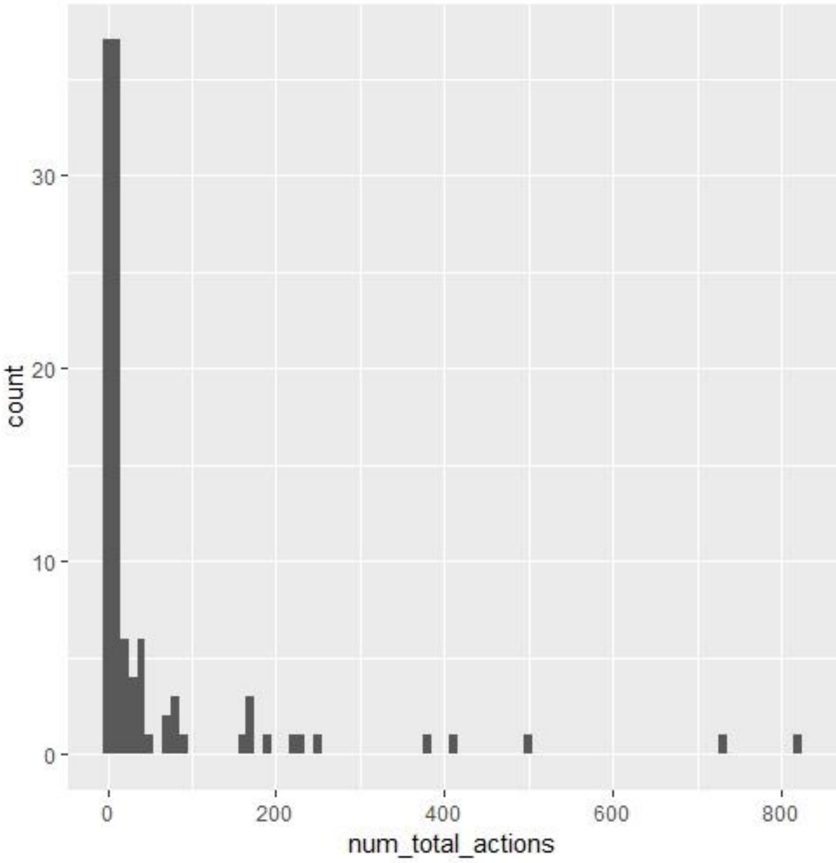
Figure 1. Distribution of participant age



About one quarter (24%) of those registered were active (did at least one measurable action on the platform). The percentage of active participants was proportionally higher in participants affiliated to Red de Semillas (n=40), 40% of whom were active. In the subset of active participants, 63.6% only participated in the plants section, 17.3% only participated in the landraces section, and 19.1% participated in both.

Active participants did 5821 actions (see Figure 2). The number of actions per active participant varied from one to 818. However, most active participants did very few actions (mean=52.9, median=7.5). In fact, we found that most participants did no action at all (76%) while a minority did a large number of actions (4.5% of participants did more than 50 actions).

Figure 2. Distribution participants' actions in CONECT-e (subset for active participants).



Although 40% of active participants had editing and validation permissions, only about one quarter did all three types of actions (21.8% of active participants created, edited, and validated/eliminated content). Most active participants did actions of just one type, mostly content creation (42.7% of active participants).

These activity patters were significantly associated with some participant profile characteristics (see Table 2). Bivariate analyses of whether the person had some activity or not showed that active participants were significantly younger than passive participants (those who registered but did no measurable action; W= 23202, p-value = $1.173e^{-07}$). Also, active participants were more frequently affiliated with one of the project's core groups (i.e., partner school, Red de Semillas, or scientific team) than passive participants (X^2= 97.451, df = 4, p-value = $2.2e^{-16}$). Additionally, if compared to passive participants, active participants reported individualistic motivations less often and “other” motivations more often (X^2= 49.216, df = 2, p-value = $2.055e^{-11}$). Finally, the proportion of participants working in the primary sector and living in urban or intermediate areas was significantly higher for active participants than for passive ones (X^2= 12.89, df = 3, p-value = 0.004881 and X^2= 8.9427, df = 2, p-value = 0.01143 respectively).

Table 2. Association tests results. Contingency table with Chi-Square test results for categorical variables and Wilcoxon rank sum test for numeric variables. Note that the percentages do not include missing values.

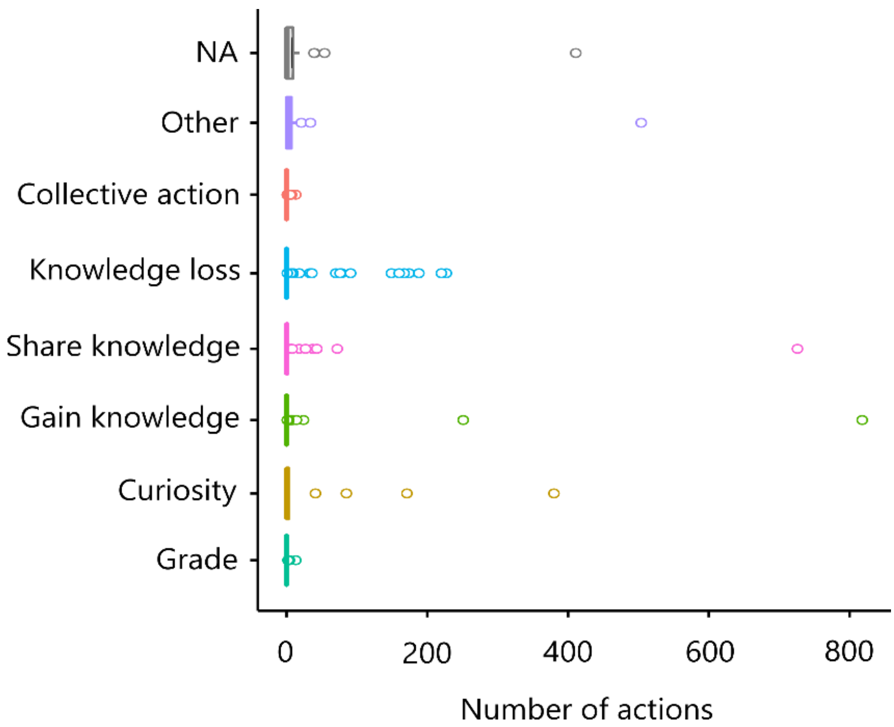
Characteristic		**No activity** **n=355 (100%)**	**Some activity** **n=112 (100%)**	**Test value** **(p-value)**
Age		Mean=38.16	Mean=29.30	23202 (<0.01)
Residence	Urban	n=154 (43%)	n=58 (52%)	8.9427 (<0.05)
	Intermediate	n=72 (20%)	n=31 (28%)	
	Rural	n=112 (31%)	n=20 (18%)	
Work sector	Services	n=128 (36%)	n=28 (26%)	12.89 (<0.01)
	Primary	n=120 (34%)	n=56 (51%)	
	Industry	n=11 (3%)	n=0 (0%)	
	Other	n=90 (25%)	n=25 (23%)	
Motivation	Collectivistic	n=151 (42%)	n=38 (35%)	49.216 (<0.01)
	Individualistic	n=163 (46%)	n=29 (26%)	
	Other	n=20 (6%)	n=31 (28%)	
Affiliation	None	n=208 (58%)	n=14 (13%)	97.451 (<0.01)
	Other	n=58 (16%)	n=17 (15%)	
	Red de Semillas	n=24 (6%)	n=16 (15%)	
	Schools	n=54 (15%)	n=48 (44%)	
	Scientific team	n=7 (2%)	n=15 (14%)	

When analyzing the number of participant actions, we found significant differences in the mean number of total actions depending on participant's motivations (Kruskal-Wallis chi-squared = 41.943, p-value < 0.01, see Table 3). Participants with individualistic motivations did significantly less actions (mean = 9.8 actions) than those with collectivistic motivations (14.5). Indeed, when looking at the disaggregated motivations (Kruskal-Wallis chi-squared = 52.848, p-value < 0.01, see Figure 3), we found that participants motivated by "preventing knowledge loss" (mean = 16.6 actions) and "sharing knowledge" (23.6) did significantly more actions than those motivated by "gaining knowledge" (7.5), and "obtain a good school grade" (1.4). However, those reporting "curiosity" as a motivation (coded as individualistic) did significantly more actions on average than the rest (mean = 32.7 actions).

Table 3. Results from the Kruskal Wallis rank sum tests with Tukey non-parametric pairwise comparisons for number of actions against reported motivation.

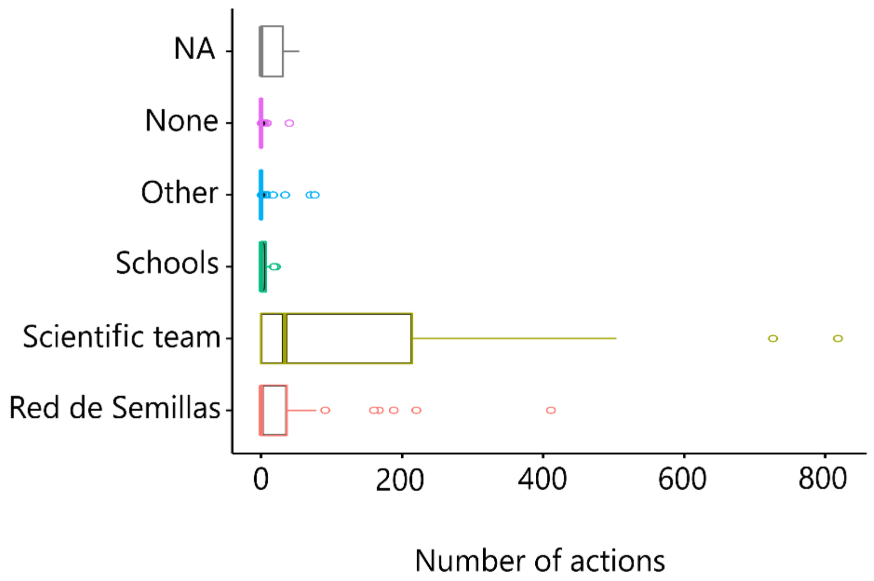
Comparison	Estimator	Lower	Upper	Statistic	p value
p(Collectivistic-Individualistic)	0.471	0.425	0.516	-1.496364	2.875212e-01
p(Collectivistic-Other)	0.675	0.583	0.755	4.305275	3.391016e-05
p(Individualistic-Other)	0.723	0.629	0.801	5.157210	4.937854e-07

Figure 3. Number of actions by participant motivations



We also found significant differences in mean number of total actions when comparing participant's affiliations (Kruskal-Wallis chi-squared = 110.24, p-value < 0.01, see Figure 4). The scientific team did significantly more actions (mean = 162.8 actions) than participants affiliated to the Red de Semillas (40.4), the schools (3.5), and those not linked to the project at all (0.4).

Figure 4. Number of actions by participant affiliations

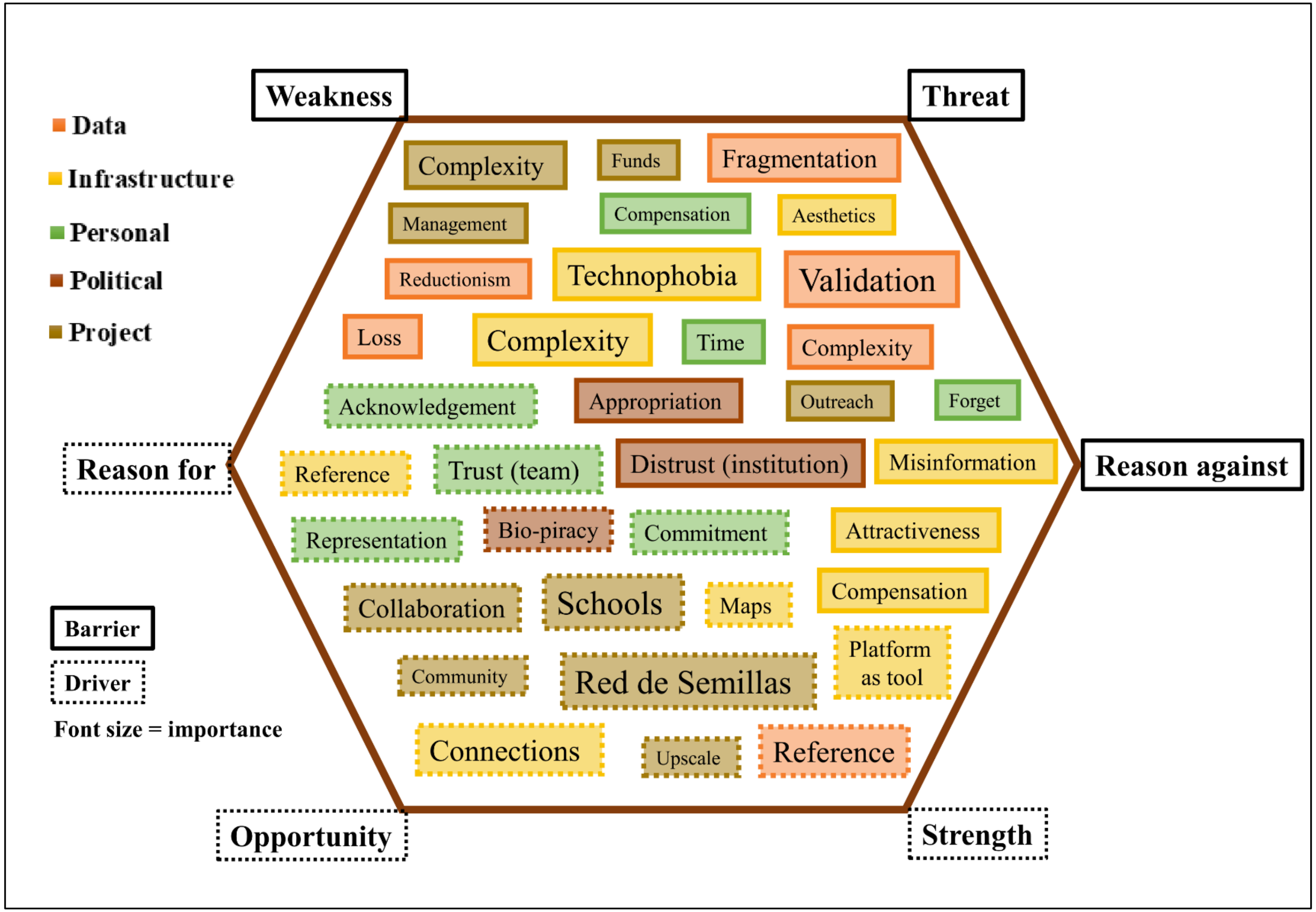


Being active or not in CONECT-e was not significantly associated with any of the other socio-demographic variables (gender, education level, use of ICT, experience with CS, and association membership). We also found no significant differences in mean number of actions based on association membership.

Barriers and drivers of participation

Workshop participants reported 32 barriers (i.e., weaknesses, threats, and reasons against participation) and 26 drivers (i.e., strengths, opportunities, and reasons for participation) affecting participation in CONECT-e (see Table 4, Table 5 and Figure 5).

Figure 5. Conceptual map of the most important barriers and drivers to participation in CONECT-e.



Most barriers (62.5%) were related to data or infrastructure (see Figure 6 and Table 4). For instance, when asked about the weaknesses of the project, workshop participants mostly mentioned the platform's unappealing user interface and unclear user flow. Indeed, workshop participants had problems classifying their data in the existing platform categories and were confused about how to create and comment on entries. When asked about the threats to CONECT-e, workshop participants mentioned the loss of TEK and the difficulties of compiling this fragmented and geographically scattered type of data, along with the threat of falling into reductionism when trying to categorize and organize this holistic and interconnected type of information. Indeed, one of the main reasons against participation in CONECT-e was technophobia or the unease with the use of open digital platforms. Other interesting barriers to participation were trust issues related to the project being too institutional and managed by universities, and personal issues such as lack of time and lack of confidence in the reliability of one's own data.

Figure 6. Type of barriers and drivers of participation in CONECT-e obtained in the World Café.

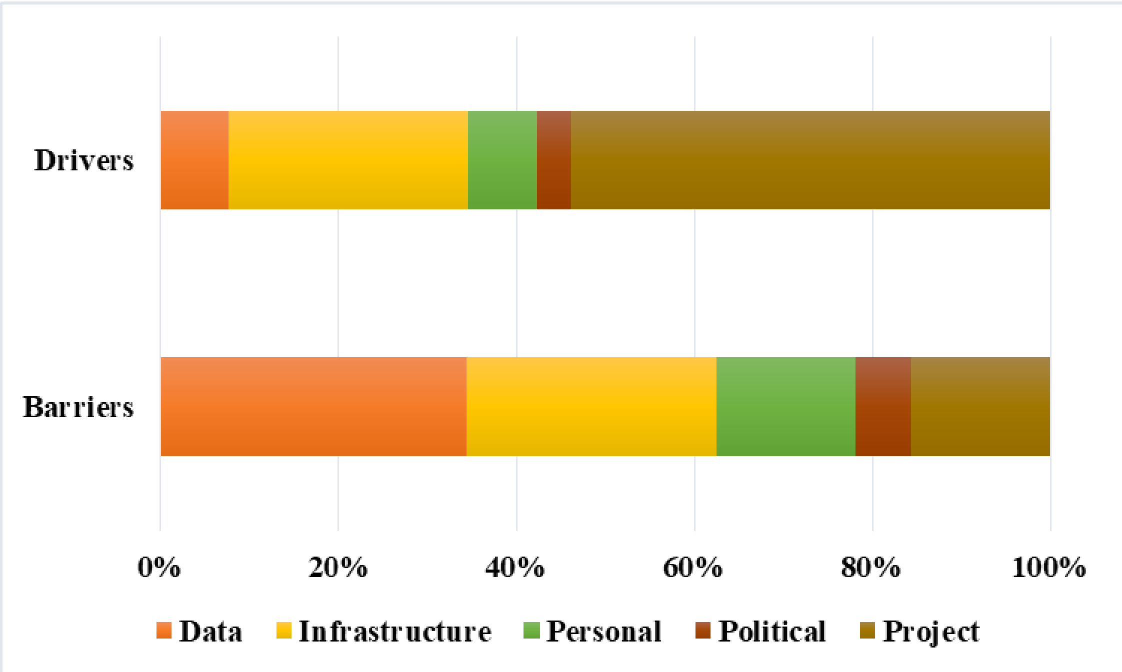


Table 4. Barriers to participation in CONECT-e according to workshop participants

Topic	Keyword	Participant Input
Reasons against participation	Forget	We do not get feedback about new platform developments, participation patters etc.
	Validation	I'm not confident that my data (TEK) is reliable
	Distrust	I don't trust the initiative, it's too institutionalized
	Time	I don't have time
	Misinformation	Some people don't know about it, sometimes one member of the local seed network is in charge of contributing data to CONECT-e and the rest of the group is not aware that the project exists
	Technophobia	Technological rejection (technophobia)
	Fragmentation	Lack of clean data (TEK): we have information on landraces but compiling, editing and adapting it so that it can be uploaded to the platform requires time
	Validation	People are unsure if what they know (TEK) is going to be useful. They are also shy to start contributing, they need some type of icebreaking
	Misinformation	Lack of project dissemination inside the Red de Semillas
	Attractiveness	The platform is not very attractive, I don't feel the "call" to participate
	Complexity	Problems to categorize landraces and other information
	Complexity	User experience/interface issues related to the need to search for existing content before creating new one
	Technophobia	Elderly people don't use ICT
	Complexity	Problems with fitting contributions (TEK) in the platform sections
	Maps	Problems with location, some administrative units do not appear
	Loss	We do not have any TEK to contribute For many landraces, it has been lost
Weakness	Comments	You cannot see well the "commenting" feature, it should be more visible
	Validation	Two landraces might be the same genetically and exist independently in your platform
	Aesthetics	The aesthetics of the platform are very static, it does not seem to be alive
	Dependence	It depends on the university and research funding
	Coordination	Participants do not coordinate with their local seed network before uploading content
	Reductionism	It only documents a small part of the information that the Red de Semillas has in their databases and archives
	Fragmentation	It's hard to collect data (TEK) since it is very fragmented/dispersed
	Validation	Issues of reliability when collecting data (TEK), someone can tell you something and then someone else does not agree and discredits you
	Validation	People can fall into botanical identification issues, which invalidates the data contributed
	Validation	Excess of information, it is hard to validate other participants' contributions
	Compensation	You do not "get" anything from CONECT-e. Some platforms at least tell you if your botanical identification was correct and gives you credit for your contributions
Threat	Loss	Data (TEK) holders are dying
	Appropriation	People might take advantage of CONECT-e, they could publish the contributed data without acknowledging the contributor. An ethical code is needed so that sensitive information is protected and all contributions are done with the agreement of the original knowledge holder
	Funds	Lack of funding
	Misinformation	Lack of dissemination out of the core team (Red de Semillas and scientific team)
	Nontraditional	CONECT-e does not give space for other contributions that are not "traditional knowledge", but that would be relevant for the users of the platform, such as modern agronomic knowledge on how to manage this or that pest

On the contrary, most drivers (53.8%) were related to the project itself, such as the relevance of the project goals and the potential benefits of participation (see Figure 6 and Table 5). For instance, when asked about strengths of the project, workshop participants talked mainly about the great potential they saw in collaborating with researchers and other citizens in the documentation and protection of TEK. Indeed, workshop participants saw CONECT-e not only as a tool for Spanish ethno-sciences, but also as a powerful tool for Red de Semillas, agricultural technicians, and schools, potentially expandable to South America and other regions. Also, when asked about opportunities of the project, workshop participants stated that documenting and maintaining all this information in one place (as opposed to storing it in unconnected databases) was key in the success of CONECT-e and in encouraging participation of the Red de Semillas. Indeed, one of the main reasons for participation in CONECT-e was aligning with the project goals and trusting the individuals involved in its design and promotion.

Table 5. Drivers of participation in CONECT-e according to workshop participants

Topic	**Keyword**	**Participant Input**
Reasons for participation	Reference	CONECT-e can be a reference used in the website and work of Red de Semillas
	Acknowledge	The platform acknowledges contributions and is useful to share experiences among participants
	Bio-piracy	It is a tool to defend our TEK against bio-piracy
	Trust	Knowing who was behind its development (scientific team)
	Schools	Very useful in schools
	Red de Semillas	Because Red de Semillas was committed to the project
	Representation	Because the Red de Semillas delegates working in CONECT-e were active and did follow-ups
Strengths	Red de Semillas	The project has a lot of synergy with what the Red de Semillas is doing, each local seed network could create their landraces catalog in CONECT-e
	Upscale	It could be a tool used at a global scale, and show how TEK (and seeds) travels around the world
	Platform as tool	It’s a very good tool for those local seed networks that have not developed yet any platform or database on their own
	Red de Semillas	CONECT-e can be useful to promote local seed network events. Also, there could be data entry events in which all the seed networks come together to enter data (pictures, landrace names etc.) in CONECT-e
	Schools	Developing intergenerational educational activities in CONECT-e was a great idea that can be expanded even further

	Collaboration	Local seed networks can use CONECT-e to do more landrace prospecting in collaboration with schools and agricultural technicians
	Schools	CONECT-e is a very interesting tool for schools
	Reference	It can become a guide to how to document TEK
	Collaboration	CONECT-e can become a catalogue of landraces for each region and the project can establish collaborations with local administrations and agricultural technicians in the field
	Reference	CONECT-e can simplify complex information and become a reference for basic standard and homogeneous TEK databases
	Maps	Maps are the most interesting platform feature, even if sometimes the UI are complicated to understand. They can be potentially useful for demonstrating the need for more TEK documentation in some regions and ask for more funding and participant activity in those places.
	Validation	Even if the knowledge documented is not immediately validated it might have value for the participants, the rating and commenting system in CONECT-e is a good way to support some sort of peer validation of the information
Opportunities	Schools	CONECT-e could be further disseminated in schools via the teachers, give them the tool but also do more follow-ups.
	Connections	CONECT-e could foster connections between similar platforms if more hyperlinks were introduced, also connecting participants to events and announcements related to TEK conservation.
	Connections	The platform is useful to connect users (although this could improve a bit), that is somebody posts new information others can see it and comment it.
	Platform as tool	Agricultural technicians have been doing landrace catalogs for years that are not so known, CONECT-e could be a tool to share (and sometimes rescue) this work if more synergy is built with this group of potential participants.
	Schools	Intergenerational activities with groups of students can be more widespread, introducing CONECT-e in school curricula.
	Connections	There is potential for creating a forum panel in CONECT-e to increase user interactions
	Red de Semillas	There is potentially more synergies to be built between Red de Semillas and CONECT-e, also with the local seed networks.

DISCUSSION

Results from this work shed light on the participation dynamics in CONECT-e and how they are shaped by participation barriers and drivers. In this section, we discuss our results in the light of previous research findings. We end this discussion by highlighting several caveats that might affect the empirical results presented here.

Disentangling participation barriers and drivers in CS

Although CONECT-e was not able to overcome the education and technological barriers (registered participants were highly educated and active ICT users), the project managed to attract female and rural participants who usually have a lower-profile presence in CS and science in general (Stephens 2013; Dawson 2019; Graham et al. 2014). Indeed, as opposed to other CS projects (Haklay 2016), registered participants' gender was balanced and we found no significant differences in activity between genders, meaning that both female and male participants were equally active in CONECT-e.

Nevertheless, having wider diversity of enrolled participants in CS does not necessarily mean that participation barriers are overcome, since participant activity might still be uneven. In CONECT-e, for instance, even though the project attracted some elderly and rural participants, their engagement in terms of measurable actions was significantly lower than expected if activity and age/residence were independent. In other words, even if elderly people in rural areas registered in CONECT-e, on average they did less measurable actions than other participants. Although potentially biased by the fact that the platform was promoted through a school program (boosting active participation of younger participants), these results seem to confirm that overcoming the age and rurality participation barriers is challenging in technology-mediated citizen science, as had been the case for other CS projects (Schrögel et al. 2018; Graham et al. 2014). Indeed, workshop participants highlighted that technophobia or unease with the use of digital technologies was one of the main barriers to participation, even if the topic of the project (TEK documentation) was familiar and relevant to elderly and rural populations.

This finding could be simply the expression of the existing rural/age ICT-use gaps (Graham et al. 2014). As argued by Newman and colleagues (2012), adaptation of technologies and greater intergenerational communication are necessary to overcome such barriers. However, our qualitative results suggest that it could also be signaling the complexity of bridging scientific and lay knowledge systems in a situation where knowledge hierarchies still exist (Agrawal 2002; Nadasdy 1999). Indeed, workshop participants argued that a lack of confidence in the reliability of one's own data and difficulties in following the scientific classification of TEK were barriers to participation. These results resonate with previous work, which highlighted that, in industrialized contexts such as the one in our case study, TEK has been widely despised and its value has been undermined (Naredo 2004; Reyes-García et al. 2015; Benyei, Calvet-Mir, et al. 2020). This devaluation of TEK potentially could have led some participants to feel that their knowledge and expertise were not sufficiently legitimate to contribute to a project hosted by a university. Moreover, beyond the specific context of TEK devaluation, these results are in line with other examinations of CS that highlighted that low self-value and other epistemic barriers pose a challenge to diversified participation (Forte and Bruckman 2008; Strasser et al. 2019; Dawson et al. 2019). In our case study, the platform structure followed a scientific logic, documenting TEK into categories that might not be familiar or relevant to the people using this knowledge. Thus, although the project tried to create an extended peer community of lay and scientific actors with diverse epistemologies including ethnobotanists, farmers, activists and students, it did not manage to completely overcome the lay/scientific knowledge divide that characterizes normal science and that CS aims to level out (Funtowicz and Ravetz 2003).

When looking at the factors driving participation in CONECT-e, and in contrast to other CS projects examined in which the main motivation was contributing to science (Curtis 2015), we found that having political motivations aligned with the project's objectives (prevention of TEK, loss and sharing TEK) was associated with active participation. Moreover, as reported in similar studies (Nov, Anderson, and Arazy 2010), our results show that being affiliated with the project's core groups (partner school, Red de Semillas, or scientific team) is associated with a participant's activity. These results might relate to the support and dissemination efforts given to these specific groups, but it might also reflect the conceptual and practical alignment of these groups with the project (e.g., having common purposes and methods) and the relationships of trust and transparency built up by the project with some participant groups. Indeed, workshop participants reported that aligning with the project goals and trusting the individuals developing the project were drivers of participation. Thus, partnering with key actors and organizations with similar goals, such as Red de Semillas, in our case, is important not only for driving and sustaining participation, but, most importantly, for making the project meaningful and trustworthy for participants. More so, it is important to highlight the relevance of compensating these groups for their engagement, be it economically or with other kinds of support/compensation strategies. In CONECT-e, for instance, Red de Semillas was compensated financially (managed collectively and internally), and the schools received books on traditional ecological knowledge for their libraries. Although compensating participants in CS is a highly debated topic (Aisling Irwin 2018), it is common practice in community-based monitoring and other environmental justice initiatives that rely on equitable and bottom-up partnerships (Liboiron and Molloy 2017).

Finally, it is important to highlight that project features seen as barriers to participation can also be seen as participation drivers depending on the context. For instance, in the case of CONECT-e, workshop participants talked about the categorization and compilation of TEK as both a participation barrier (conflicts between the categories and the holistic nature of TEK) and a driver (having a single organized repository for this information). More so, the fact that TEK is being rapidly lost was seen as both a participation barrier (lack of data) and a driver (encouraging participants due to the urgency of the issue). Furthermore, workshop participants talked about trust both as a participation barrier (distrusting the institutions and bio-pirates) and driver (trusting the project team). The issue of trust is key in CONECT-e, since TEK misappropriation is a very tangible matter, and the project strategy to avoid it through copyleft licenses was not well understood or trusted, especially at the beginning of the project. Thus, solving participation barriers and strengthening the features driving participation in CS can be tricky and will really depend on the goals and participants of the project and the moment in the project life cycle.

Participation dynamics in CS: beyond participation as single actions

Our results suggest that CONECT-e does not follow the "90-9-1 rule" referring to unequal participation in technology-mediated knowledge co-production projects. Despite the long-tailed distribution of participant actions, with most participants not doing any measurable action and a small minority of participants responsible for most of the contributions, the proportion of active participants in CONECT-e (24%) was higher than reports from similar projects such as Wikipedia, Stardust@home or SETI@home (Nov, Arazy, and Anderson 2011; Haklay 2016; Fuster Morell 2010).

However, the threshold that defines a meaningful contribution, allowing us to define a participant as "active," is very context-specific and thus open to discussion. The "90-9-1 rule" was defined on the basis of contributions to online documents and blogs (Haklay 2016; Nielsen 2006). In these contexts, the types of actions a participant can do are quite homogeneous (adding or editing text) and quantifiable (number of words, number of posts etc.). Yet, establishing a threshold to define whether a participant is part of the top 1% in platforms such as CONECT-e, in which actions can be of different types (e.g., posting a picture vs. editing a text) and some actions are not measurable (e.g., talking with someone about the content you read), is more complex. Does posting fifty pictures and editing some text written by others make a participant more active than drafting one new long and detailed entry? The number of individual actions is a good quantitative summary of participation, but, as also reported by other authors (Ponciano and Brasileiro 2014), it falls short of describing the complexity of participation typologies.

Indeed, considering the complexity of participation dynamics in CONECT-a that was also highlighted for other online CS projects (Aristeidou, Scanlon, and Sharples 2017), we suggest that participation in CS digital platforms might be better understood in the framework of ecosystemic participation, used for OCC (Fuster Morell 2010). More specifically, we propose that the diversity of participation configurations (active and passive participation, with different roles and levels of engagement) be considered as functional diversity in an ecosystem (i.e., the range of organisms' interrelated functions in natural ecosystems). For instance, in the case of CONECT-e, any participant, regardless of their number of contributions/actions, can be learning and applying the TEK contained in the platform. Thus, even participants who are only browsing through or sharing the content can still be considered main contributors to the ultimate goal of generating a TEK commons, which requires knowledge production but also sharing and use (Calvet-Mir et al. 2018). Indeed, if we look through the ecosystemic participation lens (which would require additional measurements, see the caveats section below), participation in CONECT-e should be viewed as interdependent layers of actions, as opposed to independent aggregated single actions (Fuster Morell 2010). For example, one layer would be contributing one's own knowledge, another layer would be contributing third party knowledge and acting as an intermediary between knowledge holders and the platform, an additional layer would commenting and editing content based on third party or one owns' knowledge, as well as reproducing the knowledge in other forums or applying the knowledge in practice. All these layers are interdependent and contribute to the ultimate goal of the project.

Caveats

Three main issues related to our research methods might have influenced our results and should be taken into consideration when establishing conclusions from our work.

Firstly, we examined participation during CONECT-e's first year. Our results on participation dynamics may therefore be biased by the participation surge that most projects initially experience, which is hard to maintain in the long term (Nov, Arazy, and Anderson 2011). Indeed, since the future development of the platform is currently uncertain and depends on additional funding and its maintenance by the community of participants who set it up, our conclusions are partial and should be re-examined after some time.

Secondly, the evaluation workshop was conducted with a relatively well-engaged subset of project participants (members of Red de Semillas). Thus, our results are not so useful for ascertaining the participation barriers and drivers that influence passive CONECT-e participants. Furthermore, as it often happens in research on CS participation, we generally lack information about the identity and motivations of those who visited the platform without registering, and thus our results on barriers and drivers do not explain the behavior of this group. We only measured content creation, editing, and validation/elimination actions, leaving out some important types of participant activity such as platform visits and content sharing. Moreover, we focused on individual actions of registered participants, while it could be argued that individual participation in CONECT-e stands on the shoulders of the collective efforts of generations of TEK guardians. These flaws could be affecting our results regarding the relationship between participant profile and activity patterns, since we can only establish conclusions about the individual profiles of registered participants and the activity patterns of those participants doing measurable actions.

Thus, we lack the necessary information to further explore the ecosystemic approach to participation in CONECT-e. In order to obtain this information we should have used automatic data collection tools (cookies, etc.) to measure the profiles of non-registered participants, and questionnaires to measure content reproduction activities. Yet, applying these types of methods poses a serious challenge to the data sovereignty of participants and can be tricky to apply considering that already unengaged participants might not be willing to answer a questionnaire.

Finally, since we measured motivations with a closed categorical variable upon registration our results might not reflect the diversity and complexity of motivational drivers of participation. Although we drew on previous research to select the motivation categories (Rotman et al. 2012; Nov, Anderson, and Arazy 2010), a relatively large proportion of participants stated they had "other" motivations (10% of total participants, 28% of active participants). Moreover, participants with "other" motivations were significantly more active. However, since the question was not open-ended, we were not able to discern these "other" motivations.

CONCLUSION

Three main conclusions can be drawn from our results. Firstly, overcoming education, age, and residence barriers to active participation in CS is challenging even in co-created projects. This is potentially due to the perceived self-illegitimacy and low access to ICT of less educated, elderly, and rural populations. Secondly, participant alliance with the project's objectives and relationships of trust with the project team can be important driving factors for participation in CS, which is also shaped by a changing and diverse combination of individualistic and collectivistic participant motivations. Finally, there is a need to think beyond participation as single actions and regard participation diversity in CS as functional diversity in an ecosystem, since both active and passive participants can have complementary functions in terms of producing and reproducing knowledge.

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