Environmental Education Research

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ceer20

Multiple forms of engagement and motivation in ecological citizen science

Keren Kaplan Mintz, Ofer Arazy & Dan Malkinson

To cite this article: Keren Kaplan Mintz, Ofer Arazy & Dan Malkinson (2022): Multiple forms of engagement and motivation in ecological citizen science, Environmental Education Research, DOI: 10.1080/13504622.2022.2120186

To link to this article: https://doi.org/10.1080/13504622.2022.2120186

View supplementary material

Published online: 08 Sep 2022.

Submit your article to this journal

View related articles

View Crossmark data

Full Terms & Conditions of access and use can be found at
https://www.tandfonline.com/action/journalInformation?journalCode=ceer20

ENVIRONMENTAL EDUCATION RESEARCH
https://doi.org/10.1080/13504622.2022.2120186

Routledge
Taylor & Francis Group

Check for updates

Multiple forms of engagement and motivation in ecological citizen science

Keren Kaplan Mintz[a,b], Ofer Arazy[c] and Dan Malkinson[a,d]

[a]Shamir Research Institute, University of Haifa, Kazerin, Israel; [b]Department of Learning and Instructional Sciences, University of Haifa, Haifa, Israel; [c]Department of Information Systems, University of Haifa, Haifa, Israel; [d]Department of Geography and Environmental Studies, University of Haifa, Haifa, Israel

ABSTRACT
Although participation in citizen science can improve cognitive and affective learning outcomes, many citizen science projects exhibit low retention rates. By gaining an understanding of forms of engagement, reasons for ongoing participation, and the impact of project design on participant motivation and engagement, we can help keep people involved in such projects. We address these issues by investigating motivational drivers and forms of engagement among volunteers in an ecological citizen science project. Our mixed-method approach involved interviews conducted with 26 core participants and questionnaires completed by 89 participants. Our analyses reveal an array of motivational drivers and various forms of engagement. While seeking to contribute to nature conservation was an important motivation for joining the project, the primary driver for ongoing participation was learning through social interactions. Moreover, the citizen science project design influenced participants' motivation and engagement.

ARTICLE HISTORY
Received 9 November 2021
Accepted 26 August 2022

KEYWORDS
Citizen science; engagement; motivation; project design; informal learning

1. Introduction

Citizen science (CS), defined as public participation and collaboration in scientific research, has been recognized as an important element in the conceptualization of open science (European Commission). Given its dual emphasis on research and education and its facilitation of free-choice learning, CS is also categorized as a form of informal science education (Bonney et al. 2009a; Phillips et al. 2019). Participating in CS can improve people's knowledge about scientific methods, promote scientific literacy, and impart various skills (Bonney et al. 2009a). It may also promote affective learning outcomes such as improved attitudes toward science, self-efficacy, and increased motivation for action (Fischer, Cho, and Storksdieck 2021). Many CS projects focus on environmental topics and hence can promote both conservation and environmental education outcomes (Ardoin, Bowers, and Gaillard 2020; Ballard, Dixon, and Harris 2017; Wals et al. 2014). Furthermore, participation in such projects often involves free-choice learning, direct contact with the natural environment, and social interactions with other participants, all of which are considered to be important aspects of environmental, experiential, and social learning (Ballard,

CONTACT Keren Kaplan Mintz kmintz@univ.haifa.ac.il Shamir Research Institute, University of Haifa, Kazerin, 1290000, Israel.
Supplemental data for this article can be accessed online at https://doi.org/10.1080/13504622.2022.2120186.
© 2022 Informa UK Limited, trading as Taylor & Francis Group

Dixon, and Harris 2017; Falk 2005; Tal 2012). Commitment to lifelong learning is an essential part of environmental education (Reid et al. 2021; UNESCO 1977). In addition, environmental education for adults and community engagement activities can offer rich opportunities for engaging the public in environmental issues (Reid et al. 2021). Many ISE organizations have acknowledged the contribution of CS to lifelong learning and have begun collaborating with STEM researchers to co-design CS experiences for diverse audiences (Bell et al. 2016). It is therefore important to develop CS projects in a way that will encourage ongoing engagement.

Nevertheless, despite CS's clear potential in promoting public engagement and environmental learning, challenges still exist in designing projects so as to encourage long-term retention rates (Bonney et al. 2016; Fischer, Cho, and Storksdieck 2021). In many CS projects, most volunteers perform only a few tasks before leaving the project. Similar to the trend seen in online shared data projects, a relatively small number of volunteers make most of the contributions (Haklay 2018; Nov, Arazy, and Anderson 2011; Segal et al. 2015). To address these issues, research is needed to investigate the factors affecting the qualitative and quantitative aspects of participation and retention rates.

Recent studies have examined people's motivations for participating in CS projects and the factors affecting retention rates (Maund et al. 2020; Nov, Arazy, and Anderson 2014; Rotman et al. 2012; West, Dyke, and Pateman 2021). One important factor in the context of retention rates is the extent to which volunteers' activities address their psychological needs (Clary and Snyder 1999). In the case of CS, several aspects of project design, among them opportunities for learning provided by participation, feedback from scientists, and opportunities for communication among volunteers, are considered important and may encourage ongoing participation (Bonney et al. 2016; Nov et al. 2013; Golumbic, Baram-Tsabari, and Koichu 2020b; Rotman et al. 2012). Yet, only a few studies thus far have examined how project design features support engagement and motivation for continuous participation. Furthermore, most research on CS engagement tends to focus on quantifying data contribution outputs (e.g. Nov, Anderson, and Arazy 2010) and therefore fails to capture the multidimensionality of engagement and its various cognitive, behavioral, and affective forms (Phillips et al. 2019). Another research void is related to the study participants. Researchers obtain most of their data from existing participants. Hence, very little is known about the motivation to join a project and the perceived barriers of those who temporarily join and leave soon after (Fischer, Cho, and Storksdieck 2021). Our study seeks to fill these gaps by investigating multiple facets of people's motivation to join and remain with an ecological CS project. The study examines different groups of participants and the relationship between these groups and project design.

2. Literature review

When designing CS programs, the planners must consider both the motivational drivers for joining such a project and the forms of participation. These factors are differentiated in that motivation refers to 'why' (reasons for joining or for continuing to participate in a project), whereas engagement refers to 'how' (forms and means of participation) (Phillips et al. 2019; Reeve 2018). Engagement is often conceptualized as a result or a facet of motivation (Reeve 2018; Ryan and Deci 2000). Nevertheless, research also acknowledges that engagement in certain activities can serve as a source of further motivation to participate in volunteer activities (Clary and Snyder 1999). Given that both operate within a sociocultural system and reciprocally influence one another, Phillips et al. (2019) contend that in CS research, motivation and engagement should be studied together. To obtain a comprehensive understanding of participation modes in a CS project, we propose investigating four facets of engagement and motivation: (1) motivation to join a project versus motivation for continuous participation; (2) qualitative

aspects of engagement; (3) influence of project design on engagement and motivation; and (4) link between engagement opportunities and motivation characteristics.

2.1. Motivation to join versus motivation for continuous participation

Two relevant theoretical lenses are often employed to explore motivations for informal learning and volunteer activity: self-determination theory (SDT) (Ryan and Deci 2000) and functional analysis theory (Clary and Snyder 1999). Both theories consider motivation as a construct that can be characterized not only by its level (i.e. how much motivation) but also by its orientation, and both explore motivation as a multidimensional construct. SDT highlights people's inherent motivational tendencies for learning and growth and how these tendencies can be supported. Central to SDT is the concept of intrinsic motivation, which refers to doing something because it is inherently interesting. This form of motivation contrasts with extrinsic motivation, which refers to doing something because it leads to a separate outcome. Intrinsic motivation supports basic psychological needs such as autonomy, competence, and relatedness (Ryan and Deci 2000). Given the voluntary nature of CS, the concept of intrinsic motivation is suitable for investigating the motivation to engage in such projects (Nov, Arazy, and Anderson 2014; Phillips et al. 2019). The functional approach to motivation was developed specifically in reference to volunteer activity and suggests that the actions people perform can support different psychological functions (Clary and Snyder 1999).

Several studies have employed these theories to explore motivation in CS (e.g. Alender 2016; Lopez 2021). Yet only a few have examined how different sources of motivation lead to different outcomes, such as level of participation and satisfaction (Golumbic, Baram-Tsabari, and Fishbain 2020a; Tiago et al. 2017). Process models of CS suggest that the motivation to participate changes over time (Rotman et al. 2012; West and Pateman 2016). Whereas joining a project may be based on a variety of motives, the motivation to continue participating is mainly related to perceptions of ongoing learning and the desire to contribute to science and the environment (Cox et al. 2018; Tiago et al. 2017). West and Pateman (2016) identify three stages of participation: decision to participate, initial participation, and sustained participation. These researchers also suggest that many of the people who sign up for projects do not even proceed to the stage of initial participation. Furthermore, many citizens who join a project merely because of curiosity do not participate on a regular basis (Golumbic, Baram-Tsabari, and Fishbain 2020a). Therefore, general interest in the topic of a particular program is not in itself a sufficient motivation for participation (Fischer, Cho, and Storksdieck 2021).

2.2. Qualitative aspects of engagement

Engagement refers to individuals' active involvement in a task (Reschly and Christenson 2012). Engagement is commonly defined as a multidimensional construct with four aspects: emotional, cognitive, behavioral, and agency (Reeve 2018; Reschly and Christenson 2012) and is considered one of the ways in which motivation is articulated (Reeve 2018). According to Phillips et al. (2019), whereas many disciplines examine engagement through a multitude of theoretical perspectives, among them affective, behavioral, cognitive, and sociocultural lenses, most studies of CS engagement focus on quantifiable measures related to data contribution or other output measures (Phillips et al. 2019). Degree of participation is the main aspect of engagement discussed in CS. In contrast, according to the multidimensional perspective of engagement, degree of participation is only one of several behavioral facets of engagement, along with time devoted to performing the task, effort, and persistence (Reeve 2018; Reschly and Christenson 2012). Phillips et al. (2019) claim that the exclusive use of quantitative data to measure engagement

leads to critical gaps in understanding the full range of engagement. According to these researchers, empirical research is needed to determine what constitutes engagement in CS. Accordingly, they proposed a framework for exploring engagement in CS as a multidimensional concept that encompasses cognitive, social, behavioral, affective, and motivational dimensions. In line with Phillips et al. (2019), we also advocate a multidimensional conceptualization of engagement, which Reeve (2018) contends should include behavioral, emotional, cognitive, and agency facets as well as a social facet as suggested by Phillips et al. (2019).

2.3. Influence of project design on engagement and motivation

Understanding the influence of project design on participants' motivation and engagement can help in developing CS projects that better suit participants' needs and preferences. Project design includes organizational aspects, among them the types of scientific activities in which the public is involved (Bonney et al. 2009a), the feedback provided to participants (Rotman et al. 2012), and the forms of social interactions between project members (Rotman et al. 2012; Sagy et al. 2019). Acknowledging the effect of project design on motivation and engagement may help retain volunteers and increase their engagement. Nevertheless, thus far only limited research has addressed this topic (Golumbic, Baram-Tsabari, and Koichu 2020b; Rotman et al. 2012). In the present study we focused on four aspects of project design:

2.3.1. Type of scientific activity:

Based on the project's scientific objective, CS can entail various scientific activities, including monitoring together with complex designs and even experiments (Bonney et al. 2009b). In some projects, participants are asked to adhere to specific protocols. Other projects are more opportunistic and open-ended, with no specific guidelines (Henckel et al., 2020). Often the choice of protocol is based on scientific considerations and does not account for participants' preferences, needs or motivations.

2.3.2. Learning opportunities:

Successful CS projects provide participants multiple opportunities for learning, such as online learning materials and offline learning opportunities (Bonney et al. 2016; Golumbic, Baram-Tsabari, and Koichu 2020b).

2.3.3. Feedback:

CS feedback can be personal (referring to the volunteer's activity) or collective (referring to the outcome of the entire project). Recognition of individual contributions and constant collective feedback from scientists about the group's overall contribution are important factors in promoting ongoing motivation (Rotman et al. 2012).

2.3.4. Opportunities for social interactions:

Another common feature of successful CS projects is that they provide opportunities to promote social interactions among the participants through online forums, chat rooms, and other social network tools (Golumbic, Baram-Tsabari, and Koichu 2020b; Sagy et al. 2019). Many of these interactions take place through 'communities of practice' (Sagy et al. 2019; Sbrocchi et al. 2022): communities in which individuals engage in joint activities and build relationships that enable them to learn from each other (Wenger 2010). These interactions can take place either virtually or through face-to-face interactions. Nevertheless, face-to-face interactions have proven to be

an important mechanism for facilitating quality relationships and providing opportunities for learning (Sbrocchi et al. 2022).

2.4. Aligning project design with participants' needs

The motivation for ongoing participation is based on compatibility between the project design and the participants' needs (Lopez 2021; West and Pateman 2016). Some common project features are important for promoting engagement and motivation among all participants. Yet it is also important to acknowledge individual variations in participants' needs and expertise (Bonney et al. 2016). Given that people's reasons for becoming involved in volunteer work vary, as do their personal needs, the extent of their ongoing participation will be related to the extent to which their contribution fulfills their psychological needs (Clary and Snyder 1999). Nevertheless, more research is required to understand interpersonal differences and how they affect people's activity and willingness to continue their involvement in CS projects.

The present study aims to explore variations in motivation and engagement. Specifically, we have two goals. First, we investigate motivational dynamics and engagement among volunteers who contribute to a project on an ongoing basis (the core group). Second, we examine similarities and differences in motivation and in perceived barriers to participation among groups of volunteers who differ in the extent of their contribution to the project. Thus, we investigate the following research questions:

(RQ1) What characterizes the motivation and engagement of the core group participants?

(RQ2) To what extent is motivation for continuous participation among core group participants aligned with their initial motivation to join a project?

(RQ3) How do perceptions of the project design influence participants' engagement and motivation for ongoing participation?

(RQ4) To what extent are differences in participation levels linked to variations in participants' motivation to join and to their perceived barriers to participation?

3. Methodology

3.1. Setting

The research setting is a biodiversity monitoring CS project carried out in a rural area in northern Israel. The project was initiated by the local municipality in collaboration with a research team from the University of Haifa. The project's objectives were to collect data on fauna and flora in the region and to engage the local community in nature exploration activities, with the specific goal of increasing residents' affinity for the local environment. A part-time employee of the regional council who is an expert naturalist and a curator for the global iNaturalist platform serves as the community manager. This job entails encouraging participation, curating the contributed observations, and teaching observers the monitoring procedures. All data collected in the project are posted on the project's website and the iNaturalist website so that participants and non-participants can monitor it. Participant recruitment for ecological CS projects can include both local residents and tourists (Schaffer and Tham, 2019). In the present project the focus was on local residents. The organizers sought to recruit a diverse group of participants, who differed in terms of residential locality (as people tend to sign up close to their place of residence), age, gender, and biological/ecological expertise (so that the reports would cover a variety of taxa and species). Table 1 summarizes the project design characteristics.

Table 1. Characteristics of the project design.

Characteristics	Description
Type of scientific activity	Upload observations about local animals and plants to iNaturalist using a mobile phone or through a computer. Three participants served as iNaturalist curators. Participants could also provide identifications of their own observations or identify the observations of other participants.
Guidance characteristics	An open, unstructured protocol. There were no fixed guidelines regarding what, where, how much, or when to monitor. In addition, no guidelines were provided regarding procedures such as the number of pictures to take at a certain location.
Learning activities	Volunteers who participated on a regular basis were invited to take part in a WhatsApp group and occasional face-to-face field excursions. The core group contained about 40 participants. During the excursions, participants engaged in joint learning about local biodiversity. The community participants used WhatsApp to share interesting observations, ask questions, and exchange knowledge on other environmental issues related to local flora and fauna. For other participants the project did not provide organized learning activities or a virtual community open to any new registered volunteers.
Individual feedback	After an observation was identified, automatic feedback (in English) was received from the iNaturalist platform.
Group feedback	The lead scientist on the project provided information once on the data accumulated and scientific conclusions.

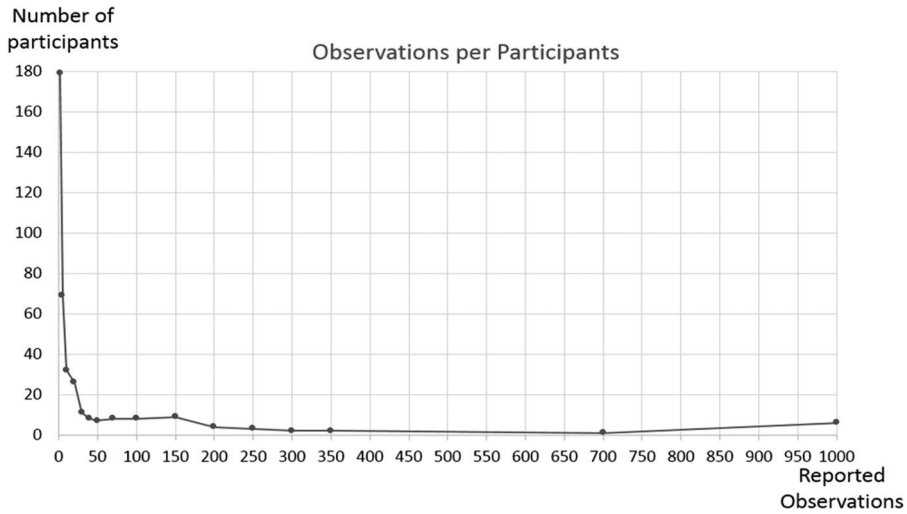

Figure 1. Distribution of participants.

The project was formally launched in January 2016. During its first two years, the organizers conducted various activities to increase participation among local residents. As part of these recruitment activities, people were encouraged to download and log into the project app. Apparently, however, many of them did not use the app at all. When the current study began, more than 700 people were registered for the project. Of these, only 350 had uploaded observations. Among those who uploaded observations, most (250) uploaded fewer than ten (Figure 1). The distribution depicted in Figure 1 is common for CS projects as well as for other forms of online volunteer projects. Yet, given that one of the objectives was to engage local community members in the project, the leaders were interested in determining the factors that promoted participation or that served as barriers. They also sought to understand what differentiates those who participate regularly from other registered members.

3.2. Methods

We employed a mixed-method approach to data collection and analysis. This approach enabled us to identify general patterns and conduct a deeper analysis of processes, so that it was suitable for studies that incorporate qualitative and quantitative research questions (Johnson and Onwuegbuzie 2004). First, we conducted semi-structured interviews with 26 of the project's core group participants. Researchers have established that using open-ended questions is helpful in assessing multiple aspects of motivation and engagement (Mintz and Tal 2014; Phillips et al. 2019). The qualitative exploration provided us data regarding how the core participants engage in the project and the sources of their motivation. The second part of our study was an online questionnaire distributed to all registered participants. We used this method to investigate the reasons for variations in participation, the between-group differences in ongoing participation, and participants' perceptions of the project design. The interviews sought to address all of the research questions. The questionnaire was designed to address RQ3 and RQ4. The research received ethical approval (IRB) from the University of Haifa, No 141/19.

3.2.1. Data collection

The interviews were designed to provide a comprehensive understanding of participants' motivation for joining the project and continuing to engage in it. Email invitations were sent to 32 participants from the core group, defined as observers who had participated in the project on a regular basis for at least one year. Of these, 26 agreed to be interviewed (81.25% participation rate). The interviews were conducted over the phone, audio-recorded, and transcribed. An informed consent statement was included at the beginning of the interview.

The online questionnaire was distributed via email to all 754 registered project volunteers, along with a letter describing the goal of the survey and explaining that participation was voluntary and confidential. Two reminder emails were sent approximately two and four weeks after the initial invitation. An informed consent statement was included at the beginning of the survey. To achieve an objective measure of the behavioral variable 'number of observations uploaded,' we sent the survey separately to six groups of participants classified according to the number of observations they had uploaded (0; 1–5; 6–20; 21–50; 51–100; 100+). A total of 89 participants responded. The response rate naturally varied between the groups: In the '0 observations' group the response rate was 6%, in the 100+ observations group it was 52%, and in the other groups it ranged from 14% to 33%. Given that three of the groups contained fewer than ten participants, we merged the groups into three representative groups of participation level: participants who did not contribute at all (Group 1, $n = 32$); participants who contributed between 1 and 50 observations (Group 2, $n = 42$); and participants who contributed more than 51 observations each (Group 3, $n = 15$).

3.2.1.1. Interviews. The interview questions focused on sources of participants' motivation to join the project, sources of motivation to continue participating, descriptions of participants' engagement, and descriptions of the barriers to participation they encountered. Examples of the interview questions include the following: (1) 'Why did you join the project?' (2) 'Describe your activities as a participant'; (3) 'What motivates you to continue participating?' (see the supplementary materials).

3.2.1.2. Questionnaire. As most registered participants did not participate in the project on a regular basis and did not upload observations, the questionnaire focused on exploring their reasons for joining the project and their perceived barriers to participation, as well as differences in these variables among the three groups described above. The

questionnaire had several parts. The first item was an open-ended question asking participants to indicate their initial motivation for joining the project. In the second part, participants were asked to indicate the extent to which four different barriers prevented them from uploading more observations, on a 5-point Likert scale ranging from 1 = did not affect me at all to 5 = affected me very much. The content of the items was based on barriers described by the interview participants: (1) technical problems in operating the app; (2) time required to upload the observations; (3) lack of a community with which one can observe nature and upload observations; and (4) lack of awareness of the project while one is outdoors. The third part included demographic details such as age and gender (see the supplementary materials).

3.2.2. Data analysis

3.2.2.1. Interviews. Analysis of the interviews was inductive and deductive. First, we looked for emerging themes in the data and identified categories and sub-categories. Next, we aligned our categories with categories that had already been established in the literature (Morgan 2007). We analyzed the data in three phases: coding, applying the principles of grounded theory (Charmaz 2006; Straus and Corbin, 1990), and content analysis (Krippendorff, 2019). The first phase entailed open coding of five interviews based on carefully reading each line of the transcript and categorizing it into one or more categories and sub-categories. Based on the literature review, we then developed a codebook that defined each of the categories and sub-categories. The second phase involved establishing inter-coder reliability through peer debriefing of two coders: the first author and a research assistant who was a graduate student in psychology. Using the codebook, these two coders independently analyzed the data from nine interviews and refined the distinctions between the sub-categories and the definitions until reaching 80% inter-coder agreement (Campbell et al., 2013). In the last phase, using the refined codebook the first author continued applying focused coding to the remaining interviews (Charmaz 2006). The content analysis revealed four categories: motivation to join, motivation to continue participating, engagement, and perceived barriers. Each category was further divided into sub-categories. All together, we identified 13 sub-categories. In cases of overlapping units, we followed the suggestion of Krippendorff (2019: 165–6) to conduct double coding. Each code was treated as a binary variable (either present or absent), such that each segment text could be attached to more than one code. As Krippendorff suggested, this method yields a data language that allowed us to conduct more complex analyses. Table A1 in the supplementary materials shows the definitions used in the codebook and examples of statements for the sub-categories.

3.2.2.2. Questionnaire. We analyzed the questionnaire using SPSS-25 software.

4. Results

4.1. Motivation and engagement of the core group

The overall analysis of the interviews explored and characterized the patterns of engagement and motivation among all interviewed participants and also compared participants from two groups: (1) the highly contributing group (Group 1, $n = 9$), who had contributed most of the

data to the project (at the time of this research > 100 observations); and (2) the moderately contributing group (Group 2, $n = 17$), who also continuously participated in the project, but reported fewer than 100 observations. All members of Group 1 except one worked in areas related to nature and botanical research (e.g. a biology teacher, a fieldtrip guide, a biology researcher), and three of them served as project curators. Four of them were women. Six were over the age of 65, and three were already retired. Among the 17 interviewees in Group 2, 11 worked in occupations related to environmental protection and research. Their ages were more varied, ranging from 30 to 67, and nine of them were women.

To gain deeper insights into their patterns of motivation and engagement and how the project design affected them, for each group we counted the number of statements that referred to each research category and its sub-categories. We then calculated the ratio of responses per participant. Given that the groups did not contain an equal number of participants, this method enabled us to compare the two groups on a standardized scale.

4.1.1. Motivation for participation and project design

Table 2 depicts the distribution of the results pertaining to motivation for joining. Since each participant could give more than one reason for joining the project, the sum of the responses could exceed the number of participants in a group. We identified a total of 32 statements for this category. As the table indicates, in both groups the leading reason for joining the project was interest in gaining knowledge, followed by a desire to contribute.

Table 3 shows the results for motivation to continue participating. This category included 60 statements: 26 in the highly contributing group, constituting 2.89 responses per participant, and 34 in the moderately contributing group. However, the distribution of motivational dimensions was similar in both groups. The most common source of motivation for ongoing participation was learning, with a total of 17 statements describing learning as an important motivational source. Learning during fieldtrips and social learning with and from other people were also repeatedly mentioned. Opportunities for social interactions also served as one of the leading motivational sources for continuous participation. Opportunities both for learning and for social interactions are based on the online platform's affordances and the way in which the project is structured, designed, and managed. Hence, a project's design can influence participants' motivation and engagement.

Furthermore, it is important to note that the contribution made by social interactions to participants' motivation did not focus on social interactions per se. Rather, it was based on social interactions with people who were experts in nature exploration and were interested in the topic and in the possibility of exploring nature together with others. Here are two examples: 'Interacting with people from the area who are interested in nature is something very important

Table 2. Frequencies of responses for different sources of motivation to Join.

Group (N)	Contribution	Personal request	Knowledge	Sum	Response per participant
1 (9)	3	1	5	9	1
2 (17)	7	6	10	23	1.35
All (26)	10	7	15	32	1.23

Table 3. Frequencies of responses for different sources of motivation for continuous participation.

Group (N)	Emotional	Professional	Social	Learning	Contribution	Sum	Response per participant
1 (9)	5	3	6	8	4	26	2.89
2 (17)	7	3	8	9	7	34	2
All (26)	10	6	14	17	11	60	1.53

to me'; 'The community is a nice group. Being part of it is fun. We have social meetings and fieldtrips. A few months ago we had a mushroom project in which we focused on detecting and identifying mushrooms, and it was very enjoyable.' As mentioned, many of the interviewees were professionals working in nature-related fields. Therefore, one of their motivations for participating involved the possibility of supplementing their professional development and professional network. This unique aspect of the project design made it possible to form a community of practice and consequently enhanced participants' motivation and engagement. Making a contribution, which emerged as one of the three reasons for joining, was also one of the main reasons for ongoing participation in both groups. Finally, emotional motivation was also mentioned as a source of motivation for continuous participation. As one participant said: 'I enjoy this very much, and this is why I invest so much time in it.'

Taken together, the findings suggest that for this core group of participants, the reasons for ongoing participation are similar, although not identical, to their reasons for joining the project. In both cases, their interest in gaining knowledge and their desire to contribute to science were identified as important sources of their motivation. Nevertheless, their motivation for continuous participation was also based on three other factors: emotional, social, and professional.

4.1.2. Forms of engagement

The interviewees described various ways in which they were engaged in the project: cognitive, social, agentic, and emotional (Table 5). We did not include behavioral engagement in the analysis because the main participatory activity was behavioral (uploading observations). From the outset, the researchers knew the number of observations the participants had uploaded and used this information to distinguish between the two groups. In both groups, cognitive engagement was a central part of participant engagement and was expressed in about a third of the statements describing engagement (Table 6). Cognitive engagement was described in the context of uploading the observations and in the context of exploring the website. For example:

> 'When I upload an observation, I use a botanic guide to provide the exact identification.'

> 'When I upload observations on the website, I also look at other people's observations and photographs. It is very helpful to monitor all the information and see all the species names. After that you remember it; the information gets into your head.'

Table 4 . Frequencies of responses for different forms of engagement.

Group (N)	Agency	Social	Emotional	Cognitive	Sum	Response per participant
1 (9)	5	4	6	7	22	2.24
2 (17)	2	6	8	8	24	1.41
All (26)	7	10	14	15	46	1.77

Table 5 . Frequencies of responses on perceived barriers.

Group (N)	Technical barriers	Scientific feedback	App feedback	Social interaction	Sum	Response per participant
1 (9)	7	2	1	0	10	1.11
2 (17)	11	3	5	3	22	1.29
All (26)	18	5	6	3	32	1.23

Table 6 . Descriptive statistics of questionnaire participants.

Group	Number of observations	N	Women (%)	Age (SD)
1	0	32	62%	47.2 (15.2)
2	1–50	42	56%	42.8 (13.2)
3	50+	15	53%	51.7 (14.5)
Total		89	58%	45.9 (14.4)

Emotional engagement was also central to the interviewees' experience, as articulated through expressions of love, interest, and joy: 'I enjoy it all: the contact with nature, taking pictures, and knowing I am helping someone'; 'I am truly in love with the idea of this project'. The participants' unique examples of agency constituted another interesting finding. These examples included descriptions of extra efforts and/or creative thinking invested in enhancing and promoting the CS project. One such example was that of a volunteer who identified a new invasive bird species in the field and rushed home to get his camera and document it in order to upload the observation. Another volunteer talked about taking local kindergarten children and their teacher on monthly fieldtrips to explore nearby nature. On these fieldtrips they examined flowers and uploaded their pictures to the app, with the volunteer providing explanations. The volunteer stated that she hoped the children would tell their parents about these experiences and motivate them to join the project. The number of responses per participant was relatively higher among the highly contributing group than among the moderately contributing group, indicating that a higher level of participation was associated with more subjective descriptions of engagement (Table 4).

4.1.3. The links between engagement, motivation, and project design

The content analysis of the interviews with the core group participants enabled us to analyze the links between engagement and motivation in two ways. First, as described above, when overlapping units appeared in the qualitative content analysis, we performed double coding and attached the units to more than one sub-category. In analyzing engagement and motivational processes, this procedure aided us in detecting associations between the two. In several instances, one statement was appropriate both for describing motivation for continuous participation and for describing engagement. Here are two examples:

> Since becoming a member of this project, I have been more active and more engaged. I am more aware of nature. One of the things I enjoy in the WhatsApp community is the information provided about natural occurrences. They let us know about special events, such as bird migration, flower blooming and so on. Sometimes I go see these and sometimes I just enjoy the fact that I am involved. I could remain a member of this group without uploading observations, but I feel that if I receive so much, I need to give something in return.

> Everything related to this project has contributed to my knowledge. Definitely. These processes involve one person asking something and another answering, and sometimes I also answer, but of course I learn from others' responses as well. I knew nothing about mushrooms for example, so I have learned a lot. I think that the well-known Jewish principle according to which when you help others you also help yourself is very relevant here.

These excerpts exemplify how aspects of learning, emotional engagement, and social engagement are articulated together and have reciprocal effects. Not only does motivation lead to engagement, greater engagement also leads to stronger motivation for ongoing participation. It therefore seems that the connection between motivation and engagement in the project is bi-directional, such that participants who are more motivated are also more engaged. They upload many observations, take part in meetings of the community of practice, have higher levels of cognitive and emotional engagement, and also express agency engagement with the aim of enhancing the project as a whole. At the same time, participating in social learning activities satisfies internal needs and increases participants' overall motivation to contribute to the project on an ongoing basis.

The same conclusion emerges from comparing the following sub-categories: motivation to join, participation, and engagement. As aforementioned, within the group of core participants, the sources of motivation to join and continue to participate were similar and based on gaining knowledge and contributing. Similarly, learning and being involved in cognitive processes were central to participants' engagement. It therefore seems that having an opportunity to learn can

serve as a meaningful source of continuous motivation. Additionally, these examples also underscore how project design can facilitate both engagement and motivation. Namely, the project's administrators facilitated peer-learning and the formation of a community of practice, thus contributing to sustained participation. Being part of this community of practice served as a powerful driver for engagement in the project. The possibility of interacting through messaging (i.e. the WhatsApp group), the organized fieldtrips, and the opportunity to network with peers who are biodiversity experts—all important features of the project design—offered educational and social opportunities that promoted involvement, enhanced emotional, social, and agentic engagement, and ultimately increased the motivation for prolonged participation.

4.1.4. Perceived barriers for the core participants

The interviewees identified four types of perceived barriers to participation. Two were related to feedback: scientific feedback for the group, and personal feedback from the app after uploading observations. Participants in both groups also mentioned technical barriers in using the app (Table 5). Nevertheless, it is interesting to note that although most participants mentioned technical problems, these difficulties did not prevent them from continuing to participate. Each participant found his/her solution to work around them. Overall, the highly contributing group members talked less about the barriers, indicating that those who were more dedicated to the project were less concerned about barriers. Another difference between the groups is that the moderately contributing group members expressed a greater desire for feedback from the app.

Finally, we also asked the interviewees about their perceptions of the project's opportunistic monitoring protocol, namely, whether it served as a motivator for or a barrier to participation. Answers to this question were divided. Whereas those who were very active in the project preferred an open protocol, the moderately active group of participants preferred more guidance regarding the monitoring. For more details, please refer to the supplementary materials. This provides another example of how project design can influence participants' motivation and engagement, as the decision regarding the monitoring protocol (i.e. opportunistic monitoring) is an essential element of a project's design.

A summary of the interview analyses revealed one main theme central to all participants: the important role of learning in their engagement in the project and their motivation to contribute to the project on an ongoing basis. The community of practice organized by the project leader played an important role in providing this learning.

4.2. Between-group differences in motivation to join and in perceived barriers

Eighty-nine registered members of the CS project answered the questionnaire. Of these, 32 had never uploaded any observations. In order to address the second research question, we grouped the participants into three groups: no observations (group 1), 1–50 observations (group 2), and 50+ observations (group 3) (Table 6).

4.2.1. Motivation to join

An open-ended question in the questionnaire focused on the reasons for joining the project. Respondents' answers to this question were grouped into five categories: environmental concerns (e.g. 'I love nature'), willingness to contribute (to research/nature), knowledge (e.g. 'obtaining knowledge on nature in the area'), interest (simply implying: 'interest'), and professional reasons (e.g. 'I was asked by my workplace to join'). As some participants provided more than one reason for joining, we coded the answers in binary form (yes/no) (Table 7). Across groups, the most common reason for joining was willingness to contribute, followed by interest. It is interesting to note that concern for the environment was the leading reason for joining among those who ultimately did not contribute any observations (33.1%) and was mentioned by 23.9% of the participants in the second group (1–50 observations).

Table 7 . Motivation for joining the project among questionnaire participants.

Group	N	Environmental concern (%)	Contribution (%)	Knowledge (%)	Interest (%)	Professional
1	32	10 (31.3%)	5 (16%)	7 (21.8%)	8 (25%)	3(9%)
2	42	11 (26.2%)	18 (43%)	5 (11.9%)	8 (19%)	4 (9%)
3	15	0 (0%)	5 (33%)	2 (13.3%)	8 (53.3%)	0 (0%)
Total	89	21(23.6%)	28 (31.4%)	14 (15.7%)	24 (27%)	7 (8%)
Chi-Square value		5.83	6.28	1.44	6.70	1.54
Sig		0.054	0.04	0.49	0.04	0.46

Table 8 . Descriptive statistics of barriers among questionnaire participants.

Group	Technical (SD)	Time (SD)	Companionship (SD)	Awareness (SD)
1($n=32$)	2.06 (1.46)	1.91 (1.25)	2.16 (1.19)	2.59 (1.54)
2 ($n=42$)	2.52 (1.47)	2.50 (1.4)	1.95 (1.3)	2.21 (1.24)
3($n=15$)	2.40 (1.35)	2.07 (1.33)	1.53 (1.13)	1.53 (.92)
All ($n=89$)	2.34 (1.45)	2.21 (1.35)	1.96 (1.24)	2.24 (1.35)

This finding indicates that environmental concern by itself may serve as a reason for joining an ecological CS project of this nature but is not sufficient for people to contribute. On the other hand, willingness to contribute was mentioned as a reason for joining among a third of the third group ($n=5$) and 43% ($n=18$) of the second group, but only among 16% ($n=5$) of the first group, with significant between-group differences (chi-squared (6.28), $p=0.04$). Interest was also relatively higher among members of the third group compared to the other two groups (Chi-square (6.70), $p=0.04$). There were no significant group differences with regard to learning and professional reasons.

4.2.2. Perceived barriers

We identified four barriers to participating: technical constraints related to the app, time required for uploading, lack of companionship in nature observations, and lack of awareness of the project while outdoors. Participants were asked to rank to what degree each barrier prevented them from uploading observations on a 5-point Likert scale (1 = not at all; 5 = very much). The highest ranking barrier was technical constraints related to the app, followed by lack of awareness of the project while outdoors. We conducted an ANOVA to test the between-group differences in perceived barriers (Table 8).

Significant differences emerged for lack of awareness of the program ($F=3.34$ $p < .05$, df =2). A post-hoc Bonferroni test revealed that the source of the difference was a higher level of lack of awareness among the first group compared to the third. Some of these barriers, such as the smartphone app, are related to project design, whereas others, such as lack of companionship during nature observations, are less directly related to project design. Together, our findings show that decisions regarding project design can serve both as facilitators and as inhibitors for participants' motivation and engagement.

5. Discussion

We undertook this research to gain more insights into the nature of engagement in CS. In-depth interviews with core participants in an ecological CS project yielded abundant information about the multidimensional nature of engagement and the reciprocal relationships between engagement and motivation. Furthermore, our findings revealed various sources of ongoing motivation, among them emotional, professional, social, learning, and contributing motivation. These findings

are in line with previous literature that conceptualized engagement and motivation as multidimensional concepts, as posited by the self-determination theory (SDT) (Ryan and Deci 2000) and the functional analysis theory (Clary and Snyder 1999). Furthermore, our findings highlight the importance of examining motivation and engagement using complementary quantitative and qualitative methods.

The questionnaires answered by the broader community provided additional insights. They identified differences between subgroups of members in terms of motivation to join a project and perceived barriers to participating. In particular, our study sampled a subgroup that is rarely included in studies of motivation and engagement (Fischer, Cho, and Storksdieck 2021): those who registered for the project but did not actively participate (West and Pateman 2016). In the sections that follow, we highlight the novelty and contributions of this study.

Prior studies in environmental education have stressed the importance of a whole-person approach to learning that involves the learner's knowledge, skills, and affective attributes (Mintz and Tal 2014; Margaret et al., 2010; Sipos et al., 2008). The current study contributes to this literature by demonstrating how participation in an ecological CS project can facilitate such a holistic learning process by enhancing participants' cognitive engagement together with their emotional engagement and social engagement, and in some instances also heightening participants' agency. In line with previous research (Fischer, Cho, and Storksdieck 2021; Rotman et al. 2012; West and Pateman 2016), we found that the motivation to participate developed over time. There is a difference between the motivation to join and the motivation to continue participating. The current study adds to previous literature by demonstrating the importance of social, emotional, and professional motives in fostering ongoing participation. Furthermore, our results show that whereas nature protection is an important motivation for joining the project, the desire to learn and to socialize with others are more salient motives for promoting ongoing participation. This insight is in line with prior studies of online communities, which demonstrate that ideology and collective goals, such as protecting nature, are often a necessary condition for joining a project but are not sufficient for driving continuous participation (Schroer and Hertel, 2009).

By examining the various ways in which participants engage with the project, this study sheds light on the reciprocal relationships between motivation and engagement throughout the life of the project. Motivation drives initial and ongoing participation, but these are also shaped by the members' experiences. In particular, active engagement in the project enhanced participants' emotional connections, their commitment, and consequently their motivation to continue contributing. Such reciprocal relationships between motivation and engagement have rarely been documented in studies examining online communities (Balestra et al., 2017). Indeed, to the best of our knowledge this is the first study to investigate this reciprocal relationship between motivation and engagement in CS projects.

Our findings concerning participants' preferences regarding project design alternatives also contribute to the literature. We established that participating in the community of practice served as a strong driver for engagement. At the same time, as aforementioned, other aspects of the ecological project design, such as the limited social and scientific feedback and various technical constraints, served as barriers to participation. Notwithstanding these constraints, we maintain that providing all members—existing and new—with meaningful learning activities that offer opportunities for social interactions is likely to promote participant engagement. Whereas previous literature has discussed the role of project design in shaping participant motivation (Rotman et al. 2012; West and Pateman 2016), very few CS studies have addressed this aspect. Thus, we maintain that CS project design influences participant engagement, which in turn raises motivation for continuous participation

In addition, the interviewees' perceptions of the open monitoring protocol were divided. Those who were very active participants favored this approach, whereas the moderately active

participants preferred a more structured monitoring protocol. This finding also speaks to the compatibility between individuals' attitudes and the project's design. Finally, the ecological CS project we studied had two main objectives: to collect fauna and flora data in the region and to engage the local community in nature exploration activities. Ultimately, only a relatively small group of highly committed volunteers continued reporting observations over time, suggesting that participation did not meet the volunteers' needs (Clary and Snyder 1999). When considering all aspects of the project design and the scientific activities required from citizen scientists, we found a gap between the project administrators' explicit objectives and the actual coordination of the volunteer efforts. Much of the coordination was dedicated to supporting individuals who were very interested in biodiversity research. Thus, the actions of the project's administrators seemed to support the project's scientific objectives more than its educational and community objectives.

Finally, the study also highlights the importance of explicitly addressing what ecological projects actually contribute to nature conservation. In our research, concern for the environment was the main motivation for joining among many of those who joined the project but did not actively participate or participated very little. These results are somewhat at odds with previous findings regarding the importance of environmental concerns as a key motive for active engagement in ecological CS projects (Ryan et al., 2001; West Dyke, and Pateman et al., 2021). One possible explanation for these individuals' lack of engagement may be that in this project the linkage between CS monitoring data and conservation was not explicitly described to participants (Lopez 2021). We therefore recommend that ecological CS projects explicitly describe the ways in which project participation contributes to nature conservation.

5.1. Implications for practitioners

Beyond the theoretical contributions of this study, our findings also have important implications for practitioners. Based on our findings, we recommend the following points to consider when designing and managing ecological CS projects:

1. Define your target audience and determine what experience they should have in the subject matter. Analyze whether the project is suitable for everyone interested, or whether only for those with certain interests or qualifications. Based on these definitions, develop a support system for the project consisting of educational activities, social activities, and feedback processes that suit the target audience.
2. Develop various educational activities that can support participants' engagement in and understanding of the required activities. If the project's scientific activities are simple and not very engaging, learning activities are essential to increase intrinsic motivation. Given that people have different needs and expertise, develop several learning activities that can address the needs of all target groups.
3. Provide opportunities for social interactions. Where possible, provide physical interactions because they can enhance the quality of the group's interactions.
4. Develop a feedback system that can provide participants with: (a) clear, automatic, and individual feedback after uploading data; (b) individual social feedback from other participants; and (c) scientific feedback on a regular basis.
5. Given people's differences with regard to their desire and need for structured guidance, provide at least two participation options: open protocols and structured protocols. Of course, doing this also depends on the nature of the CS project.
6. For ecological CS, provide the volunteers with as many details as possible about what the project contributes to environmental conservation.

5.2. Research limitations and suggestions for future research

While this study provides novel insights regarding the relationships between CS project design and participants' engagement and motivation, it has several limitations. First, although our study yielded important findings regarding the motivation of those who joined the project but chose not to participate actively, more research is warranted to better understand the differences in goals and needs between active and non-active participants. Second, the present research focused on a single CS project. Additional research is needed to investigate whether the patterns of findings from our study generalize to other CS projects. Third, the present study explores engagement in a CS project among local residents. While participants resided in different villages and townships and had different biological/ecological expertise, all were part of a single local community, which somewhat constrained participants' socio-cultural diversity. Future research can potentially explore motivation and engagement among a more diverse group of participants, for example tourists (Schaffer and Tham 2019).

6. Conclusion

The important potential of CS in enhancing science literacy and environmental awareness has been discussed extensively in the scholarly literature. Our study emphasizes the role of learning, not only as an outcome of participation but also as an important driver of ongoing engagement and participation. The scientific activities offered in a CS project are often not sufficiently attractive for all participants. If project administrators want to improve the intrinsic motivation for participation and at the same time enhance participants' learning, they must offer engaging learning opportunities.

From a practical point of view, our research findings can contribute to designing projects that are better aligned with the needs of a diverse community. We believe that providing varied learning opportunities for all participants will lead to higher levels of motivation and participation in ecological CS. Consequently, this will increase the potential of ecological CS projects to serve as a meaningful form of lifelong learning. In addition, greater participation and engagement will ultimately contribute to scientific and environmental causes.

Disclosure statement

No potential conflict of interest was reported by the authors.

Acknowledgment

We thank Ariel Shamir and TCSS team for their help in initiating this research and their support and feedback along the way. This research was supported in part by the University of Haifa's Data Science Research Center.

ORCID

Keren Kaplan Mintz http://orcid.org/0000-0002-4565-2913

References

Alender, B. 2016 "Understanding Volunteer Motivations to Participate in Citizen Science Projects: A Deeper Look at Water Quality Monitoring." *Journal of Science Communication* 15 (03): A04. doi:10.22323/2.15030204.

Ardoin, N. M., A. W. Bowers, and E. Gaillard. 2020. "Environmental Education Outcomes for Conservation: A Systematic Review." *Biological Conservation* 241: 108224 10.1016/j.biocon.2019.108224.

Balestra, M., L. Zalmanson, C. Cheshire, O. Arazy, and O. Nov. 2017. "It Was Fun, but Did It Last?." *Proceedings of the ACM ON Human-Computer Interaction* 1 (CSCW): 1–13. doi:10.1145/3134656.

Ballard, H. L., C. G. Dixon, and E. M. Harris. 2017. "Youth-Focused Citizen Science: Examining the Role of Environmental Science Learning and Agency for Conservation." *Biological Conservation* 208: 65–75. doi:10.1016/j.biocon.2016.05.024.

Bell, J., J. Falk, R. Hughes, G. Hunt, J. Parrish, M. Ruffin, and G. Troxel. 2016. "Informal STEM Education: Resources for Outreach, Engagement and Broader Impacts." *Science Education (CAISE)*. 1–28.

Bonney, R., H. Ballard, R. Jordan, E. McCallie, T. Phillips, J. Shirk, and C. C. Wilderman. 2009b. "Public Participation in Scientific Research: Defining the Field and Assessing Its Potential for Informal Science Education." A CAISE Inquiry Group Report. *Online Submission*.

Bonney, R., C. B. Cooper, J. Dickinson, S. Kelling, T. Phillips, K. V. Rosenberg, and J. Shirk. 2009a. "Citizen Science: A Developing Tool for Expanding Science Knowledge and Scientific Literacy." *BioScience* 59 (11): 977–984. doi:10.1525/bio.2009.59.11.9.

Bonney, R., T. B. Phillips, H. L. Ballard, and J. W. Enck. 2016. "Can Citizen Science Enhance Public Understanding of Science?" *Public Understanding of Science (Bristol, England)* 25 (1): 2–16. doi:10.1177/0963662515607406.

Campbell, J. L.,C. Quincy, J. Osserman, and O. K Pedersen. 2013. "Coding in-Depth Semistructured Interviews." *Sociological Methods & Research* 42 (3): 294–320. doi:10.1177/0049124113500475.

Charmaz, K. 2006. *Constructing Grounded Theory: A Practical Guide through Qualitative Analysis*. London, Great Britain: Sage.

Clary, E. G, and M. Snyder. 1999. "The Motivations to Volunteer: Theoretical and Practical Considerations." *Current Directions in Psychological Science* 8 (5): 156–159. doi:10.1111/1467-8721.00037.

Cox, Joe., Eun Young Oh, Brooke Simmons, Gary Graham, Anita Greenhill, Chris Lintott, Karen Masters, and Jamie Woodcock. 2018. "Doing Good Online: The Changing Relationships between Motivations, Activity, and Retention among Online Volunteers." *Nonprofit and Voluntary Sector Quarterly* 47 (5): 1031–1056. doi:10.1177/0899764018783066.

Falk, J. H. 2005. "Free-Choice Environmental Learning: Framing the Discussion." *Environmental Education Research* 11 (3): 265–280.

Fischer, H., H. Cho, and M. Storksdieck. 2021. "Going beyond Hooked Participants: The Nibble-and-Drop Framework for Classifying Citizen Science Participation." *Citizen Science: Theory and Practice* 6 (1): 1–12. doi:10.5334/cstp.350.

Golumbic, Y., A. Baram-Tsabari, and B. Fishbain. 2020a. "Engagement Styles in an Environmental Citizen Science Project." *Journal of Science Communication* 19 (6): A03. doi:10.22323/2.19060203.

Golumbic, Y. N., A. Baram-Tsabari, and B. Koichu. 2020b. "Engagement and Communication Features of Scientifically Successful Citizen Science Projects." *Environmental Communication* 14 (4): 465–480. doi:10.1080/17524032.2019.1687101.

Haklay, M. 2018. "Participatory Citizen Science." In *Innovation in Open Science, Society and Policy*, edited by S. Hecker, M. Haklay, A. Bowser, Z. Makuch, J. Vogel, and A. Bonn, 52–62. UCL Press: London, UK.

Henckel, L., U. Bradter, M. Jönsson, N.J. B Isaac, and T. Snäll. 2020. "Assessing the Usefulness of Citizen Science Data for Habitat Suitability Modelling: Opportunistic Reporting versus Sampling Based on a Systematic Protocol." *Diversity and Distributions* 26 (10): 1276–1290. doi:10.1111/ddi.13128.

Johnson, R. B, and A. J. Onwuegbuzie. 2004. "Mixed Methods Research: A Research Paradigm Whose Time Has Come." *Educational Researcher* 33 (7): 14–26. doi:10.3102/0013189X033007014.

Krippendorff, K. 2019. *Content Analysis: An Introduction to Its Methodology*. Sage, Los Angeles.

Lopez, C. 2021. "Motives for Citizen Science Program Participation and the Role of the Organization: Lessons from Water Quality Monitors in Texas." *Citizen Science: Theory and Practice* 6 (1): 3. doi:10.5334/cstp.341.

Margaret P., D.. Mustakova-Possardt, and A. Reid. 2010. "A Whole-person Approach to Educating for Sustainability." *International Journal of Sustainability in Higher Education* 11 (4): 339–352. doi:10.1108/14676371011077568.

Maund, P. R., K. N. Irvine, B. Lawson, J. Steadman, K. Risely, A. A. Cunningham, and Z. G. Davies. 2020. "What Motivates the Masses: Understanding Why People Contribute to Conservation Citizen Science Projects." *Biological Conservation* 246: 108587. doi:10.1016/j.biocon.2020.108587.

Mintz, K, and T. Tal. 2014. "Sustainability in Higher Education Courses: Multiple Learning Outcomes." *Studies in Educational Evaluation* 41: 113–123. doi:10.1016/j.stueduc.2013.11.003.

Morgan, D. L. 2007. "Paradigms Lost and Pragmatism Regained: Methodological Implications of Combining Qualitative and Quantitative Methods." *Journal of Mixed Methods Research* 1 (1): 48–76. doi:10.1177/2345678906292462.

Nov, O., O. Arazy, and D. Anderson. 2014. "Scientists@ Home: What Drives the Quantity and Quality of Online Citizen Science Participation?" *PLoS One* 9 (4): e90375. doi:10.1371/journal.pone.0090375.

Nov, O., O. Arazy, K. Lotts, and T. Naberhaus. 2013. "Motivation-Targeted Personalized UI Design: A Novel Approach to Enhancing Citizen Science Participation," Proceedings of the 13th European Conference on Computer Supported Cooperative Work (ECSCW'2013), Paphos, Cyprus, Sept. 21–25.

Nov, O., D. Anderson, and O. Arazy. 2010. "Volunteer Computing: A Model of the Factors Determining Contribution to Community-Based Scientific Research." Proceedings of 19th International World Wide Web Conference (WWW2010), Raleigh, NC, April 26–30, 2010.

Nov, O., O. Arazy, and D. Anderson. 2011. "Dusting for Science: Motivation and Participation of Digital Citizen Science Volunteers." Proceedings of iConference 2011, February 8–11, 2011, Seattle, WA.

Phillips, T. B., H. L. Ballard, B. V. Lewenstein, and R. Bonney. 2019. "Engagement in Science through Citizen Science: Moving beyond Data Collection." *Science Education* 103 (3): 665–690. doi:10.1002/sce.21501.

Reeve, J. 2018. *Understanding Motivation and Emotion*. 7th ed. Wiley Custom. Hoboken, UK.

Reid, A., J. Dillon, N. Ardoin, and J. A. Ferreira. 2021. "Scientists' Warnings and the Need to Reimagine, Recreate, and Restore Environmental Education." *Environmental Education Research* 27 (6): 783–795. doi:10.1080/13504622.2021.1937577.

Reschly, A. L, and S. L. Christenson. 2012. "Jingle, Jangle, and Conceptual Haziness: Evolution and Future Directions of the Engagement Construct." In *Handbook of Research on Student Engagement*, edited by S. L. Christenson, A. L. Reschly, and C. Wylie, 3–19. Springer, Boston, MA.

Rotman, D., J. Preece, J. Hammock, K. Procita, D. Hansen, C. Parr, and D. Jacobs. 2012. "Dynamic Changes in Motivation in Collaborative Citizen-Science Projects." In Proceedings of the ACM 2012 Conference on Computer Supported Cooperative Work, February, pp. 217–226. doi:10.1145/2145204.2145238.

Ryan, R. L.,R. Kaplan, and R. E. Grese. 2001. "Predicting Volunteer Commitment in Environmental Stewardship Programmes." *Journal of Environmental Planning and Management* 44 (5): 629–648. doi:10.1080/09640560120079948.

Ryan, R. M, and E. L. Deci. 2000. "Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions." *Contemporary Educational Psychology* 25 (1): 54–67. doi:10.1006/ceps.1999.1020.

Sagy, O., Y. N. Golumbic, H. B. H. Abramsky, M. Benichou, O. Atias, H. M. Braham, and D. Angel. 2019. "Citizen Science: An Opportunity for Learning in the Networked Society." In *Learning in a Networked Society*, 97–115. Springer, Cham.

Sbrocchi, C., G. Pecl, I. van Putten, and P. Roetman. 2022. "A Citizen Science Community of Practice: Relational Patterns Contributing to Shared Practice." *Citizen Science: Theory and Practice* 7 (1): 3. doi:10.5334/cstp.358.

Schaffer, V., and, A. Tham. 2019. "Engaging Tourists as Citizen Scientists in Marine Tourism." *Tourism Review* 75 (2): 333–346. doi:10.1108/TR-10-2018-0151.

Schroer, J., and, G. Hertel. 2009. "Voluntary Engagement in an Open Web-Based Encyclopedia: Wikipedians and Why They Do It." *Media Psychology* 12 (1): 96–120. doi:10.1080/15213260802669466.

Segal, A., Y. A. Gal, R. J. Simpson, V. Victoria Homsy, M. Hartswood, K. R. Page, and M. Jirotka. 2015. "Improving Productivity in Citizen Science through Controlled Intervention." In Proceedings of the 24th International Conference on World Wide Web, pp. 331–337. doi:10.1145/2740908.2743051.

Sipos, Y., B. Battisti, and K. Grimm. 2008. "Achieving Transformative Sustainability Learning: engaging Head, Hands and Heart." *International Journal of Sustainability in Higher Education* 9 (1): 68–86. doi:10.1108/14676370810842193.

Straus, A, and Corbin, J. 1990. *Basics of Qualitative Research*. Sage, Newbury Park, CA.

Tal, T. 2012. "Out-of-School: Learning Experiences, Teaching and Students' Learning." In *Second International Handbook of Science Education*, edited by Fraser, 1109–1122. Springer, Dordrecht.

Tiago, P., M. J. Gouveia, C. Capinha, M. Santos-Reis, and H. M. Pereira. 2017. "The Influence of Motivational Factors on the Frequency of Participation in Citizen Science Activities." *Nature Conservation* 18: 61–78. doi:10.3897/natureconservation.18.13429.

UNESCO. 1977. "The Tbilisi Declaration" in Intergovernmental Conference on Environmental Education. UNESCO, UNEP, Tbilisi, USSR, 14–26. https://www.gdrc.org/uem/ee/EE-Tbilisi_1977.pdf.

Wals, A. E., M. Brody, J. Dillon, and R. B. Stevenson. 2014. "Convergence between Science and Environmental Education." *Science (New York, N.Y.)* 344 (6184): 583–584. doi:10.1126/science.1250515.

Wenger, E. 2010. "Communities of Practice and Social Learning Systems: The Career of a Concept." In: *Social Learning Systems and Communities of Practice*, edited by C. Blackmore, 179–198. Springer, London.

West, S., A. Dyke, and R. Pateman, 2021. "Variations in the Motivations of Environmental Citizen Scientists." *Citizen Science: Theory and Practice*, 6(1):14. doi:10.5334/cstp.370

West, S. E, and R. M. Pateman. 2016. "Recruiting and Retaining Participants in Citizen Science: What Can Be Learned from the Volunteering Literature?" *Citizen Science: Theory and Practice* 1 (2): 15. doi:10.5334/cstp.8.