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ORIGINAL PAPER

Citizen science beyond invited participation: nineteenth century amateur naturalists, epistemic autonomy, and big data approaches avant la lettre

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Abstract Dominant forms of contemporary big-data based digital citizen science do not question the institutional divide between qualified experts and lay-persons. In our paper, we turn to the historical case of a large-scale amateur project on biogeographical birdwatching in the late nineteenth and early twentieth century to show that networked amateur research (that produces a large set of data) can operate in a more autonomous mode. This mode depends on certain cultural values, the constitution of specific knowledge objects, and the design of self-governed infrastructures. We conclude by arguing that the contemporary quest for autonomous citizen science is part of a broader discourse on the autonomy of scientific research in general. Just as the actors in our historical case positioned themselves against the elitism of gentlemen scientists, avant-garde groups of the twenty first century like biohackers and civic tech enthusiasts position themselves against the system of professional science—while "digital citizen science" remains to oscillate between claims for autonomy and realities of heteronomy, constantly reaffirming the classic lay-expert divide.

Keywords Citizen science · Participation · Autonomy · Amateur naturalists · Digital media · Ornithology · Big data epistemologies

1 Introduction

Scientific research conducted by or with volunteers is currently gaining a lot of attention from policy makers, scientists, civil society and the media. The discourse on this phenomenon is characterised by re-evoked hopes of a

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democratisation of knowledge, emancipation of individuals, and a decentralisation of (epistemic and political) power (Bowser and Shanley 2013; Xue 2014). Following science and technology scholars and advocates of the new kind of participatory science (Tsueng et al. 2016; Kullenberg and Kasperowski 2016; Curtis 2015; Ponciano et al. 2014), the growth of *miniaturised computational power*, which prompts big data approaches (especially in natural history) and the *rise of the web 2.0,* which made new technologies and social modes of participation in the co-production of knowledge possible, are the main drivers of digital participation. The interrelated hopes for the democratisation of knowledge via participation got—in various narratives of policy makers and scientists—amalgamated in the term (or buzzword) 'citizen science'.

Citizen science may change the meaning of public participation in science, which traditionally revolved around critical techno-scientific issues and addressed citizens as participants in a political discourse (van den Daele 2013). Citizen science differs from these kinds of participatory exercises. It promises to bring citizens closer to the core of scientific knowledge production itself by involving them in data gathering, data generation and data interpretation. Herewith associated are two intertwined, sometimes complementary discursive hopes: more autonomy and reflectivity for citizens in contact with science and the possibility for scientists to include large crowds of volunteers into their research projects (critically: Strasser et al. 2019).

Dominant forms of contemporary citizen science make use of a crowdsourcing model, based on soliciting contributions from a large group of participants. These forms can be understood as a digital variant of *invited participation* in research that allow for an analysis of large datasets (Brabham 2013; Franzoni and Sauermann 2014; Kelty and Panofsky 2014).

The distinction between invited and uninvited participation was initially used to differentiate deliberative exercises designed by established institutional actors (with predefined and restricted roles for citizens) from self-organised modes of participation originating in civil society (Wynne 2007; Wehling 2012). We suggest that citizen science, for the most part, follows the model of invited participation. While some authors aspire to use the term citizen science also for uninvited amateur research (Finke 2014), the term is dominantly used today to describe invited modes of volunteering for professional research projects: "Many researchers and practitioners characterise citizen science instrumentally, that is, as a tool, method, or form of research collaboration" (Eitzel et al. 2017: 7).

This kind of participation and its presumed value are summarised in an illustrative way by the "biodiversity lab", an Indian citizen science aggregator, in a Twitter post from April 2016:

> "What makes a good #citizenscience project? One that involves a dataset that is too large for a single researcher to classify/index." (BHL 2016).

Hence, the crowdsourcing model of public participation implies a clear division of labour between professional scientists and volunteers. Furthermore, many recent citizen science projects making use of crowdsourcing strategies conceal the actual labour aspects and seriousness of scientific work, for example through gamification

and a strong emphasis on community building. It is (at least implicitly) assumed by those designing and leading citizen science projects that the citizens' desire to participate may first and foremost be triggered in our current (western) culture by framing something as fun. An extreme example of this style is the series of "Play to Cure" crowdsourcing smartphone apps developed by Cancer Research UK (2016).

A great number of contemporary citizen science projects can be described as top-down organised enterprises. As such they follow a big data approach towards the production of data and limit the participation of volunteers to predetermined micro tasks for instance comparing images, taking and sharing pictures of specimens for biodiversity or biogeographical surveys, and/or to perform puzzle like exercises. A example of the latter can be observed in *Stall Catchers*, a project by Cornell University that asks participants to identify stalled blood vessels in mice brains via a game like user interface.

Many volunteers, in line with the underlying epistemological premise of projects like these, are able to produce large amounts of information and will contribute by doing so to research questions that require, by design, large sets of data. Strict limitation and standardisation of the tasks that are open for volunteers seem to be a key design element in such projects, in that organisers and designers of said projects aim also to obtain data of high quality. They seek to do so by limiting the possibility of participants to act in *epistemologically deviant* ways. However, the logics of big data might contradict this fear of epistemic deviancy by emphasising the strength and usability of large but to a certain degree impure datasets (see Mahr et al. 2018).

This kind of citizen science, as we will argue later in this contribution, is based on conservative divisions of labor and power between participants and project leaders. The participants collect, share, or compare information in predetermined ways, while professional project leaders and designers are in charge of all epistemic decisions. Hybrid roles like those offered within the MIT based project *Eyewire* for a small amount of *power gamers* are a rare exception.

Historical examples like popular epidemiology in low income neighborhoods, grassroots level women's health studies of the menstrual cycle, and HIV activism during the 1970s and 1980s show, that alternative modes of citizen science existed and succeeded but have been mostly associated with *emergent concerned social groups* (Callon and Rabeharisoa 2008). These endeavors are not yet necessarily recognized as a strand of what we nowadays frame as citizen science. But in the wake of the current societal backlash in western societies concerning distrust in expertise (e.g. critiques of vaccination, flat earth theories or the denial of climate change), the *ownership* of women's bodies (e.g. Alabama abortion rights and the so-called pro-life activism), and the inclusion of minorities, a more open and democratic mode of public participation resurfaces again. This alternative mode of citizen science blurs the boundaries between knowledge producers, political decision makers, designers, and those who claim to possess epistemic authority.

However, even within the epistemic and social *foundations* of more classic fields, like ornithological biogeography, resides a similar potential for fruitful ways of alternative co-production between certified experts and volunteers on multiple levels. An example could be the construction of a more *liquid* research design, which allows

contributors to share and discuss epistemic ideas. This quest for openness is not only result of the aforementioned social issues, tackled by an emergent new type of *scientific citizenship* but is, in our view, engraved into the nature of science as an ideally non discriminatory quest for knowledge itself. Against this backdrop citizen science might become a motor for re-developing science in a more inclusive and epistemologically diverse form—so our hypothesis.

In this paper, we will explore, therefore, the hypothesis that currently dominant models of digital citizen science not only preserve and reaffirm the aforementioned traditional power structures but also reinforce the divide between "experts" and "laypersons". Paradoxically this implicit strategy appears to succeed through emphasising participation (not as equal actors but "invited" contributors) and thereby simultaneously obfuscating the possibility of a revitalisation of autonomous lay research as an educated and critical corrective, which could take the role of "scientific citizenship" one step further. Attempts by national and international science organisations to "professionalize citizen science" also fit into this picture, as a science governance expert noted during a workshop on "international standards for citizen science" in Zurich 2015 (see University of Zurich 2015).

In the first section of this paper we will give a brief introduction to the discourse on public participation in science (1). In the second section, we turn to a historical case study of a large-scale amateur project on biogeographical birdwatching in the late nineteenth century that utilised a "big data approach avant la lettre" and compare it with more top–down organised "crowd science" forms of birdwatching which emerged in the twentieth century and which are still popular today. A prominent example for this is the Christmas Bird Count organised by the National Audubon Society. From this historical lesson we can learn much about the possibilities and challenges of amateur research today. Namely that people-driven science need not necessarily be restricted to heteronomous contributions as the current trend for crowdsourced digital citizen science implies. Indeed, these amateur researchers were already making use of uninvited modes of complex networked knowledge production before the digital era (2). Our case study exemplarily demonstrates the importance of socio-epistemic and political values as well as their interconnections, the constitution of knowledge objects, and the design of self-governed infrastructures for a more autonomous citizen science—as we will show in the third section of this paper (3). We conclude by arguing that the underlying social negotiation processes between the extremes of invited and uninvited participation, as well as between formal expertise and amateurism, are part of a broader discourse on the autonomy of scientific research (4).

2 Digital citizen science as invited participation in research

Within the "post-war social contract" (Jasanoff 2003: 227) between science and the state, both were regarded as complementary and autonomous functional systems. This also affected the social perception of the scientist's role: Scientists were largely regarded as an esoteric truth class, sharply separated from ordinary citizens (Collins and Evans 2002). Through this distancing and structural autonomy, state and citizens could hope, according to this ideology of policy, to receive highly

reliable knowledge from science (as a system) and scientists (framed as professional experts). "The post-Kuhnian *cultural revolution* from the 1970s" (Wynne 2003: 401 cf. Wynne 1992), in addition to a new wave of public criticism of science and technology, led to a deconstruction of expert knowledge in general and a demystification of the institution of science in particular (Maasen and Weingart 2008: 2). A new social contract between science and the public was suggested, as civil society's voices began to be heard and various forms of public engagement with science and technology were established (Gibbons et al. 1994; Jasanoff 2003). Although public participation in science was never a mass phenomenon (and mostly biased in terms of race, sex, gender and social class), it demonstrated that distinctions between scientists and lay people/amateurs were essentially socially constructed roles, stabilised by professionalisation, institutionalisation and formalisation (Gieryn 1983, 1999). However, the people assuming these roles did not need to have identical competence and expertise: the ability to contribute to science does not necessarily depend on a certified status as a scientist. Scientists only possess expertise in a specific area, and some members of the public, while lacking formal qualifications, might contribute to a certain field of inquiry. Therefore, Collins and Evans suggest that individuals outside of universities and R&D departments can possess and/or acquire non-certified expertise, which is not formalised and not bound to professional status or organisational positions. We may not all be certified scientific experts but, as laypeople, we can be amateurs and acquire certain types of scientific knowledge (Collins and Evans 2002, 2007; Evans 2008). An example for this would be the local histories of our hometowns or in certain spheres of the natural sciences such as ecology.

In line with a general discussion of public involvement in STS (Jasanoff 2003; Lengwiler 2008), Collins and Evans developed their argument with very specific contexts and settings of public involvement in mind: they turned their attention to public participation in critical technoscientific issues "where science and technology intersect with the political domain because the issues are of visible relevance to the public" (Collins and Evans 2002: 236).

Despite claims of a "new production of knowledge" (Gibbons et al. 1994), public participation first and foremost remained an exercise in deliberative governance and was "not remotely about publics becoming involved in specialist scientific questions themselves" (Wynne 2007). Furthermore, the role construct of the scientific researcher (as expert with discursive significance) had not been affected by experiments in public participation (Dickel and Franzen 2015). The institution of contemporary science still seems to present greater barriers to public participation than any other functional system (Schimank 2012: 120–121).

With the emergence of citizen science, public participation gains the potential to transgress those institutional boundaries and aims to enter the heart of scientific knowledge production: research itself. Public participation in actual research was long considered futile and counterproductive because of the gap between expert and lay knowledge. As the cultural theorist Uwe Wirth states, in German-speaking countries, the word "dilettantism" was reframed: from the eighteenth century's neutral (or even positive) description of the activity of laypersons trying to participate in scientific knowledge production to a description of the activities of "pretentious foreigners in the sphere of science, talking about things they never can understand"

(Wirth 2010). Cases with very specific socio-epistemic conditions like the "construction of lay expertise" (Epstein 1995) in the case of AIDS activism during the 1980s and 1990s seem to be the exceptions that prove the rule.

The (ideological) aim of citizen science is to prove the rule wrong. Today, various formats of citizen science involve the public in processes of the production and analysis of data. New approaches to expand its scope and impact are under discussion in grassroots initiatives but also in transnational politics. For example, a recent EU executive report aims to mainstream (digital) citizen science in research activities, funding and science policy: "Just as science communication, Citizen Science should become an integral part of ongoing scientific activities" (Serrano Sanz et al. 2014: 23).

The current attention in media, society and political discourse being paid to citizen science is largely due to the assumed possibilities of interactive digital media (Dickel and Franzen 2015). The development of the Internet into a highly interactive space, often labelled web 2.0 or social web (Schmidt 2008), widens public access in all areas of social life. Tools with various degrees of interactivity like blogs, communication platforms (e.g. Google Hangouts), wikis (the most prominent example being the online encyclopaedia Wikipedia), and diverse social media platforms, together with the rise of processing power and data storage capacities, make possible novel forms of cooperation and collaboration. This phenomenon may even have an impact beyond professional and organisational boundaries.

A closer look on the level of practice reveals that participatory exercises in citizen science based on digital media can hardly be described as collaboration on a level playing field, since digital citizen science projects often follow a crowdsourcing model (Franzoni and Sauermann 2014). Crowdsourcing can be defined as an open call by an actor, typically an organisation, addressing an undefined crowd of individuals. Such individuals who are asked to volunteer for a task by performing work, or contributing knowledge and/or experience. In this model, a function that would normally be carried out by employees is thus outsourced to external participants (Estellés-Arolas and González-Ladrón-de-Guevara 2012; Howe 2009).

Crowdsourced citizen science is enabled by online platforms that allow the participation of large groups of potential volunteers (see, e.g. SciStarter, Boinc or Zooniverse). The use of online tools makes it possible for individuals in different places, at different times and with different backgrounds, to be involved. The crowdsourcing approach is open for various goals and tasks and can easily be adapted for various citizen science projects. "Crowd science" (Franzoni and Sauermann 2014) supports large-scale projects that would otherwise be impossible in a traditional lab with a limited set of employees (Franzoni and Sauermann 2014: 17). Moreover, the repeatability of crowdsourced tasks is helpful for data validation (Roy et al. 2012: 61). Via crowdsourcing, individuals may contribute to science in diverse ways, including data collection and analysis. Furthermore, the voluntary aspect of "crowd science" reduces costs, when compared to large-scale in-house computing or the use of crowdsourcing Internet marketplaces like Amazon Mechanical Turk (MTurk), which actually give micropayments to participants.

The most popular platform for digital enhanced citizen science is Zooniverse (a large citizen science web portal). It grew from the popular crowd science project

Galaxy Zoo, devoted to the classification of galaxies by means of digital mass participation. Today, the platform hosts 38 projects and is administered by researchers from five universities. Over one million people have volunteered in the various citizen science projects integrated at the web portal. Zooniverse describes itself as

> "[…] the world's largest and most popular platform for people-powered research. This research is made possible by volunteers — hundreds of thousands of people around the world who come together to assist professional researchers. Our goal is to enable research that would not be possible, or practical, otherwise. Zooniverse research results in new discoveries, datasets useful to the wider research community, and many publications. At the Zooniverse, anyone can be a researcher. You don't need any specialised background, training, or expertise to participate in any Zooniverse projects. We make it easy for anyone to contribute to real academic research, on their own computer, at their own convenience" (www.zooniverse.org/about).

In the crowd science model of citizen science, the definition of problems, the development of methods, and the evaluation of results are firmly in the hands of professionals, while the role of citizen scientists is restricted to predefined tasks. Hence, participation in crowd science does not actually revitalise the role of the independent amateur researcher with non-certified expertise under new technological conditions. Instead, it allows for the (unpaid) outsourcing of specific research tasks to a virtual workforce. Citizens take the role of digital assistants whose job is to support the organisers of scientific crowdsourcing projects typically professional scientists (Haklay 2013). In many cases, participants do not even need to possess an uncertified expertise in a certain research area. They only need to possess (or acquire) a very narrow and specific competence (like categorising images or descriptions, e.g. in the project Mark2Cure) that complements the work of professional academics. Therefore, citizen science in the mode of crowdsourcing constitutes a division of labour that reaffirms the modern boundaries of science, its construction as a professional institution, as well as functionally equivalent boundaries within science itself (for example, the role of most Ph.D. students in the natural sciences). To motivate the predominantly unpaid crowd work, individuals are addressed as 'good citizens': the discourse of citizen science being characterized by a rhetoric of moral responsibility (in the case of most biomedical projects), promises of societal impact and the idea of 'useful' participation (Dickel 2018).

As crowdsourced digital citizen science is organised, orchestrated and designed by professionals, it can be conceived of as a variant of "invited participation" (Wynne 2007; Wehling 2012), "initiated and organised from the outside rather than by concerned citizens themselves" and "carried out under controlled conditions" (Bogner 2012: 507) which resemble a lab experiment. As such, voices emerge which criticise the common crowdsourcing approach to citizen science as an exploitation of citizen engagement, especially with regard to their willingness to sacrifice a part (sometimes a huge part) of their recreational time to—as many of them would frame it—taking part in the production of a higher good (see, e.g. Raddick et al. 2010; Haklay 2013; Reed et al. 2013; Mahr 2014; Finke 2014).

In the following section, we tell a different story of participation in science. We explore the historical case of a self-governed amateur collective of citizens conducting their own "uninvited" research with both autonomous epistemic claims and independent research structures—all in their spare time besides of their occupations.

3 Value-based communication networks as progressive citizen science in the late nineteenth and early twentieth century

Recreation culture was an essential characteristic of the German bourgeoisie of the late nineteenth century which linked leisure-time with broad educational ambitions. It combined, for example, socio-cultural endeavours for community building and political as well as social participation with a broad interest in natural history and the emerging life sciences (Mahr 2014: 57–149). The main organizational structures of these interests were the so-called 'Naturvereine' (natural history societies) (cf. Daum 2002a). They were an empire-wide phenomenon with hundreds of thousands of members from the aspiring middle classes and operated mostly outside of the established academic system (Daum 2002b: 107–140). The activities of these societies ranged from classical knowledge popularisation linked with democratic character education to sophisticated research activities which, in some cases, left professional academic research far behind. An example of this is the biogeographical research conducted by the German Ornithological Society ('Deutsche Ornithologische Gesellschaft'—D.O.G.) between the years 1876 and 1892.

The statues and practices of the D.O.G. were typical for a German natural history society. They merged values like communality, diligence, altruism, equality, participation, education, and a late-romantic love of nature ('Naturliebe') with a strong claim for independent scientific contributions beyond academic control (Mahr 2014: 86–121). The members of the D.O.G., whose numbers sometimes topped 500 country-wide (including many local clubs as multipliers), were encouraged and socialized to educate themselves in the sense of the bourgeois value system and scientific literacy as well as scientific endeavours were crucial parts of this (Nyhart 2009: 35–78). Moreover, the ideal of good science was oriented intrinsically towards values like participation.

Against this background, the members of the association tried to contribute to research independently, with their own research topics, methods, and socio-epistemic infrastructures to assist this endeavour. The classic, hierarchically organized professional ornithologists (usually established, old-school gentleman-scientists) with their preference for morphology and taxonomy remained mostly hostile to this claim. How could amateurs or even laypeople contribute to their highly specialized research questions (Reichenow 1874–1882)? Ancillary services, perhaps, but such contribution would not be seen as an equal partnership. Therefore, many members of the D.O.G. did not want to consent to these conditions set by the professionals. In addition, the professional's concept of the research object itself (the avifauna) was not compatible with the interests of many D.O.G. members. Instead of studying dead specimens privately (like the majority of the established ornithologists), the civic ornithologists of the D.O.G. wanted to observe living birds together in the

open field (cf. Kohler 2002). As young but prominent members of the D.O.G. like Reichenow (1847–1941) and Schalow (1852–1925) stated, the shared socio-cultural values of community, participation and love of nature could be expressed in field trips, understood as both a scientific endeavour and a leisure activity. But what could be a genuine research topic for these trips? How could the D.O.G.'s members contribute to the life sciences, beyond the constraints of the highly specialized and hierarchically structured academic approach to ornithology?

The answer was found within one of the first internationalised interdisciplinary endeavours of the late nineteenth century: biogeography, which was based on large sets of quantified data. The works of Alfred Russel Wallace (1823–1913) and Philip Lutley Sclater (1829–1913) were popularized in Germany (Wallace 1859, 1860, 1876; Sclater 1858, 1876). Biogeography began to rise as an independent field of knowledge which was appreciated by many evolutionary biologists. Wallace and Sclater hoped to use biogeographical data as a tool for the future observation of evolutionary processes (like the geographical split of species) in the long term (cf. Bowler 1992: 29–38).

Ambitious young members of the D.O.G., like the aforementioned Anton Reichenow, a young assistant at the Museum for Natural History in Berlin, had adopted the new biogeographical works and saw them as an opportunity for civic science conducted within the D.O.G (Mahr 2014: 182–222). Why to chase after the science of the 'armchair ornithologists' (cf. Stresemann 1951: 304–374) if their collective of amateurs could contribute to a new, more 'modern' science—and in a way more compatible with their own goals, values and leisure culture? And why not transform the plight of the geographical fragmentation of the members of the D.O.G., their heterogeneity (in terms of skill and interest) and their pure mass into a research asset? An answer to these questions was found at the first Annual Meeting in Berlin in May 1875 (cf. Homeyer et al. 1875: 347–348). Here, Reichenow gave an orienting lecture in which he announced that from his perspective, the question of the geographical distribution of birds was an important topic that was as yet largely unnoticed by the professionals. He stipulated that the D.O.G. should take this opportunity (ibid.). Moreover, the loose structure, geographical disparity and ideals of the D.O.G. would dovetail beautifully with the necessary re-conceptualization of the ornithological research topic: from the 'armchair researchers' natural history methods of taxonomy etc., to large-scale distribution-data of species and subspecies monitored by enthusiastic civic scientists in a joint venture. The specifics of the D.O.G.'s community (e.g. spatial disparity and a huge mass of interested persons), the method (e.g. field observations—feasible to combine with the Sunday stroll), and the natural spatiality of the living object itself were rhetorically intertwined (ibid) in Reichenow's talk. The members present, representing civic ornithologists from the whole Empire, were enthusiastic about his talk and its background idea. The following day, they voted in favour of Reichenow along with a voluntary selection of other young members developing a framework for participatory research within the coming year. The protocol of the sessions states:

> The request shall be adopted. A selection of specific questions will be decided. The received observations by the observers shall be sighted, ordered and pub-

> lished in an annual statistic (by the Committee on the monitoring stations of birds in Germany) We address all bird lovers in Germany. Send us as many observations as possible! (…) (We do this) because the individual has been left to publish his own observations. Many facts which appeared to be indifferent to individual publications but which, when viewed together, are an indispensable gain for research (…). (Reichenow et al. 1876: 107–109)

In the first year of its existence, the 'Committee on the monitoring stations of birds in Germany' (Ausschuss für die Beobachtungsstationen der Vögel Deutschlands—ABdVD) was not idle. One year after Reichenow's talk, he and his colleagues had already turned to the public for public participation. In national newspapers and in the newly founded *Journal of Ornithology* (Journal für Ornithologie, owned by the association) they published a call for participation in a joint project (Reichenow et al. 1876: 109–111). In this 'Call to all bird connoisseurs of Germany' (Aufruf an alle Vogelkenner Deutschlands) the committee outlined nothing less than the first large-scale citizen science projects for bird counting.

Within the call, the ABdVD appeals to the common spirit of all amateur and lay ornithologists. Collective research in the new field of biogeographical ornithology (based on the collaborative production of large amounts of data) could be an endeavour that unites interested persons all over the country and leads to a new culture of science within German society because it is simple enough that anyone can join. Those addressed by the call should collect observations on bird distribution and bird migration throughout all areas of Germany according to a standardized and statistically analysable pattern. This pattern (as a loosely structured questionnaire) was appended to the call. The initiators also stated that this pattern could be negotiated between the participants in an annual rhythm. In terms of content, each participant was asked to observe everything possible about the distribution and migration phenomena within their own excursion area (be it a forest, a field, or their own garden) between 1 November 1876 and 1 November the following year. In the words of the ABdVD: 'We send to all bird fanciers of Germany the urgent appeal: let us have numerous observation notes and consider nothing as too marginal […]' (ibid: 108). The goal of this enterprise was to draw an increasingly accurate picture of the geographical aspects of birdlife. For this, they planned to deploy a board of D.O.G.-members to order and summarize the obtained data in comprehensive statistics. These statistics were to be published annually in the *Journal of Ornithology*. The authors of the publication would be all the participants obtaining data in each period of investigation (ibid: 110). For this purpose, the annual publications had a sophisticated system of collective authorship in which the contributors were named alongside the observational areas (see e.g. Reichenow 1878).

In addition to authorship, another social incentive to participate was offered to the volunteers: they were promised that their participation in the observation project helped their particular interests and preferences in ornithology. The more observations by the volunteers, the more (and better) material they would have at the end of each year about the phenomena or animals in which they were individually most interested (ibid: 111).

The response to the call within the community of German amateur ornithologists was extraordinary. Within a few years, the annual statistics grew to fill more than 100 journal pages and some members of the project (like Paul Matschie [1861–1926]) began to work on geographic representations of the statistics (Mahr 2014: 205–211). Most members/contributors regarded themselves as a large decentralized communication and data distribution network, without significant hierarchies but rather with a very strong output of knowledge about bird distributions and migration behaviour. In addition, every year the members discussed and evaluated their observation collecting strategy, as well as other methodological issues such as decisions to pay special attention to a certain species or observational area.

The success of the whole enterprise became apparent as parts of the research design developed by the D.O.G. was adopted by amateur ornithologists and even 'professionals' in many other countries: in 1879 in England (Committee for the migration of birds), 1882 in Austro-Hungary (Committee for the observation stations for birdlife in Austro-Hungary), and in 1883 the American Ornithologists' Union in the United States (Mahr 2014: 212). The collaborative approach towards data gathering and the re-imagination of the research object (from dead specimens to statistical data about the distribution and behaviour of living birds) was framed as exemplary for other enterprises. Nevertheless, many of them abandoned also the socio-epistemic structure of autonomy which was a main characteristic of the German project by detaching it from its organizational amateur context. The reason for this, paradoxically is, the great success of the D.O.G.'s enterprise. Since it was internationally considered as a methodological and epistemic innovation which made ornithology (nearly out of a sudden) interesting and relevant for the new life sciences like evolutionary theory (Mahr 2014: 214–219). Therefore, both professional ornithologists at universities as well as scholars of other life sciences adapted the collaborative approach. One could say that biogeographical-amateur ornithology got professionalised or, in more drastic terms, hijacked by experts. This professionalization was accompanied by a division of labour, which later became a classical distinction for the roles of amateurs and experts in collaborative research projects. Socio-epistemic autonomy was (once again) replaced by heteronomy. Now, university educated experts like Frank Michler Chapman (1864–1945) from the American Museum of Natural History started projects like the Audubon Christmas Bird Count (1900 until today) in which the research questions were raised top-down by professionals while the observational tasks were distributed to volunteering bird enthusiasts. Instead of autonomous democratic committees', professionals were now leading the epistemic parts of collaborative research. This division labour of the early twentieth century became a model for the co-production of knowledge between experts and the public for more than 120 years as the invention of the tradition of citizen science by its practitioners and advocates proofs (see Bonney and Butcher 1992; Bonney et al. 2009a, b).

The historical example presented in this section shows, furthermore, that successful knowledge production in amateur contexts does not necessarily depend on internet technologies. The biogeographical project conducted by the D.O.G. in the late nineteenth century demonstrates that, to an extent, conventional networking methods

can be adequate for large-scale enterprises. The values of the respective civic environment and of the surrounding scientific culture were just as important as communication technologies. A question soon emerged, is participation considered as a core value of science, or does competition and demarcation prevail? In our example, bourgeois values, the structure of the 'Naturverein', and the epistemic requirements of the research era all stood in a relationship to each other and led to a large network of data producers, distributors, and users. It also seems to be noteworthy that how research subjects and methodological perspectives are defined is equally important. Does the concept of the area or the research object leave space for a collaborative approach? Are there intrinsic characteristics in the area or the object (like the spatial variability of the avifauna) that enable participation?

We may learn from this case that citizen science enterprises could be more than mere crowdsourcing, given the fact that the volunteers of the D.O.G.'s birding network had the opportunity to contribute not only with their observational data but also, by discussions and voting at annual meetings, through their individual influence on the research goals. The socio-epistemic structure of their doings were therefore centred around autonomy (towards professional ornithology) and heteronomy (towards social structures).

4 Conditions for (citizen) scientific autonomization: values, objects, infrastructures

As we have seen in our historical case study, public participation in research does not depend on web 2.0 infrastructures, since nineteenth-century newspapers and postal services were sufficient enablers. While novel technologies expand the structural possibilities of mass collaboration, it does not seem to depend on them. We can learn from the historical case that three important conditions enabled independent amateur research as "uninvited participation". An interdependency of social and scientific values, infrastructures for peer-networking, and a shared vision of the research object seem to be necessary ingredients of this mode of information and knowledge production. In addition, plenty of leisure time and a system of values that calls on the individual to use his or her spare time to do something that is meaningful (beyond satisfying individual needs) were crucial. Both were part of the bourgeois culture of the late nineteenth and early twentieth centuries (Mahr 2014).

At the heart of the D.O.G.s enterprise was a set of shared values in the form of civic virtues that integrated the amateur researchers into a community. In contrast to the crowds attracted by recent dominant forms of digital citizen science, the D.O.G. formed itself as a community of peers, linked by their social positioning as bourgeois subjects who understood their leisure time as a way to participate in 'higher endeavours' like politics, culture, or in the case of the D.O.G. members, research. This form of collaboration essentially appears as an early example of "commons-based peer production" (Benkler 2006) beyond the control of institutionally certified experts.

The D.O.G. members understood participation as a focal mode of their lives. In crowdsourced approaches to citizen science, only the "zookeepers" within the

Zooniverse community come close to this. However, it remains unclear, whether they frame their participation in science as a central aspect of their lives, and whether they share a common understanding of culture and engagement.

Furthermore, the members of the D.O.G. succeeded in implementing a sophisticated self-governed communication infrastructure and took care of its functioning on social, organizational, and epistemic levels. This structuring of participation was extended to the design of the research agenda—something that in modern online citizen science projects is often pre-shaped by professional actors and permits almost no deviation, which, in turn, dramatically limits the levels of participation within a project. Another crucial part was the constant and integrative 'shaping' and 're-shaping' of shared and sharable objects. The shaping of, not simply the observational questionnaires and annual statistics but also the re-thinking of the core research objects, in our case study the birds themselves, was crucial. With the rediscovery of the spatiality of their subjects (unlike the immobilization as taxonomic specimens in the elitist knowledge culture of classical natural history), members of the D.O.G. could integrate and merge their interests, their values, and their spatially disparate and relatively loose social structures around shared interests. Ultimately, this ensured the success of their endeavour as a unique form of quantifiable data centred research. For the D.O.G. birds became knowledge objects which, according to Knorr-Cetina are "open, question-generating and complex" (Knorr-Cetina 1997: 12). They are able to generate a "structure of wanting, a continually renewed interest in knowing that appears to be never fulfilled by final knowledge" (Knorr-Cetina 1997: 13, see also Kohler 2006).

We presume that these three elements, namely a shared set of values, the emergence of self-stabilizing communication infrastructures, and an adequately loose but also recognizable co-produced knowledge object are also at the core of uninvited participation in contemporary participatory science. As such, they provide a structural framework for highly collaborative and peer produced citizen science.

This can be illustrated by Delfanti's (2013) study on biohackers, one of the most prominent examples of contemporary citizen science that aspires to create an autonomous sphere of participatory, peer produced science and civic tech. Delfanti's research suggests that biohacking (also called DIYbio) is defined by a hacker ethos combined with Mertonian norms (shared values), an open source approach to knowledge exchange (communication infrastructures), and a shared interest in experimenting with biotechnology (the knowledge object).

The recent discourse on the desirability of "autonomous" citizen science as a more open and truly egalitarian mode of knowledge production (which is said to be closer to the ideals of science than the profession of science itself) can be interpreted as a utopian answer to perceived problems of heteronomy in contemporary scientific knowledge production (Finke 2014; Patterson 2010). This threat of heteronomy is often linked to an economization of science in the form of business-driven research, a managerial governance of academic institutions (from universities to publishers), and pressures to publish or perish in order to build a successful career in the highly competitive culture of contemporary academia. These developments seem to increase the barriers to curiosity-driven research, constitute threats to the self-governance of knowledge production and reception, and imply an erosion of epistemic

values and/or the Mertonian norms of science (Merton 1938; Gläser and Schimank 2014).

5 Conclusion: the future of citizen science

Along with the professionalization of research in the nineteenth and twentieth centuries, science described itself increasingly as an autonomous system of knowledge production, distinct from the knowledge production of lay persons but also free from the direct influence of external forces on the core of knowledge production. This (self-) understanding of science has been undermined by current trends of economization, leading to the diagnosis that science has lost its autonomy to external influences (Gläser and Schimank 2014).

In the face of this loss of autonomy, proponents of uninvited citizen science position themselves as an external corrective to the (economized) professional scientific culture. Thus, they are seen as proponents of a revitalized ideal of autonomous research, like the large-data sets producing amateur ornithologists of our case study. To realize this ideal, collectives like gyne- and biopunks build new scientific communities outside of established academic institutions in order to reclaim science (Meet the GynePunks 2016). They reject the crowdsourcing approach to citizen science, because it would keep them in a heteronomous position, bound by the structures of a system that is itself threatened with loss of its autonomy (for example in the arenas of politicization and economisation). Hence, just like the D.O.G. approach, the quest for peer produced citizen science can be interpreted as a *(counter-) cultural* project, that addresses perceived structural deficits of contemporary scientific knowledge production (Weise 2011). As framed in the Biopunk Manifesto:

> "[We are] looking for a model which can redistribute the economic and social value produced by peer production. Companies and scientific institutions are asking citizens to contribute by crowdsourcing knowledge, sharing and analysing data, or performing scientific research. Will they be able to open themselves up to a more inclusive relation with P2P science? Well, if they won't, they might have to face rebellion" (Patterson 2010).

Our study uncovered a historical link to these contemporary struggles of autonomous (citizen) science. In contrast to the gentleman scientists of the eighteenth and early nineteenth centuries, the D.O.G. was a product of the new civic culture of the nineteenth century in the form of the German bourgeoisie. Just as the D.O.G. positioned itself against the elitism of gentleman scientists, the biohackers and civic tech enthusiasts of the twenty first century position themselves against the system of professional science. In both cases, self-governed infrastructures are prototyped and civic values are combined with claims of embodying a form of life closer to assumed scientific ideals.

However, it remains to be seen whether the complexity of contemporary science will allow the new proponents of amateur science to compete with the contemporary scientific elites in established areas or to reframe academic fields and thus reconnect science with the public. The D.O.G. is an asynchronous example for this.

A more modest scenario would be that a niche will be carved for uninvited citizen science in researching neglected knowledge objects (like local histories) while professional science will continue to integrate citizen scientists as crowdworkers in rather heteronomous settings.

Especially in scientific fields that use large amounts of data, like the information science of taxonomy, a turn to "crowd science" (Franzoni and Sauermann 2014) may seem auspicious. MicroPlants is an example for a taxonomy project (hosted at Zooniverse) that addresses the public as a crowd of volunteers contributing to research on biodiversity in times of "an extinction crisis" (http://microplants.fieldmuseum.org). In a paper on the project, crowd participation is presented as an answer to a problem of scarcity of certified expertise and public ignorance: In the face of "cataclysmic biodiversity loss", digital citizen science should compensate "a lack of trained taxonomists and a lack of interest and engagement by the public". Hence, the authors "provide a model of a crowd-sourced data collection project that produces quality taxonomic data sets and empowers citizen scientists through real contributions to science" (Konrat et al. 2018).

Instead of "training and educating the volunteers" in taxonomic classification or deploying a system of reputation and evaluation similar to peer review (Lukyanenko et al. 2011: 467), project managers may make use of design approaches that make participation as easy as possible. Based on the assumption of a gap of expertise "between scientists and ordinary people", crowd science projects may tend to reframe the problem of participation as a problem of "information transfer" (Lukyanenko et al. 2011: 465) and make the input of user as easy as possible. Hence, the processing of information and its transformation to scientific output becomes not only a black box but also a hermetic sphere in which the voices of the data collecting volunteers are rarely heard.

The intention of invited citizen science is to make research accessible to anybody. This accessibility is enabled by user interfaces that facilitate participation for laypeople while putting the control of information infrastructures and knowledge objects firmly in the hands of the designers and (professional) project leaders. The participation of volunteers in the definition of research goals and methodologies can rarely emerge in top down and highly pre-structured projects like for example MicroPlants.

In our historical case study, self-governed infrastructures for peer-networking and *participatory taxonomy* enabled a rather democratic knowledge culture. We showed that it was based on shared civic values, derived from late nineteenth century German bourgeoise *serious leisure culture* with all its inclusive and exclusive strengths and flaws. An example of this can be seen in the huge gap in participation for those who do not align with the prototypical white middle-class and educated men who formed the backbone of the Wilhelminian period. Although this knowledge culture was clearly biased and doesn't mirror todays quest of informed and self-empowered citizens who seek to partake (in less mediated ways) in scientific enterprises, it succeeded in producing a democratic co-production of knowledge beyond just assigning tasks top down or to rely on the isolated figure of classic gentleman scientist, by establishing and maintaining a set of *shared social research values*. In this regard, the case study helps us to understand that a reductionist, techno-centrist and top-down perspective does not need to be the future of citizen science or even science

itself. Today's information infrastructures that promote participation in the production of scientific knowledge, however, are increasingly shaped by platforms and standardizations that are vastly inaccessible for in-depth co-production of volunteers, designers, and researchers. Besides of isolated attempts to connect citizen science in a sustainable way with ideas and practices of *openness* (Vohland and Göbel 2017) this is also true for a majority of existing citizen science projects. Nevertheless, at the fringes of the institutional boundaries of scientific knowledge production an epistemic revolution is on its way that might even influence the scientific mainstream. Grounded in feminist, counter cultural and hacker-values grassroots projects like *Open Insulin* and *Open Source Estrogen* by Mary Maggic are beginning to reshape and renegotiate the boundaries of knowledge production—both in terms of inherent power structures and of the relation of science to other societal sub-systems like health care and economy. This revolution might finally bring science as a whole closer to its ideological values of "universalism", "community", "disinterestedness", and "organized skepticism".

Terminology matters (Eitzel et al. 2017). The very term "citizen" in citizen science might already generate expectations of a democratization of knowledge production, which cannot be fulfilled by the dominant crowd approach to citizen science. This calls for democratization, articulated by proponents of a more autonomous citizen science, also raises the question of whether the heteronomies of economization (attributed to professional science) are displaced by heteronomies of politicization in the prototypes of peer produced citizen science that follow the interests of specific publics and their political agendas.

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