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Engaging lay people to build a resilient Big Science organization? Some preliminary insights

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Main purpose

Knowledge co-production in "Big Science" projects – *i.e.* scientific endeavours characterized by organizational complexity due to their size, exploratory nature, and diversity of participating specializations, cultures, and individual orientations (Child, Ihrig, and Merali, 2014) – is a brand-new concept, which is based on the assumption that lay people are able to establish dynamic and contingent relationships with professional researchers and/or expert scientists, in an attempt to contribute in forming, validating, and adapting knowledge (Bonney et al., 2014). While this topic has been overlooked for a long time, scholars and practitioners are currently paying an increasing attention to it. In fact, knowledge co-production in Big Science projects has been investigated in various contexts, ranging from sustainable and appropriate use of natural resources (Berkes, 2009), to environmental challenges (Armitage, Berkes, Dale, Kocho-Schellenberg, & Patton, 2011) and genomic research (Stegmaier, 2009).

Our aim here is to draw a more comprehensive picture of this phenomenon, in order to better frame, on the one hand, the conceptual and contextual underpinnings of knowledge co-production in Big Science and, on the other hand, to disentangle the role played by lay people who – as volunteers – support expert scientists in pushing forward scientific knowledge. Also, this paper focuses on how knowledge co-production empowers Big Science organizations' capacity and dynamic reach, enabling them to develop a greater ability to manage unforeseen and/or unforeseeable external forces and to become more resilient. Further, it identifies key themes and research evidence that can usefully contribute to theory and practice in this crucial area. Summing up, three research questions inspired our study:

- What "artefacts" and "choices" are available to Big Science organizations to effectively integrate the roles and perspectives embraced by lay people into their routines and practices?
- What roles are lay people used to play in knowledge co-production initiatives?
- And, last but not least, what is the "value added" of knowledge co-production for Big Science organizations?

This short paper is organized as follows. The second section provides a brief overview of the conceptual foundations of this study and depicts the research gap we aim to fill. The third section summarizes the research strategy and the methods which were used to obtain a tentative answer to the above research questions. The fourth section reports the main findings and emphasizes the twofold contribution of this study, which is presented in the fifth and concluding section of the manuscript.

Theoretical background and research gap

Scholars have used a wide array of constructs to depict the processes of lay people engagement in Big Science projects (Hand, 2010). Among others, "citizen science" (Wildschut, 2017), "participant-driven research" (Woolley, et al., 2016), and "crowd science" (Franzoni & Sauermann, 2014) have been variously used to refer to the involvement of lay people in research ventures aimed at collecting, categorizing, and/or analysing scientific data. Even though each of these constructs discloses distinguishing shades and features, they are conjoined by the common attempt to foster the establishment of a partnership between expert scientists and lay people, in order to unleash the full potential of knowledge co-production in Big Science projects (Tiago, Pereira, & Capinha, 2017).

Sticking to these considerations, Callon (1999) identified "knowledge co-production" as an alternative approach to the traditional "public education" and "public debate" models, which are still prevailing in the scientific realm. The latter rely on a clear and deep demarcation between expert scientists and lay people; in contrast, the knowledge co-production model assumes that lay people play an important role in the collective action of knowledge production, supporting expert scientists to enhance the individual and collective understanding of the reality being investigated.

Recent studies have shown that lay people are able to collect adequate and accurate data when they are involved in Big Science projects, even though their limited experience with scientific endeavours may imply incomplete evidence collection (Kallimanis, Panitsa, & Dimopoulos, 2017). Previous experience of lay people has been found to perform as a determinant of more smooth and effective data collection (Lewandowski & Specht, 2015). In addition to prior knowledge, the involvement of lay people in specific training activities may boost their co-production potential, thus increasing their effectiveness in backing the activities of expert scientists (Ratnieks, et al., 2016).

In an attempt to sketch the attributes of the knowledge co-production processes in citizen science projects, Brandeis and Zamanillo (2017) suggested that laypeople engagement develops through six ensuing steps:

1) Initiation: the leading organization enacts the process of knowledge co-production, clarifying the role of each actor in the citizen science initiative;

2) Preparation: the leading organization arranges the tools and protocols to foster the process of knowledge co-production and engage lay people;

3) Involvement: lay people are recruited on either a voluntary basis or upon invitation;

4) Training and facilitation: lay people receive training to enhance their co-production potential;

5) Data collection, classification and/or analysis: lay people collect and/or process available data, interacting – either directly or indirectly – with the expert scientists;

6) Verification: the leading organization verifies the data provided by lay people and validate their contribution in the advancement of the scientific knowledge.

Beyond establishing the conditions for lay people engagement, these steps enable organizational resilience, which is understood as a double capacity of organizations (Gilly, Kechidi & Talbot, 2014): on the one hand, it consists of the organizational ability to resist external shocks and to limit their negative consequences; on the other hand, it involves the capability to anticipate environmental changes and to boost the organizational responsiveness. In particular, "initiation" and "preparation" are intended to set the conditions for knowledge co-production and to increase the organizational adaptiveness: norms and procedures are set, in an attempt to enact and exploit the lay people' sleeping resources. "Involvement" and "training and facilitation" nourish the organizational ability to anticipate changes, improving the co-producing potential of lay people and enriching available slack resources to meet environmental challenges. Lastly, "data collection, classification and/or analysis" and "verification" could be conceived as control processes, which allow the organization to prevent disruptive behaviors of lay people.

In spite of these considerations, little is known about how each of the above steps contributes in knowledge co-production. In fact, the "knowledge co-production" perspective has been rarely embraced to delve into the distinguishing attributes of citizen science projects. This is surprising, since scholars have largely stressed the existence of knowledge co-production dynamics at the roots of citizen science projects (Freitag & Pfeffer, 2013). Therefore, it has been claimed that "*…the significance of citizen science to global research...might be far greater than is readily perceived*" (Cooper, Shirk, & Zuckerberg, 2014, p. e106508). Moreover, it is worth noting that current scientific literature on this topic is strewn among many disciplines, fields and approaches, while insufficient consideration is given to the organizational context in which the co-production activities occur. As well, no studies exist that would allow us to connect knowledge co-production and organizational resilience.

Recent developments in the field of public services co-production (Parrado, Van Ryzin, Bovaird, & Löffler, 2013; Bovaird, Stoker, Jones, Loeffler, & Roncancio, 2016) is of little help to capture the peculiarities of knowledge co-production in Big Science environments. Indeed, while knowledge co-production shares a number of attributes with public service co-production, there are substantial differences between the two, that limit the possibility for generalization and cross-fertilization. These points support the originality and the timeliness of this study, which represents one of the first attempts to illuminate the organizational issues at the basis of knowledge co-production in Big Science projects.

Chosen approach and methods

A mixed approach was used. Firstly, our excursion into the field of "knowledge co-production" was guided and informed by a realist overview of the current scientific literature. The process of knowledge co-production enacted by the involvement of voluntary scientists is a relevant emerging field worldwide, and it is increasingly recognized by leading entities in the Big Science arena (Balcom, 2015; Barr, Haas, & Kalderon, 2016). Nevertheless, to the authors' knowledge, the role of these (complementary/supplementary) actors needs to be better clarified and conceptually framed, in order to disclose their factual input in research endeavours (Bugiolacchi, et al., 2016).

To contribute in filling this gap, a qualitative approach was taken, which consisted of a single case study method (Yin, 2014). Such a research design was consistent with the purpose of thoroughly investigating the distinctive role of lay people involved in knowledge co-production in a unique scientific setting. Moreover, attention was paid to the organizational tools and artefacts aimed at enabling lay people engagement. The case study focused on the HiggsHunters citizen science project, which was intended to involve lay people in classifying data provided by the ATLAS (A Toroidal LHC ApparatuS) experiment at CERN. In particular, lay people were asked to identify long-lived particles – as well as other unusual features – in images of Large Hadron Collider (LHC) collisions; besides, they were encouraged in pointing out "*…anything they thought was 'weird' in any image*" (Barr, Haas, & Kalderon, 2017, p. 4). As compared with previous citizen science projects at CERN, which mainly relied on the passive ability of lay people to donate the idle time on their computer to help simulate proton-proton collisions, the HiggsHunters projects strived to engage lay people in actively indicating "*…new particles beyond the knowledge of particle physics – dramatically changing our understanding of the subatomic realm*" (Barr, Haas, & Kalderon, 2017, p. 4). More than 32.000 non-expert citizen scientist were involved on a voluntary-basis in the initiatives, being asked to classify 1.200.000 features of interest on about 39.000 distinct images (Barr, Haas, & Kalderon, 2016). Similar projects have been recently launched in other scientific realms – including astronomy (Darch, 2014) and geography (Hepburn, 2017).

Sticking to Yin (2014), the research design consisted of four phases: 1) the preparation for data collection; 2) the collection of relevant evidence; 3) the analysis of collected evidences; and 4) the arrangement of the research report. As suggested by Dul and Hak (2008), multiple sources and different methods were used to gather relevant information. At the beginning, a document analysis was performed to achieve a better understanding of the topic being investigated. Then, secondary data obtained from previous research were examined. Lastly, yet importantly, unstructured interviews to expert scientists involved in the knowledge co-production initiative were realized to gather first-hand evidence. The triangulation of these sources allowed to improve the reliability and the consistency of this research.

Main findings

HiggsHunters was found to perform as an integrating platform, which hosted multiple interactions among a large number of co-producers – including expert scientists and lay people – who actively participated in the process of knowledge generation and sharing. Metaphorically speaking, it was the core of a knowledge ecosystem, where different actors participated in a joined knowledge co-production effort. However, the relationships between expert scientists and lay people were intrinsically affected by the information asymmetry suffered by the latter, as well as by the difficulty to make volunteers able to effectively take part in a research project deeply rooted in particle physics. This circumstance hindered the organizational ability to promptly develop resilience.

To face the former issue, a sort of boundary spanner was introduced, in an attempt to handle the power relations between the expert scientists and lay people. Knowledge co-production interactions were mediated by digital tools and Information and Communication Technologies (ICT_s). Specifically, the "Zooniverse" web portal, the world's largest citizen science platform hosting more than 1 million lay people interested in participating in knowledge co-production initiatives (Shuttleworth, 2017), was exploited to boost the collaboration between expert scientists and lay people involved in the HiggsHunters project. The use of this on-line platform had a twofold implication: on the one hand, knowledge co-production was realized without interfering with everyday expert scientists' activities; on the other hand, digital tools allowed to "routinize" the engagement of lay people in the LHC activities, thus improving the institutional legitimation of the HiggsHunters project. From this point of view, boundary spanning through ICT_s allowed to "initiate" the knowledge co-production process and to "prepare" the requisites to lay people and expert scientists collaboration, putting the seed of organizational resilience.

To deal with the second issue, lay people were invited to attend at several preliminary training activities. Preliminary training turned out to be crucial for two reasons: 1) it provided volunteers with basic information and skills to actively participate in the process of knowledge co-production; 2) the development of basic skills minimized the risks arising from the lack of direct interaction between the expert scientists and the lay people, which may result in diverging perspectives and conflicting aims, harmful to knowledge co-production. In other words, training activities established common rules, language and understandings among those who participated in the HiggsHunters project, thus realizing the full potential of lay people engagement. Moreover, it allowed to nourish the seed of organizational resilience, increasing the slack assets available to the organization.

It is worth noting that Higgshunters was not conceived as a temporary project, which was going to be suppressed at the end of the co-producing initiative. Rather, it involved the creation of a "civil science" community, which gravitated around the LHC activities. This was crucial to boost the commitment of laypeople to knowledge co-production and to establish an *esprit de corp* among those who participated in it. The acknowledgement of laypeople's contribution in several scientific papers – which emphasized that, in several circumstances, they were more effective as compared with the ATLAS algorithm in detecting exotic particles' dynamics (Barr, Haas, & Kalderon, 2017; 2016) – further increased the engagement of lay people in the knowledge co-production initiative. Also, volunteers' engagement was supported by the "verification" activities implemented by expert scientists, who performed as buffers to the turbulence produced be knowledge co-production to ordinary organizational activities.

Ultimately, lay people were found to play two main roles in the case being investigated. Involved in analysing and classifying more than 1.200.000 features of interest on about 39.000 distinct images, they performed as "*relievers*". Actually, big data management is a difficult challenge for Big Science organizations, since they may lack adequate and timely resources to handle them. In this specific circumstance, the recruitment of lay people had two concurrent effects: firstly, it allowed to promptly process a huge amount of data, which were critical to push forward the research activities; moreover, expert scientists had the opportunity to focus their attention on value-added activities, since classifying tasks were delegated to lay people.

Moreover, volunteers had an "enabling" role. Their participation in analysing and classifying the features of interest detected by the expert scientists was a fundamental source of information for expert scientists. They had the opportunity to revise their conceptual models and practices in light of the contextual and challenging perspective embraced by lay people, who were not "contaminated" by professional rules and institutional ties in interpreting the images of interest. The information provided by lay people – especially those concerning unusual features and weird dynamics – were beneficial to revise the algorithm arranged by expert scientist to automatically classify the images made available by LHC. From this point of view, they concurred in the enhancement of traditional organizational processes.

Sticking to these considerations, lay people engagement paved the way for two relevant outcomes. On the one hand, it contributed to the success of the scientific endeavour. In fact, the engagement of lay people allowed to activate the sleeping resources of the community to advance the research activities realized at the LHC, backing expert scientists with no additional expenditures. On the other hand, knowledge co-production generated relevant social spill-overs. Among others, this initiative was an important point of contact between undergraduate and graduate students in physics and one of the most important research institutions in the world. Also, it concurred in social development at the community level, rising laypeople awareness of their potential for the advancement of the current understanding of the subatomic realm.

Contribution

This paper tries to disentangle knowledge co-production issues in the Big Science realm from both a conceptual and a practical point of view. As far as conceptual issues are concerned, it suggests that Big Science and knowledge co-production between expert scientists and laypeople follow a similar developing path, which leads to organizational resilience. Performing as citizen scientists, lay people may be engaged in standardized and routinized research activities – such as data classification – while expert scientists have the opportunity to focus on value-added and innovative activities. The ecosystem metaphor helps in making this point (Dougherty & Dunnel, 2011): Big Science organizations should strive for creating a knowledge ecosystem, capable to foster the community involvement in a perspective of knowledge co-production. This entails the development of greater slack resources and the expansion of the organizational adaptability, which are crucial to achieve organizational resilience.

However, laypeople engagement is not free of charge. Big Science organizations have to develop fitting infrastructures and procedures to encourage the participation of volunteers in their projects. Moreover, an effort should be made to minimize the risks of unproductive engagement of lay people: this happens when they are not properly prepared and trained to effectively participate in knowledge co-production. Digital tools and ICT_s play an essential role to boost the process of knowledge co-production. At the *macro* level, the use of ICT-based platforms allows the parcelling out and delocalization of scientific research processes, organizing them in manageable steps. Hence, they enable volunteers' engagement, which does not require deep prior knowledge and/or tailored competencies (Baker, 2016). At the *meso* level, ICT_s and on-line communities facilitate the communication and the interaction between the expert scientists and lay people, establishing a structured, but flexible procedure to allow the latter involvement in research endeavours and to transfer the results of their work to expert scientists (Faraj, Jarvenpaa, & Majchrzak, 2011). Lastly, at the *micro* level, lay people are both the users of the online platforms and the necessary functional components of the overall system, representing the core unit around which it is organized (Ekbia & Nardi, 2012).

Adopting a perspective informed by organization studies, it could be argued that Zooniverse served as a boundary spanner, which allowed to support the activities of the expert scientists involved in the LHC experiments. On the one hand, the use of a boundary unit was intended to preserve the (loose) organizational mechanisms which coordinated the relationships between expert scientists from the potential interference of lay people. On the other hand, it concurred to maintain a demarcation between expert scientists and lay people, which was useful to realize the full potential of knowledge co-production: indeed, it avoided the emergence of diverging perspectives and diverging aims (Woodcock, et al., 2017). However, further research is needed to shed light on this issue.

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