A new theoretical engagement framework for citizen science projects: using a multi-temporal approach to address long-term public engagement challenges

Sonia Liñán, Xavier Salvador, Ana Álvarez, Andrea Comaposada, Laura Sanchez, Nuria Aparicio, Ivan Rodero and Jaume Piera

EMBIMOS, Institut de Ciències del Mar (ICM-CSIC), Barcelona, Spain
Anèlides Serveis Ambientals Marins, Barcelona, Spain
Quanta Systems, S.L., Barcelona, Spain

* Author to whom any correspondence should be addressed.
E-mail: jpiera@icm.csic.es

Keywords: volunteers’ recruitment, citizen science engagement, citizen engagement model, participatory engagement models, Janus participatory framework

Supplementary material for this article is available online

Abstract

Effective citizen engagement is generally accepted as one of the most important steps for the success of citizen science programs. However, there is a lack of a common theoretical framework for recruitment and most projects rely on intuition or trial-and-error to develop their engagement strategies. Effective citizen science engagement needs theoretical participation frameworks and the concurrent action of different engagement roles to implement the framework. Besides, we must consider the various short-term and long-term engagement needs of the communities involved in the project. Furthermore, citizen science platforms are evolving towards infrastructures with technical but also social components to ensure long-term engagement. In this study, we have developed and tested an engagement framework for environmental citizen science projects using a novel approach that combines strategies and theoretical models that have proven efficient in other disciplines, such as human behaviour change and persuasion. Our framework is based on four interconnected pillars that feed each other: theoretical engagement models for behavioural change; social design for citizen science platforms; strategies for maintaining volunteer motivation; and strategies to increment the volunteers’ ability. The combination of these four pillars results in a framework that integrates both short-term and long-term interaction mechanisms. This multi-temporal approach ensures keeping volunteers motivated and engaged for long periods, a requirement for many citizen science-monitoring programs. In addition, the theoretical framework points out the benefits of considering citizen science projects as a collaboration between multiple stakeholders to ensure long-term engagement. These stakeholders include the volunteers, but also new roles such as enabling communities that act as a bridge between volunteers and academia. Specifically, we have successfully tested this framework in a marine citizen science case study that monitors urban beaches. Furthermore, together with the proposed framework, we provide specific guidelines to help managers to design tailored strategies for their citizen science projects.

1. Introduction

Environmental evidence-based policies require a large amount of data, and citizen science is one efficient strategy to achieve this knowledge challenge. However, maximising the number of observations requires, in turn, maximising the number of people who participate in providing experimental data for researchers. It is clear then that recruitment and long-term engagement are crucial to the success of citizen science projects. Although, to date, there is no theoretical framework of reference, and most projects often rely on tradition, intuition or trial and error. A theoretical framework of reference for engagement in
citizen science will provide guidance to citizen science practitioners on how to create effective recruitment and retention actions. Besides, citizen science is consolidating itself as a scientific discipline [1] and needs to be built on a solid theoretical basis for each of its conceptual elements, including those related to voluntary recruitment.

Creating a successful engagement strategy is complex and requires multiple approaches. On the one hand, theoretical models based on behavioural change may have a main role in citizen engagement [1] since those models have shown effectiveness in other environmental projects seeking the engagement of the public [2, 3] and are successfully used to design social media campaigns [4–6]. On the other hand, researchers point to motivation as one of the most common challenges in citizen science [7–9], both for motivating new volunteers and continuing the motivation of those already participating [9–11]. Research suggests that matching project activities with volunteer motivations may be one of the best methods for enhancing recruitment and getting long-term engagement [12–17]. People participate in environmental citizen science projects because they have an intrinsic value for the environment and want to support research efforts and learn and gain knowledge [18]. But long-term participation is complex and includes intrinsic and extrinsic motivations defined by the self-determination theory [19]. Continuous motivation depends on multiple factors: trust in the scientific community, the setting of common goals, acknowledgement and attribution, mentorship, education and outreach, and policy and activism [20]. Besides, most environmental citizen science projects use citizen science platforms, also known as citizen observatories (COs), as environmental monitoring and information systems that invite citizen scientists to share observations via website or smartphone [21]. Citizen science projects and COs need to consider the links between technical and social components to achieve an effective engagement. Also, they must consider strategies to promote behavioural change and boost motivation. COs need to be designed to construct a positive experience for the volunteers.

This study reviews different models and proposes an integrated framework for engagement to be used as a theoretical framework in environmental citizen science, specifically in marine citizen science. The framework integrates concepts from other scientific disciplines, mainly those elaborated in human behaviour, human–machine interactions, and user/social experience. The proposed framework is validated in a particular case study of a biodiversity participatory monitoring program on urban beaches. Furthermore, together with the proposed framework, this study provides specific tools that will help managers to design tailored strategies to overcome the specific engagement challenges of their citizen science project.

2. Method

2.1. Creation of the engagement framework

First, we conducted a focused literature review of engagement models and strategies in different disciplines to identify and select the ones that shape our engagement framework. The review was not limited to citizen science, but other disciplines such as social marketing and persuasive technologies have also been considered. Secondly, we identified the recommended engagement roles to execute our framework.

2.2. Validation of the engagement framework in a case study

For the validation of our engagement framework in a real-case scenario, we implemented it in Urbamar-Bio, an urban beach monitoring citizen science project. We mapped the specific stakeholders needed to cover all the recommended engagement roles, considering the location of the beaches and their socio-economic particularities.

A literature review allowed us to identify the most common barriers in engaging volunteers in marine citizen science. Then, we set up a solution matrix where stakeholders were assigned tasks or actions to overcome barriers. Follow-up meetings and actions were conducted to ensure the optimal implementation of the actions.

Finally, we evaluated the results of implementing engagement framework in the case study. When evaluating a citizen science project and its engagement strategy, there is a lack of consensus in the evaluating frameworks that allow comparing results of different projects and initiatives. Since more engagement in terms of participation does not necessarily mean that the engagement is more effective [22], we evaluated the engagement strategy keeping in mind the achievement of the project objective (to monitor the urban beaches). For these purposes, we established a set of key performance indicators (KPIs) to measure the assessment of the scientific project goal. Participation data was obtained via the CO application programming interface (API) and plotted with R.

3. Results

3.1. Selection of the theoretical frameworks

Based on a focused literature review of existing theoretical models for behavioural change and social user experience, we selected two behavioural change models: the behaviour model for a persuasive design created by Fogg [23] and the conceptual hook model proposed by Eyal [24], and one model for social experience: the layered model of social experience developed by Yamakami (YM) [25].

The Fogg behaviour model (FBM) explains that community participation is the product of three factors: motivation, triggers, and ability. Participants must (a) be sufficiently motivated to participate, (b)
be triggered in the right way to perform the action (participate in a citizen science project in our case), and (c) have the ability to obtain the desired behavioural change. The first two factors, motivation and trigger, are the main drivers of widespread and voluntary engagement. In contrast, the third factor, the ability, is usually conditioned by the design of the observing protocols, which determines the effectiveness: the simpler the requirements for making the observations, the larger the number of individuals that may be involved [26, 27]. The FBM proposes that after experiencing the trigger, people with sufficiently high levels of motivation and ability will perform the behaviour. FBM has been widely used in technology design [22, 28–32] and is starting to be applied in social marketing campaigns in public health [33–38]. The FBM may be a valuable tool for citizen science projects aiming to change individual behaviour, collecting biodiversity observations in our case [23].

The Eyal hook model (EHM) conceptualises a four-phase process used to form habits in a target audience. It consists of a series of consecutive hook cycles formed by (a) internal or external triggers that cause an (b) action where the person behaves singularly to get (c) variable rewards that motivate them to keep expressing the new habit and that let them to (d) invest in the project giving some service such as time, data, or knowledge. Through consecutive hook cycles, citizen science projects can reach their goal of volunteer engagement without depending on constant messaging [24].

COs are evolving towards infrastructures with technical but also social components to ensure long-term engagement. The layered model of social experience developed by YM defines social experience as ‘the design of the way a person feels about other humans through computer-user interface’ [25]. YM defines the key factors of transition paths (layers) towards social experience to achieve users emotionally connected with a platform and a long-term relationship. First, at the layer of social cognition, the technological platform—a CO in our case—proposes activities to be carried out. Then, in the layer of goals and operations, the CO shows visual feedback of the achievement of the goal and interactions around this achievement. After that, the layer of short-term relationship incorporates activities of social reward, and the layer of emotion contains the design of activities to increase the joy of achievement. Finally, after passing through all the previous layers, the user establishes a relationship with the CO based on trust and building roles, which leads to the long-term relationship layer and the success of a citizen science project [25].

3.2. Creation of the engagement framework for citizen science
For building our framework, we identified four main pillars: (a) theoretical engagement models based on behavioural change, (b) theoretical models of technology user and social experience, (c) strategies for maintaining volunteers’ motivation over time, and (d) strategies for incrementing volunteers’ ability.

We built an engagement framework for citizen science combining the FBM, the EHM and the YM, augmented with strategies for incrementing the motivation and ability of the volunteers (figure 1). This framework aims to persuade the volunteer to perform a target action in our citizen science project to obtain an investment of time or knowledge. EHM and the FBM are short-term cycles, with only minutes or days between actions. In contrast, the YM is a long-term process taking weeks to months to advance layers (figure 2). The short-term cycles contain short-term engagement actions, which iteration causes the long-term engagement described in the YM.

In our framework, the trigger is present as the first step of the EHM but is also crucial in the FBM jointly with ability and motivation. The second phase of the EHM is the action. The easier the action, the more users will perform it [22]. The simplicity of the proposed action is also crucial for improving volunteers’ ability, hence key in the FBM. The third phase of the EHM is the reward of the triggered actions, and if these rewards are variable, the user is far more likely to get engaged. This again is connected with the FBM, since the reward is one of the known elements to increment the motivation of the volunteers. Finally, to change the behaviour of the volunteers according to the EHM, the user must invest in creating and maintaining the habit. Furthermore, for this investment to happen, the FBM affirms that motivation, triggers, and ability must happen simultaneously, which happens in our engagement framework thanks to the combination of the EHM and the strategies to increment ability and motivation. Since humans are creatures of habit, investment in a habit becomes a form of inertia, so changing is difficult once hooked on something. With this, we can obtain the long-term engagement of volunteers. According to the YM, the volunteers establish a long-term relationship with the citizen science project once they have invested in a habit several times, that is, with the iteration over the steps present in the framework.

COs are similar to social media networks and need similar strategies to engage and retain volunteers. The YM contemplates a paradigm shift when talking about the social experience and user experience. It highlights the importance of human–human interaction between users of a technological platform instead of the classic interaction between human–machine. By including it, we want to stress the importance of including human–human interaction when designing these technological platforms to engage and retain volunteers.

One of the most essential elements of the framework is a multi-temporal approach that connects both short-term and long-term actions and rewards.
Figure 1. Proposed theoretical engagement framework for citizen science. The upper part of the figure shows the YM model (purple), while the lower part contains the combination of the hook model by Eyal (orange circles) and the FBM (blue circles), all converging in the volunteer investment (red circle). The green rectangles contain examples of strategies for increasing motivation and ability. The different layers of the YM model are annotated within the main elements of the Eyal model and the Trigger in the Fogg model as purple numbers.

Figure 2. Short and long-term interactions Janus framework: rewards as an example. User experience focused models (Eyal and Fogg model) and social experience focused model (YM) both generate short and long-term rewards. Academia produces scientific outputs that are translated into long-term rewards and acknowledgement for the volunteers. Decision makers use data obtained from volunteers to create evidence-based policies, which act as long-term rewards for the volunteers. The role of the enablers for generating rewards is described in section 3.3.
Figure 3. Implementation of the engagement framework: mapping of stakeholders. The first box on the left shows the four engagement roles that are essential for achieving an effective engagement strategy according to our framework. The second box on the right represents the Quintuple Helix of innovation used to implement our engagement framework in the case study UrbamarBio. The different roles are represented in the Quintuple Helix as the primary interaction between three actors: (a) academia, which provides knowledge, data curation and a CO, (b1) industry enablers and (b2) government enablers. The industry enablers represent the industry involved in non-formal education activities and that provide access to a pre-existing community, expertise in public engagement at a local level, and the capacity to overcome typical logistics barriers of citizen science projects. The government enablers are those who provide the legal and socio-economic frameworks to develop participatory activities (such as special permits for outdoor activities or event facilities close to the area). Both academia and the enablers are influenced by the (c) citizens, including schools and non-governmental organization (NGOs). Finally, the (d) context, known as local biodiversity and cultural heritage, is the driver for participatory environmental and social projects.

(figure 2). Often, different stakeholders and communities are involved in a citizen science project apart from the volunteers or citizen scientists. For example, volunteers can participate at different levels in a citizen science project, but they need short-term rewards, triggers, and other short-term engagement actions to keep them motivated and continue participating [39, 40]. In contrast, the scientific outputs and the creation of evidence-based policies resulting from the work of volunteers in a project usually take months to years and act as a long-term reward for volunteers. When implementing an engagement strategy, it is necessary to consider this temporal duality: both the long-term and the short-term engagement. This multi-temporal duality is represented in figure 2 with a double-faced figure looking to opposite sides, as a simile to the roman God Janus of transitions and dualities.

3.3. Engagement roles mapping for implementing the engagement framework
To take our framework from theory to practice, citizen science practitioners need to identify who will perform the short-term and long-term engagement actions. With this purpose, and according to our engagement framework, we identified four essential engagement roles (figure 3): (a) generating effective triggers, (b) motivating people, (c) reducing potential participation barriers (increasing ability) and (d) generating rewards for volunteers. Each one of the four engagement roles needs to be fulfilled to ensure that both long-term and short-term interactions will be performed.

In some projects, a single stakeholder can perform all roles. However, since different kinds of knowledge and ability are needed to perform the four roles, in other projects than one stakeholder may be needed.

3.4. Implementation of the engagement framework in a case study
This case study, UrbamarBio, consists of the long-term high-resolution spatio-temporal participatory monitoring of coastal biodiversity in 20 urban beaches in three cities (Barcelona, Badalona and Sant Adrià del Besós). From 2016 to 2021, volunteers reported observations (photographs) of coastal and marine living organisms on the CO Natusfera, now MINKA.

The target behaviour was the engagement of volunteers to upload observations to the CO. Figure 4 shows a three-step implementation guide of the engagement framework: (a) barriers identification, (b) stakeholder-engagement role mapping, and (c) solution-matrix construction.
3.4.1. Identification of the barriers to participants’ short-term and long-term engagement interactions in the case study

Marine systems can be more challenging to monitor than land-based ones. They present additional barriers in terms of logistics and ability. In the case of UrbamarBio we identified eight main barriers (figure 4) to participants’ short-term and long-term engagement interactions, which are common in most marine citizen science projects [41–43]: (a) motivation; (b) diving or snorkelling skills; (c) use of an online technological CO to report data; (d) underwater equipment such as fins and diving goggles; (e) bad weather; (f) expensive insurances for snorkelling/diving; (g) it may be more challenging for volunteers to ‘take ownership’ of a site without obvious demarcations or recognisable boundaries; (h) lack of knowledge of underwater fauna and flora.

3.4.2. Identification and mapping of the stakeholders

To implement our framework in UrbamarBio, first, we mapped the stakeholders that will perform the four essential engagement roles. To help us identify the stakeholders for UrbamarBio, we used the well-known Quintuple Helix model of innovation [38], which considers the knowledge interchange between the political, academic, economic, cultural and environmental spheres (figure 3). The Quintuple Helix may be used to map stakeholders for some citizen science projects, considering that not all projects need all stakeholders. Still, all the framework’s four engagement roles must be fulfilled. For example, in marine citizen science, the recruitment of the participants often occurs via partnerships with nature organisations [9, 37], which act as enablers contributing to the four engagement roles.

In UrbamarBio, the main driver of the case study was the academia stakeholder, the Institute for Marine Science (ICM-CSIC), a research institute with expertise in marine biodiversity participatory monitoring. As an industry enabler, we identified a small local enterprise, Anèl·lides, focused on marine environmental education with a large citizen database, knowledge of the socio-economic

Figure 4. Implementation guide. An example guide of how to implement the proposed engagement framework in a real-case scenario. While the different steps and the proposed table can be used in any project, the specific barriers and stakeholders correspond to UrbamarBio project.
context, underwater equipment, and strong connections with local NGOs, schools, and councils. As government enablers, we identified the government entities responsible for managing the studied beaches. Target volunteers or citizen scientists were people over 12 years old with basic swimming and/or diving skills within 5 km of the area of study.

This study's natural environment consisted of 20 urban beaches from three cities with a density of over 9000 person km$^{-2}$. They were in front of a population centre and suffered from the lack of natural elements and constant influx of citizens.

3.4.3. Creation of a matrix of solutions

For each barrier identified, we created a series of solutions based on the engagement framework elements. We also identified the role of participants or citizen scientists, enablers, and academia in each solution. As a result, we created a solution matrix to overcome the case study barriers. Table 1 shows the solutions implemented. A similar matrix for the other barriers can be found in supplementary tables 1–7. In addition, figure 5 shows the theoretical engagement framework annotated with examples of solutions and key stakeholders.

| Table 1. Example of solutions implemented to keep participant motivation over time in UrbamarBio. |
|---|
| **Actors** | **Triggers** | **Barriers: participant motivation** | **Rewards** | **Action** | **Ability** | **Motivation** |
| **Academia** | • Notification of new observation | — | • Acknowledge contributors’ activity (CO) | — | — | • Establish common goals: focus on local biodiversity |
|  | • Notification of new identification | — | • Validation or help in the identification of an observation in the CO | — | — | • Rewards: acknowledgements in the CO and collaborative products |
|  | • Notification of new validation | — | • Curation of the data | — | — | — |
|  | • Comments on your observation | — | • Participation in BioBlitz | — | — | — |
|  | • Participation in BioBlitz | — | — | — | — | — |
| **Enablers** | • Newsletters | • Acknowledge contributors’ activity in social media | — | — | — | — |
|  | • Social media | • Organisation of guided activities | — | — | — | — |
|  | • Events to present the collaborative products (exhibition, participatory guide) | — | — | — | — | — |
| **Citizen scientists** | — | Own observation | Collaborative identification | — | — | — |

For each barrier identified, we created a series of solutions based on the engagement framework elements. We also identified the role of participants or citizen scientists, enablers, and academia in each solution.
Some notable solutions are: (a) organization of a BioBlitz; (b) organisation of guided snorkelling and diving sessions; and (b) attribution and acknowledgement of participants creating a marine guide made only with observations from participants.

3.4.4. Performance evaluation of the case study
We evaluated the engagement strategy by considering quantitative indicators to measure the assessment of the scientific project goal (to monitor the urban beaches), and we measured a set of KPIs (table 2).

Since the creation of the project in 2016, the CO recorded 8031 observations of 632 different marine species. Most observations were made during the snorkelling and/or diving guided activities organized by the industry enabler. Although 1.187 people participated in the guided activities, only 75 people created a profile in the CO and uploaded observations (figure 6(A)). The photographs taken by almost all the participants of the guided activities were uploaded to the CO by the industry enabler using their CO profile, representing 35% of the total observations registered (more than 2.800).

Analysing the number of observations over time (figure 6(C)), we can see the effect of different external triggers, such as the participation in an international BioBlitz since 2018, the City Nature Challenge (CNC), the resume of guided activities post Covid-lockdown period in 2020, and the participation in a local BioBlitz. Figure 6(C) shows the effect of these triggers on the observation number: a short-term spike followed by a longer sustained increase in observations per month. For example, 2018 participation in the CNC translated into a ten-fold increase in observations. Instead, we observe a lower increase in 2019 due to a marine storm during the BioBlitz trigger, which forced the cancellation of the organised guided activities. Notwithstanding, we observed an increment in participation in the northern city during this period. Despite the Covid pandemic impeding the organization of group activities during 2020, data showed a 20-fold increase in observations in the South city compared to 2018 (figure 6(B)). The industry enablers’ organisation and dynamization of guided activities were substantially higher in the southern city, followed by the central and the northern ones. Results show the importance of a trigger to increase the participation of volunteers and create
Figure 6. Evaluation of observations and participants. (A) Number of participants per year mobilised by the industry enabler, number of participants that take pictures with underwater cameras supplied by the industry enabler and the number of participants that repeated the activity during the year. (B) Number of observations from 2016 to 2021 in the different cities. (C) Total number of observations per month from 2016 to 2021. Shadows represent winter and lock-down periods. CNC. Figures (A) and (B) show the long-term outcomes of the implementation of the engagement framework and figure (C) represents the short-term ones.

the habit of reporting observations in the CO. It also showed that the engagement of the community and the creation of the habit without a constant trigger (investment) only happens when the community is well established, as happened in the northern city. Irregularities in the number of observations over the years (figures 6(B) and (C)) can be attributed to the winter period, when the water is too cold and the visibility too low to perform underwater activities, hence obtaining marine observations.

Of the total observations reported in the CO, 99% reached the Research Grade. This good result was thanks to the triggers and engagement strategies designed to increment the ability of volunteers: identification training sessions, CO’s collaborative identification, and the curation of the data by the academia. The observations without Research Grade were due to volunteers’ mistakes (such as the absence of a photograph or the photograph of anthropic objects) or the lack of location or date.

The enablers’ importance can also be seen in the percentage of participants uploading photographs into the CO. In this case, a CO showing its age posed a difficult technological barrier for many participants. Out of 1187 participants, only 75 uploaded their own photos. Participants had their observations uploaded by the industry enabler profile. This has the evident benefit of uploading these additional observations but has the disadvantage of detaching the authors from their observations. Without this link, it will not be possible to reward these volunteers in the next steps of the process, such as the appearance of their names in the created participatory marine guide (figure 7), and so their future motivation to participate will be diminished.

Aside from the quantitative data analysed, another significant qualitative result was integrating a fish layer into the online biodiversity atlas of the Barcelona city council, using volunteer observations exclusively from this case study.

4. Discussion

Volunteer engagement is crucial in any citizen science project since participant engagement is directly linked with the quantity and quality of observations. However, despite its importance, there is a lack of theoretical engagement models focused on citizen science, and this means that projects lack a theoretically founded guidance for their engagement efforts. In other
disciplines, however, there have been efforts to build theoretical engagement models to formalise existing practices and help establish new methodologies for improved engagement [23–25].

In this work, we proposed a new engagement framework for environmental citizen science based on integrating existing theoretical models and strategies and adapting them to the citizen science environment (figure 1). We demonstrate its practicality through an example of its application to a marine citizen science project. The identification and mapping of the engagement roles show that each stakeholder can contribute to many different aspects of the engagement process and highlights the importance of some stakeholders acting as enablers to overcome the participation barriers. At the same time, it shows that the whole strategy could fail if any of the key roles were missing.

The evaluation of the results of this project can provide some insights into the importance of the different engagement roles. For example, local administrations provided access to changing rooms next to the beach so participants could change into their swimming suits, removing participation barriers. However, figure 6 shows that a lower number of activities organised in the north city together was linked to a decrease in the total number of observations. An example of the effect of an uncontrollable actor, the weather, can be seen in the dip in 2019 observations.

Research shows that engagement strategies that boost self-worth [44], such as training, feedback, and acknowledgement, play an essential role in sustaining activity in citizen science. But not all citizen projects can afford to have a person dedicated to these tasks. In UrbamarBio, industry enablers were vital to overcoming this economic and human resources barrier. They provided direct access to their communication channels and to their customer database previously interested in marine biodiversity and allowed the academia to transform them into volunteers. Industry enablers were also crucial for overcoming logistics barriers; they provided underwater equipment and organised guided snorkelling and diving activities preceded by training on CO usage. The CO allowed a process of collaborative identification of the observations and, besides, academia played an essential role in data curation and ensuring that the effort to take photos would be used in future research. These actions, complemented with the training on species identification and the COs triggers, were crucial to the success of the engagement strategy.

All engagement roles contribute to the success or failure of the engagement strategy. The same happens with the different components of the engagement framework (such as triggers or rewards); all of them...
should be considered when planning engagement actions since they are all essential to create a sense of community and ensure long-term engagement.

It is of the utmost importance to use a modern, functional, and user-friendly CO so the technological barrier posed by the CO is as low as possible and the volunteers can be kept in the loop. When choosing the CO we want to use to implement our citizen science project we must consider the engagement framework from the beginning. Once we have created the solution matrix with the engagement actions (short-term and long-term rewards, triggers, etc) it is important to assess whether the CO has the necessary tools to develop the engagement framework we want to carry out. It is not just a matter of thinking about the technological component, but also about the social/community component as well. For example, if we have identified data validation as an important short-term reward, do we have data curators, experts or dedicated services in the CO to ensure the rapid identification or validation of the observations?

5. Conclusion

We have generated a theoretical reference framework for citizen science engagement, which reveals the need to consider different roles and strategies (behavioural change, motivation, ability, and social design of CO) throughout the participatory process to overcome the inherent engagement barriers of citizen science projects.

The framework is based mainly on the integration of engagement activities at two different temporal scales: short term (more oriented to initial volunteers’ expectations) and long term (to link the academic outcomes with the volunteers’ acknowledgements and to produce the social experience of ‘being part of the community’).

The requirements of the proposed framework must be considered from the very beginning in the choice of the CO we want to use, or the initial steps of co-design and implementation if we plan to develop our own CO.

Data availability statement

The data that support the findings of this study are openly available at the following URL/DOI: https://natusfera.gbif.es/api.

Acknowledgments

We want to thank all the volunteers participating in the monitored urban beaches of this case study. We are grateful to the referees for their constructive input. The research described in this paper was funded by the European Commission via the Cos4Cloud and ARSINOE projects, which have received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreements 863463 and 101037424. ICM-CSIC authors acknowledge the institutional support of the ‘Severo Ochoa Centre of Excellence’ accreditation (CEX2019-000928-S).

ORCID iD

Sonia Liñán https://orcid.org/0000-0003-0431-4683

References

[1] Khan O and Canny J 2008 Promoting environmentally sustainable behaviors using social marketing in emerging persuasive technologies 6th Int. Conf. Persuasive Computer (Sydney, Australia, 19–22 May 2008)
[2] Corner A and Randall A 2011 Selling climate change? The limitations of social marketing as a strategy for climate change public engagement Glob. Environ. Change 1 1005–14
[3] Kollmuss A and Agyeman J 2002 Mind the Gap: why do people act environmentally and what are the barriers to pro-environmental behavior? Environ. Educ. Res. 8 239–60
[4] Simeon R et al 2020 Behavior change techniques included in reports of social media interventions for promoting health behaviors in adults: content analysis within a systematic review J. Med. Internet Res. 22 e16002
[5] Semambo H 2020 Social media as; an agent for behavioral change among young people: case of Facebook usage among mass communication students of Uganda Martyrs University Int. J. Res. Anal. Rev. 7 212–29 (available at: www.irar.org/IJRAR2AA1032.pdf)
[6] Dwivedi Y K 2021 Setting the future of digital and social media marketing research: perspectives and research propositions Int. J. Inf. Manage. 59 102168 (available at: www.sciencedirect.com/science/article/pii/S0268401220308082)
[7] Conrad C T and Daoust T 2008 Community-based monitoring frameworks: increasing the effectiveness of environmental stewardship Environ. Manage. 41 358–66
[8] Conrad C C and Hilchey K G 2011 A review of citizen science and community-based environmental monitoring: issues and opportunities Environ. Monit. Assess. 176 273–91
[9] Rotman D, Preece J, Hammock J, Procita K, Hansen D, Parr C, Lewis D and Jacobs D 2012 Dynamic changes in motivation in collaborative citizen-science projects Proc. ACM 2012 Conf. on Computer Supported Cooperative Work (CSCW ’12) (30 March 2022) (New York: Association for Computing Machinery) pp 217–26
[10] Jungblut S, Liebich V and Bode-Dalby M (ed) 2020 YOUMARES 9—The Oceans: Our Research, Our Future: Proc. 2018 Conf. for YOUng Marine REsearcher in Oldenburg, Germany (Cham: Springer) (Accessed 31 March 2022)
[11] Prestopnik N R and Crowston K 2011 Gaming for (citizen) science: exploring motivation and data quality in the context of crowdsourced science through the design and evaluation of a social-computational system 2011 IEEE Seventh Int. Conf. E-Sci. Workshop (https://doi.org/10.1109/EScienceW.2011.14)
[12] Chu M, Leonard P and Stevenson F 2012 Growing the base for citizen science: recruiting and engaging participants Citizen Science (Ithaca, NY: Cornell University Press) (https://doi.org/10.7591/cornell/9780801449166.003.0005)
[13] Stukas A A, Worth K A, Clay E G and Snyder M 2009 The matching of motivations to affordances in the volunteer environment: an index for assessing the impact of multiple matches on volunteer outcomes Nonprofit Volunt. Sect. Q. 38 5–28
[14] Crall A, Kosmala M, Cheng R, Brier J, Cavalier D, Henderson S and Richardson A 2017 Volunteer recruitment and retention in online citizen science projects using marketing strategies: lessons from Season Spotter J. Sci. Commun. 16 A01

[15] Fischer H A and Wentz E A 2021 Place attachment and learning outcomes among tourists who volunteer for a U.S. National Park science volunteer program Appl. Environ. Educ. Commun. 20 123–38

[16] Fischer H, Cho H and Storksdieck M 2021 Going beyond hooked participants: the nibble-and-drop framework for classifying citizen science participation Citt. Sci. 6 10

[17] Eveleigh A, Jennett C, Blandford A, Cox A L and Brohan P 2014 Designing for dabblers and deterring drop-outs in citizen science CHI ’14 Proc. SIGCHI Conf. on Human Factors in Computing Systems Pages (7 September 2022) (New York: ACM) pp 2985–94

[18] Maund P R, Irvine K N, Lawson B, Steadman J, Risely K, Cunningham A A and Davies Z G 2020 What motivates the masses: understanding why people contribute to conservation citizen science projects Biol. Conserv. 246 108587

[19] Ryan R M and Deci E L 2000 Intrinsic and extrinsic motivations: classic definitions and new directions Contemp. Educ. Psychol. 25 54–67

[20] Rotman J, Hammock J, Preece J, Hansen D, Boston C, Bowser A and He Y Motivations Affecting Initial and Long-Term Participation in Citizen Science Projects in Three Countries (available at: www.ideals.illinois.edu/handle/2142/47301) (Accessed 31 March 2022)

[21] Liu H-Y, Kobernus M, Broday D and Bartonova A 2014 A conceptual approach to a citizens’ observatory—supporting community-based environmental governance Environ. Health 13 107

[22] Yardley L, Spring B J, Riper H, Morrison L G, Crane D H, Curtis K, Merchant G C, Naughton F and Blandford A 2016 Understanding and promoting effective engagement with digital behavior change interventions Am. J. Prev. Med. 51 833–42

[23] Fogg B 2009 A behavior model for persuasive design Proc. 4th Int. Conf. on Persuasive Technology (Persuasive ’09) (30 March 2022) (New York: Association for Computing Machinery) pp 1–7

[24] Hooked Book-Product Design to Boost Customer Engagement | Nir Eyal (available at: www.nirandfar.com/hooked/) (Accessed 31 March 2022)

[25] Yamakami T 2013 An evolutionary path-based analysis of social experience design Multimedia and Ubiquitous Engineering (Lecture Notes in Electrical Engineering vol 240) ed J Park, JY Ng, H Y Jeong and B Waluyo (Springer: MUE) [https://doi.org/10.1007/978-94-007-6738-6_9]

[26] Parsons J, Lukyanenko R and Wiersma Y 2011 Easier citizen science is better Nature 471 37

[27] Pocock M J O, Tweddle J C, Savage J, Robinson L D, Roy H E and Achal V 2017 The diversity and evolution of ecological and environmental citizen science PLoS One 12 e0172579

[28] Fogg B J 2002 Persuasive technology: using computers to change what we think and do Ubiquity 2002 32

[29] Padarath S, Mohepputh P, Permessur N and Choomoo A 2018 Sentiment analysis from Facebook comments using automatic coding in NVivo 11 Adv. Distrib. Comput. Artif. Intell. J. 7 41–48

[30] Saparova D 2012 Motivating, influencing, and persuading patients through personal health records: a scooping review Perspect. Health Inf. Manag. 9 1f

[31] Fogg B J, Cueller G and Danielson D 2007 Motivating, influencing, and persuading users: an introduction to capsology The Human-Computer Interaction Handbook 2nd edn (Boca Raton, FL: CRC Press)

[32] A framework for modeling persuasive technologies based on the Fogg behavior model IEEE Conf. Publication (IEEE Xplore) (available at: https://ieeexplore.ieee.org/abstract/document/8659195) (Accessed 31 March 2022)

[33] Alrige M, Bitar H and Meccawy M 2021 Promoting precautionary behavior during the COVID-19 pandemic: development and validation of a behavior-change messaging campaign J. Infect. Public Health 14 1727–32

[34] Incorporating choice theory/reality therapy and the Fogg behavior model to empower African-American women to engage in physical activity and adopt a healthy diet to improve their overall physical health (ProQuest) (available at: www.proquest.com/docview/1758625727?pq-origsite=gscholar&fromopenview=true) (Accessed 31 March 2022)

[35] Sittig S, Wang J, Iyengar S, Myneni S and Franklin A 2020 Incorporating behavioral trigger messages into a mobile health app for chronic disease management: randomized clinical feasibility trial in diabetes JMIR MHealth UHealth 8 c19927

[36] Solhail A, Deanna T, Shadae P, Dylan G and Joseph B B 2022 Use of the Fogg behavior model to assess the impact of a social marketing campaign on condom use in Pakistan J. Health. Commun. 24 284–92

[37] Boerger N L, Barleen N A, Marzec M L, Moloney D P and Dobro J 2018 The impact of specialized telephonic guides on employee engagement in corporate well-being programs Popul. Health Manag. 21 32–39

[38] Klemmer E and Gouttebarge V 2018 A tailored web-based advice tool for skiers and snowboarders: protocol for a randomized controlled trial JMIR Res. Protoc. 7 e8770

[39] Silvertown J, Harvey M, Greenwood R, Dodd M, Rosewell J, Revelo T, Ansine J and McConway K 2015 Crowdsourcing the identification of organisms: a case-study of iSpot ZooKeys 480 125–46

[40] Tiago P, Gouveia M J, Capinha C, Santos-Reis M and Pereira H M 2017 The influence of motivational factors on the frequency of participation in citizen science activities Nat. Conserv. 21 61–78

[41] Roy H E, Pocock M J O, Preston C D, Roy D B, Savage J, Tweddle J C and Robinson L D 2012 Understanding citizen science and environmental monitoring: final report on behalf of UK Environmental Observation Framework. Wallingford: NERC/Centre for Ecology & Hydrology (available at: www.ueko.org.uk/documents/understanding-citizen-science.pdf) (Accessed 31 March 2022)

[42] Theobald E J et al 2015 Global change and local solutions: tapping the unrealized potential of citizen science for biodiversity research Biol. Conserv. 181 236–44 (Accessed 31 March 2022)

[43] Giglione J A, Meyer R, Ballard H L, Freitag A, Phillips T B and Wasser A 2015 Making marine and coastal citizen science matter Ocean Coast. Manag. 1 77–87

[44] Crawford E R, RICH B L and Bergeron B B A 2013 The antecedents and drivers of employee engagement Employee Engagement in Theory and Practice (London: Routledge)