(Co-)Producing knowledge through citizen science. A service-based view

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Abstract. This qualitative paper sets out to build upon recent developments in public management and service science literatures to better understand the increasing engagement of individuals and communities in the co-production of knowledge within Citizen Science (CS) projects, i.e., research collaborations where tasks are performed by members of the public. Mapping the scattered geography of contemporary CS, the study focuses on two cross-cutting make-or-break factors: the role of ICT and the individual motivations to participate in CS. The paper argues that a broader appreciation of CS informed by a 'service' view becomes itself a potential source of new insights not limited to the CS field. In particular, the study proposes that framing CS as a 'service ecosystem' can provide public decision makers and IS designers with essential insights for the broader understanding of conditions, processes and outcomes of citizen's online experience.

Keywords: Knowledge co-production, citizen science, value co-creation, crowdsourcing, service logic

1 Introduction

In a seminal book, the social theorist David Beetham [1] depicts public services as inclusive goods which are subject to public scrutiny and are developed according to a norm of public ethos that values citizen participation. Embracing this perspective, citizen science (CS) – i.e. the involvement of non-expert (lay) people in scientific discovery, monitoring, and experimentation [2] – can be understood as a public service which is aimed at generating and disseminating scientific knowledge.

The increasing role of CS across many research fields is widely referenced [3-5]. Its value is increasingly acknowledged by national governments in the United States and Australia. Global NGOs, including the United Nations Environment Programme (UNEP), have also voiced their support [6]. In the European Union, CS has gained wider attention since the launch of specific research and innovation funding programmes, such as Digital Agenda, Digital ERA, and Horizon 2020 [7].

Basically, voluntary involvement in CS projects requires lay people to co-produce knowledge with (public) research institutions, and in partnership with expert scientists. As the word "citizen" suggests, participation is open to the general public without any formal training in science [8]. Citizen science is often considered a form of crowdsourcing applied to science, capable of producing scientifically sound data, as well as unexpected insights and innovations [9]. Most of the CS projects stand on public funding [7].

The interrelated conditions of emergence of collaborative scientific ventures include, on the *macro* side: the erosion of the separation between public and private spheres; the new societal dynamics, namely the new relationship between society and science; the radical rethinking of innovation models and research practices [10]; and ICT-related developments. These latter are of particular relevance, thanks to: the ubiquity of Internet and the diffusion of ICT resources across the population; the availability of tailored web-based platforms to support data collection and sharing between government, citizens, civil society, and the private sector [11] (OECD, 2019, p. 27); the affordability of user-friendly devices that allow volunteers to access online CS platforms anywhere, anytime; and the affirmation of the 'hacker-scientist mindset of the computer age' [12]. On the *meso* side, the conditions of emergence of CS include: the scale and scope of the research projects (often too cumbersome and expensive for one single research institution alone, especially in what is known as the field of 'Big Science'); the role and the variety of the non-academic stakeholders; and the configurations of the field of research in terms of project design, lab facilities, training tools, and other resources to support research and participation goals.

Three key rationales make the co-production of scientific knowledge of interest to public management research. First, citizen science provides occasions for the public officials to use science to address community-driven needs and issues [13] and to involve citizens in monitoring the changes taking place around them [14]. Second, data collected in these 'new spaces for citizen action' [5] can potentially contribute to informed policy-making [15]. Third, from the viewpoint of the public research institutions, implementing CS means expanding the in-house knowledge production boundaries and addressing crucial questions about resource management and implementation decisions. Hence, CS requires the public decision makers to make a 'deliberate design' effort [16] about aligning goals, outcomes and trade-offs.

At this critical point in time, disciplines such as information systems, public management, and service science need to dialogue and reciprocally merge, meld and inform co-production of knowledge in CS environments. In this study we see CS as a joint knowledge production endeavor performed in an 'ecosystem' [17: 161], i.e., "a community of interacting entities – organizations and individuals that coevolve their capabilities and roles and depend on one another for their overall effectiveness and survival". The following pages elaborate on these issues. More specifically, the purpose of this paper is to (1) assess the degree to which a service lens can be applied to CS and (2) outline the ensuing implications, in terms of value creation, for the relevant actors. Regarding the first aspect, we believe it is essential and timely to recognize the multilevel nature of activities performed by organizations and laypeople. With reference to the second aspect, understanding the citizen's value creation process is fundamental to co-production design and implementation because it allows for the determination of the appropriate configuration of resources for individuals and communities.

Overall the paper makes three contributions. First, we extend the influential ideas originally proposed by Osborne and Strokosch [18], on the co-production of public services (or the mix of activities that both public officials and citizens contribute to the provision of public services: "the former are involved as professionals, or 'regular producers,' while 'citizen production' is based on voluntary efforts by individuals and groups to enhance the quality and/or quantity of the services they use" [19: 1002]), applying these to a domain (CS) that remains under-appreciated in the organizational debate. Second, combining the 'service' logic (i.e., a logic which emphasizes the centrality of the user's experience and the systemic vision of public service delivery) with an organizational perspective, we explore the potential of a service-based view of knowledge co-production practices. Finally, we outline key areas deserving further investigation for both the practice and the theory.

For the purpose of this paper, the terms 'citizen(s)', 'volunteer(s)' and 'lay people' are used as synonyms, even though insightful distinctions have been proposed by the extant literature, including [20-22]. However, it is not intended to be the definitive interpretation, given that the proposed discussion is the first step of an ongoing research project aimed at reframing the practice of knowledge co-production and building new bridges among disciplines.

Accordingly, the paper (Section 2) offers a panoramic view of the current studies on citizen science but mainly focuses on two landmark features: the role of the ICT and individual motivations to participate. Section 3 illustrates the chosen qualitative research approach. Section 4 provides an interpretation of CS informed by a service logic; this analytical key highlights the centrality of citizen scientists as value creators, the systemic vision of citizen science and the dual role of the ICT (i.e., as both operand and operant resource) in CS projects. Section 5 discusses the practical and research implications. Section 6 sets out the conclusions.

2 Related work

Citizen science is a term that lacks a precise definition [23]. In general, the label describes scientific activities – from the virtual to the physical – in which individuals who are not professional researchers in a particular field actively participate in a research project in partnership with scientists or on their own. Thus, individuals' engagement can vary dramatically, from collecting data for someone else's project to working alongside researchers to develop and execute nearly every part of a project [24].

The variety of terms describing the larger space of public participation in science demonstrates the diversity of both the research disciplines in which CS is applied, and also those interested in understanding citizen science (*e.g.*, public understanding of science, science and technology studies, Internet studies, human-computer interaction). Increasingly, the term citizen science is used to refer to all of these variations on scientific collaboration with the public [25].

According to a recent scientometric article [23], the main fields of study employing CS are biology, ecology and conservation research. Moreover, the social sciences and geography have increasingly started to invite volunteer contributors to research. In quantitative terms, the largest scientific output is to be found in the fields of ornithology, astronomy, meteorology and microbiology [23]. However, it should be noted that most CS projects fall outside the scope of scientometric evaluation, since scientific output is not a main goal.

Literature has generated valuable knowledge in identifying and understanding citizen science. Extant research documents the rise of CS in various geographical contexts and levels, illustrates diverse empirical cases and offer accompanying theoretical reflections. Space limitations mean that, here, the thematically structured overview will focus on the two key aspects that affect CS in the public realm: ICT developments and citizen motivations to participate. Here we examine the relevant literature from an organizational perspective rather than from a purely technological perspective.

2.1 The role of the ICT

There is a wide consensus in attributing the impetus for citizen science to the progress of the ICTs [26] and, in particular, to the Web 2.0 movement, "in which individuals are no longer passive browsers but active contributors" [27: 418].

The technologies required to leverage the power of non-scientists to collect and analyze data vary. For instance, in Kenya, researchers have developed Hotspotter, an image recognition software which can identify individual zebra by their barcode-like stripe pattern and body shape. In 2015, hundreds of volunteers participated in photographing zebra using GPS-enabled cameras. Images were then run through Hotspotter which led to the identification of 2350 unique animals [11, 28].

The spread of the Internet into everyday life has substantially increased CS projects' visibility, functionality, and accessibility [13]. Further, user-friendly interfaces "….have made participation possible for groups that previously were not reached or well served by citizen science, such as those with literacy or numeracy skills that are not text based" [13: 1436]. Similar to what happens in crowdsourcing contexts, the 'focal agent' (e.g., a research institution) "…broadcast[s] problems to crowds so that potential solvers can decide whether to self-select and solve problems" ([29: 368]. It is remarkable that the focal agent does not evaluate each potential solver to choose a qualified one. At the same time, "…not every member of the crowd that self-selects to solve the problem is in the right position to solve it" (ibidem).

Social media and the Internet also have enabled citizen science projects that can be accomplished only through online platforms. People who are passionate about a subject can quickly locate a relevant CS project, follow its instructions, submit data directly to online databases, and join a community of peers. eBird, for example, engages the global birdwatching community to collect more than 5 million bird observations every month and to submit them to a central database where they can be analyzed to document the quantity and distribution of bird populations [13]. Another good example is *Zooniverse*, an online platform that currently hosts more than eighty active CS projects and has more than 1.5 million registered volunteers [30]. Professional scientists use Zooniverse to crowdsource the analysis of unprecedented volumes of data by asking volunteers around the world to classify or transcribe pre-existing evidence (e.g. sound files, videos, or pictures, such as the millions of images of galaxies, moon craters, and particle collisions). A frequently mentioned Big Science project is Higgs Hunters. Launched in 2014, it helps physicists search for *exotic* particles in data from CERN's (European Organization for Nuclear Research) Large Hadron Collider in Geneva, the world's highest energy particle accelerator. The quality of the volunteers' contribution to and participation in this online research effort (hosted on the Zooniverse platform) has been recognized by the scientific world several times [13, 31].

Citizen science activities are often structured around campaigns, where volunteers gather and annotate a specific type of data [32]. Further, some projects are bounded by a specific time or place. In contrast, eBird and Higgs Hunters solicit the inputs of the citizen scientists continually and without geographical constraints.

Public engagement in science ventures can take a variety of forms. According to [24: 1-3], CS range along a spectrum of contributory, collaborative, and co-created projects. The former are generally designed by scientists, and members of the public contribute primarily through data collection. While collaborative projects are also designed by scientists and involve data contributions by the public, volunteers may be involved in project refinement, design, data analysis, or the sharing of results. Co-created projects are designed by scientists and members of the public working together, where at least some of the participants are actively involved in most, if not all, steps of the research process. Co-created citizen science projects – also called "Community Science" [33] – represent the highest level of volunteer engagement, and alongside collaborative projects may provide a platform to reach new audiences with topics and approaches that are relevant to individual and community interests. As such, "community science initiatives may have the greatest potential to achieve a wide range of public understanding impacts" [33: 9]. However, the move of currently engaged volunteers from projects that are largely contributory toward more co-created projects is slow [24].

The need to support the volunteers in the transition from the role of simple data collectors to that of co-creators of meaningful citizen science projects leads to the second key aspect of CS: the motivations to participate.

2.2 Motivations to participate

The value of CS to scientific institutions is clear. According to Bonney and colleagues [13: 1437], CS projects "…truly do science – that produce reliable data and information usable by anyone, including scientists, policy-makers, and the public, and that are open to the same system of peer review that applies to conventional science". Some drawbacks to co-created projects include a higher investment of time required by those managing the project and serving in supporting roles (e.g., scientists, subject-matter experts, platform managers) [24].

No less meaningful is the value of CS to volunteers. Citizen scientists have always been a highly composite category in socio-demographic and cultural terms. Indeed, in CS projects, the maximization of diversity and inclusion is considered the best means to foster in-depth scientific learning-by-doing [6]. Also, the new spaces opened up by the ICT developments is set to increase the variety of the sites and contexts of application in which knowledge co-production occurs. This heterogeneity 'by design' has an influence on the ways citizen scientists perceive the value to be gained from entering the project and the value of their experience.

Extant research shows numerous possible outcomes for individuals, in terms of, for example, increased knowledge, skills, scientific literacy [24]. Participation in co-created projects also may provide lay people with a greater understanding of the scientific process, their community structure, social context, and opportunities to communicate their findings to the public [33]. Increased social interactions are often necessary in co-created projects to deepen understanding and sustain engagement, and these may be viewed as either a motivation or barrier to participation.

In general, managing the motivation and self-efficacy of lay people in citizen science projects is tricky. Motivation to participate is multifaceted [34]. Research reveals a range of intrinsic and extrinsic motivators, and also highlights great diversity in what drives active participation. According to Deci and Ryan [35] and Cappa et al. [8], intrinsic motivation is connected to self-determination in participating due to satisfaction in performing a valuable scientific task and in increasing their understanding of scientific issues, while extrinsic motivation is related to the intention to contribute based on some reward. Research has highlighted the importance of both intrinsic and extrinsic motivations for the success of virtual communities, as some people may participate mainly due to their self-interest or to contribute to a social aim, while others are primarily interested in the reward they can obtain.

Empirical research on factors that motivate participation and retention in citizen science projects distinguishes between motivations for participating in field-based versus online ventures. While the demographics and motivations of virtual citizen scientists working on field-based projects have long been studied by sociologists, and the mechanics of user contributions to such sites have been extensively examined by data scientists, it is only relatively recently that the philosophers of science have taken an interest in this theme [36].

Studies of local, community-based citizen science projects – reported by [24] – have shown that opportunities for in-person social interaction among participants and fulfilment of a general interest are common motivators for participation. In contrast, research into online citizen science projects has shown that contributing to scientific research and bolstering participants' online reputations are key motivators [37]. Online CS projects show extraordinary turnover rates. Moreover, participant motivations have been shown to fluctuate over the course of an online project and to differ based on the quality or quantity of participation in online environments. Many of these purely online projects are broadly focused on science, technology, engineering and mathematics (STEM) topics, while community-based projects tend to address local issues (e.g., environment protection, the monitoring of at-risk areas).

"Matching project activities with volunteer motivations may be the best method for achieving volunteer satisfaction and retention and also may enhance recruitment" for individuals with diverse interests and backgrounds [24: 2]. CS projects that align with participants' hobbies, previously existing interests, or previous engagement in other activities are believed to be the most likely to keep levels of motivation high (Bonney et al., 2009, p. 47). Once individuals are recruited, effective training and collaborative learning, often using online training tools, may enhance engagement, especially in co-created projects, and connectedness.

Research to date suggests it is important to streamline online training and collaborative resources as much as possible, to ensure that they are easy and fun to use and to directly link them to a tangible project of interest to participants [24].

In a nutshell, ICT developments and citizen motivations to participate are two key drivers and mainstays of citizen science. The ICTs provide the research institutions with unprecedented opportunities to involve the public in scientific work and knowledge co-production (and vice versa), but the true make-or-break factor of success is the citizen motivations to participate, which are difficult to detect and govern. Influencing citizens' personal motivation remains "a complex task, due to their often highly individual nature" [38: 301]. Despite this, ICT and motivations hold similar promise for the broader case of co-production in the public realm.

To recap, by considering CS as an established field, the above selective review offers a novel perspective in which the co-production (of scientific knowledge in this case) is not only popular and on the rise, but which already offers empirically significant and scientifically valuable experiences at different scale, is supported by authoritative public research organizations the world over, and is institutionalized.

In what follows, the two key, interlocking, make-or-break factors are more closely analyzed and reframed.

3 Research approach

The previous section references many of the historically crucial topics for co-production in public services. The central issues and concerns for management scholars include: the joint working between service users and service providers, where each player is given a well-defined role in different times and places and in a specific phase of the 'production process'; the various modes of interaction, enabled by ICT-based tools and infrastructures; and the challenge of securing the recruitment and retention of volunteers. An additional and recurrent factor in the managerial research on co-production is the prevalent instrumental position – which Osborne and Strokosch [18] call an 'add-on to service delivery' – attributed to the members of the public in relation to the service professionals in public agencies, an aspect that typically emanates from a New Public Management (NPM) perspective.

For some years now, the public management research has started to break with the mainstream thinking, in particular with the notion that the service user is merely a provider of additional input on a voluntary basis. For instance, exploring the nature of value creation in public services from a service perspective led Osborne and colleagues [18, 39] to propose a rethinking of co-production in the public realm. Its basic premise is that co-production is intrinsic to any service experience [39: 18-19]. This theoretical revisit has allowed, among other things, to directly link co-production to service innovation and to the co-creation of value in public services. Interestingly, framing co-production in a New Public Governance (NPG) perspective implies concentrating on both processes and system [39].

In the following we use this insightful work as a springboard to reframe CS. Basically, we assume that CS can be considered a form of nonscientist engagement aimed at generating and disseminating valuable scientific knowledge within the academic community and society at large. As a phenomenon, CS overlaps with crowdsourcing and is sometimes called “crowdsourcing for science”, but in fact only some citizen science projects are akin to crowdsourcing, while others are not, due to scale or structure [25]. These and other features of CS make it an interesting context for studying such wide-ranging topics as participation, relationships between laypersons and scientists, knowledge dissemination. Here, however, our concern is solely on the affinities to co-production of public services. In this view, the role of service user and that of service provider are covered by, respectively, the citizen scientist – i.e., a self-selected volunteer that engages in the research work without the hierarchical bureaucracies or formal leadership structures – and the research institution – i.e., a public sector organization (or PSO) that partners with volunteers. This tentative exercise has the goal of teasing out new insights that can broaden our understanding of the nature and role of ICT-mediated knowledge co-production in online contexts.

Methodologically, we analyze CS through the lenses of service management because we believe that useful lessons can be learned from this perspective. The next section reviews the central elements of a service-based view ([17, 18, 39-41]) then transposes this analytical key to the context of citizen science. Section 5 explores the practical and theoretical potential of this exercise.

4 A service-based view of citizen science

Citizen science depicts a composite “…socially distributed knowledge production system” [42: 10]. Culturally heterogeneous, it can be likened to a ‘service ecosystem’ in which multiple forms of interaction and exchange take place among social actors [17: 161]. According to Lusch and Nambisan a service ecosystem is “a relatively self-contained, self-adjusting system of mostly loosely coupled social and economic (resource-integrating) actors connected by shared institutional logics and mutual value creation through service exchange” [17: 161]. The social actors are also forming a kind of virtual community capable of self-adjusting and integrating resources. The central theme is how research institutions try to unlock volunteers as ‘complementary assets’[43]. Common structures (or ‘shared institutional logics’) permit the creation of the ‘service’ (singular) in conjunction with some entity, whereby “…service involves applying resources for the benefit of others or oneself” [17: 158]. According to Lusch and Nambisan, service ecosystems, service platforms, and value co-creation are the three core components (or pillars) of service innovation.

The service platform is ‘the place’ where the user (the citizen scientist) meets the provider (the research institution). Service platform is a broad term that can be applied to various types of PSO-provided resources, tangible or intangible (including websites, ad-hoc forums, software artefacts, back-office facilities, and datasets), relatively stable or emergent. Thus, the service platform hosts the iterative interactions that drive new knowledge creation and forms the fulcrum of the service ecosystem, meant as ‘the venue for innovation' [17]. The connections among the elements may be loose, "as when a variety of off-the-shelf software systems are used separately to support various project goals", or tight, as in a project website that offers multiple functionalities, including data collection tools, visualization components, blogs, news feeds, email, forums, project information, "in a unified way" [34: 168].

Interestingly, Grönroos [40] differentiates between user service logic and provider service logic, and suggests that the value creation and co-creation processes must support each other. Specifically, in tune with the service logic, it is always the user (not the provider) that creates value: first, "…using all resources available to them" and contributing their time, effort and expertise "…to achieve specific goals in a way that is valuable to them" [40: 5]; and, second, independently (i.e., in isolation) from the service provider. This latter circumstance arises, for example, when a citizen scientist interacts in person or digitally with their peers on social media. The dyadic interaction can generate positive, negative or neutral impacts on the value creation process [41].

In contrast, a provider service logic permits us to observe how the public sector organization (e.g., a research institution) plays the role of enabler and resource supplier. In that sense, the PSO ensures the availability of a supportive environment (e.g., an accessible online platform) designed specifically for the citizen scientists, or 'users' in the classic sense. This platform is a 'social information system', i.e., an information system based on social technologies and open collaboration [44]. As in the case of service logic, the idea is to achieve specific goals in a way that is valuable to users [40]. This is the approach found when, for example, a CS platform offers a variety of user tools, such as blogs, chats, educational materials, and mobile gamified apps to encourage, motivate and retain contributors from the millennial generation [32].

In essence, according to Grönroos, although the output is fundamental, the process is the defining feature of the service. This shift of focus from output to process has two important implications: for how the quality of service is perceived by the users and, therefore, also for the development and management of service: "…To be valuable help to the users, the resources, processes and competences provided by the service organization must be "*aligned* (our emphasis) with the resources, processes, and competences the service users require" [40: 6].

In the event of discrepancies, the users will, first of all, perceive low or even inadequate service quality. Secondly, this low quality will translate into inadequate value for them [40]. The two claims clearly illustrate the relationship between expectations, subjective experience and actual performance, but they also illuminate the potential reasons for non-scientist members of the public dropout in CS projects. The relationship means that expectations, subjective experience and actual performance, in turn, affect the process and outcomes of engagement in research collaborations. As service users, citizen scientists are motivated to engage in an interaction with the research institution to the extent to which they realize value from their 'situated experience' [45] with science and the knowledge they bring to the project. Importantly, value is emergent and differs between individuals and the situation in which an evaluation occurs [46].

Thus, from the PSO perspective, the effective design of the service is a necessary but not sufficient condition for a successful service delivery [47] and positive outcomes. The elusiveness of the value, the variety of motivations that underpin participation and retention, and the unpredictability of the contexts (physical and virtual) in which interactions are taking place [46] mean that what happens in the service system cannot be fully and deliberately planned by the provider. At the same time, a process of co-production that is meaningful for the relevant actors can emerge only when it is both enabled and shaped by purposeful managerial action.

To citizen science, a service-based view recognizes ICT as an integral element of the ecosystem in which a CS project is conceived and developed. Lusch and Nambisan [17: 157] highlight the dual nature of information and communication technology: *operant* resource (as the agent that acts on other essential resources, and triggers or initiates the innovation) and *operand* resource (that on which an operation - e.g., the access to an online database - is performed). As operant resource, the digital tools create novel opportunities for knowledge integration or enhance the understanding of citizen scientists beyond basic data collection. Examples of operand resources include digital infrastructures, user interfaces or smart technologies that can help hold together diverse actors and enable collaboration within the service ecosystem.

5 Potential implications

Viewing CS through the lenses of service management is a valuable way of conceptualizing and understanding citizen's engagement in co-production. A service-based view emphasizes the centrality of the user's process logic and experience, the systemic vision of public service delivery and the dual role of the ICT in support of resourceful actors, three concepts that plot an alternative course to that taken by the NPM-inspired mainstream.

Now, as a preliminary and non-exhaustive exercise, we try to identify which areas could be deserving of further investigation and development on both the practical and the conceptual fronts. The considerations below refer to the public services organizations (PSOs), in the general sense of the term, willing to realize the potential of co-production initiatives in various fields of application.

5.1 Implications for the practice

Firstly, if the imperative for public organizations is to reinvent themselves as "service" organizations [48], then the shift in thinking calls for the PSOs to pay more attention to "…the organization and its service processes and leadership such that the required fit is achieved" [40: 6]. From a management perspective, a preparatory step to maximize the expected outcomes of co-production is to identify what resources are required at the individual, organizational and systemic levels. This tripartite, in turn, provides a foundation for designing multidimensional systems of performance assessment.

Secondly, PSOs need to design better features for user-centric platforms and supporting tools. Because co-production efforts such as CS initiatives are predicated on the contribution of a large number of participants (or 'complementary resources'), user engagement and willingness to contribute are critical issues that software designers must take into account when developing, testing and implementing artefacts. Put simply, designers who want not only to limit user dissatisfaction but also to encourage continued use of web platforms should be aware of two categories of technical features: i.e., *satisfiers* and *motivators.* The former include functionalities whose absence will cause a participant to experience dissatisfaction with a website. The latter are those which add value to a website [34: 169-170]. An iterative approach to the design is essential to ensure the constant alignment of the features of the artefacts with the personal interests and needs of the users. That said, public decision makers should always be mindful of the dual role of ICT as both operant and operand resource. In the former case, the organizational units involved include information systems, service innovation and knowledge management. In the latter, the most interested units are those in charge of network management, standards and organizational routines.

Thirdly, the locus of knowledge creation and sharing is destined to move progressively toward the periphery of PSOs. The continuous redefinition of the ecosystem's geography will effectively require information systems and organizational members to take on more complex roles. The aim is to allow for continuous scanning by the PSOs to identify the signals that indicate when boundaries should be crossed and reconfigured and when they should not [49: 1401]. In this respect, PSOs face an enormous challenge in dealing with an environment that lacks physical sites and often includes anonymous participants.

5.2 Research directions

Citizen science demonstrates more heterogeneity than other co-production fields of application, e.g. the public involved in CS is heterogeneous 'by design' (see section 2.2). To gain significant traction in understanding under what conditions and constraints co-production is likely to succeed or fail, it is necessary, first, to delve into the intrinsic motivations of the members of the public. A concept that promises interesting developments for understanding the willingness to interact in CS ecosystems is that of psychological distance (or 'the perceived closeness to an experience') that Holmqvist et al. [46] recently applied to different aspects of value creation in services.

Second, the dual (operand and operant) role of ICT takes on considerable meaning in the studies dedicated to the innovation potential of technologies deployed in co-productive practices. As operand resource, the analytical attention must be placed on the capabilities of the technologies to support the coordination of the processes, the sharing of knowledge and the accumulation of the data. As operant resource, the research focus must favor the potential of the ICT to shape the design and the content of the services.

Finally, the data flows produced by the online CS platforms offer unprecedented possibilities for process tracing, which, in turn, affects actor, process or task transparency. Interestingly, the wealth of freely available information can help to plug the primary methodological gap - i.e., the absence of co-production evidence in large N settings - that challenges the researchers (e.g., [50]) and that has, until now, limited the generalizability of the findings of many empirical studies. A further important step in capturing the factors shaping motivation in ICT-mediated contexts is to keep detailed logs of most interactions among community members.

6 Final remarks

In this paper we consider the applicability of a service logic to citizen science (CS), seen as a kind of knowledge co-production. Building on Grönroos' work, we also propose that the experiential process of value co-creation by lay people affects the process and outcomes of engagement in research collaborations. In addition, teasing out and combining these insights has shined a light on several lines of action that can aid the successful practice and outcomes of ICT-based co-production in the public realm. This preliminary exercise has also demonstrated that the integration of insights from distinct theoretical perspectives (information systems, public management, and service science) enables these disciplines to learn from each other, and could even help reinforce the understanding of CS and its implications.

Overall, our paper makes a valuable contribution to the debate about how to spur citizen participation through technology, specifically how to encourage co-production through experiential value co-creation. Nevertheless, implementing co-production remains challenging for public service organizations and this circumstance limits its development in practice.

The present study's focus on the two primary factors of success, i.e., the role of ICT and the citizens' motivations to participate in CS as a specific form of co-production, is a clear limitation. This is further hindered by the use of only a service logic as interpretive key which, despite being an efficacious tool to conceptualize the research institution as a service provider and value co-creator, and to highlight the centrality of the user as value creator in the service system, is, poorly equipped to give us a full understanding of the political and policy context of public service [51].

Hence, Citizen Science offers great promise for scholarly enquiry on co-production. We believe that there are many opportunities for interdisciplinary research on these issues. The availability of empirically significant and scientifically valuable experiences, the institutionalization of the engagement of the volunteers, and the systematic use of assessment and measurement practices compared with other application fields in the public sector, characterize CS as a more mature co-production domain. However, it goes without saying that further research is required before the current CS can be considered as a likely scenario for public service co-production in the long run.

The paper presents the initial findings of an ongoing research endeavor. As such, it does not provide definitive answers but instead offers a more elaborate set of issues relating to co-production supported by ICT platforms. What this study shows is that, in the case of designing co-production platforms, attention should be focused on the unique characteristics of the citizens that use them. The paper addresses complex problems in a conventional way, but one, nevertheless, that has the potential of rewarding us with a far richer understanding of co-production in public settings.

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