CITIZEN SCIENCE:
THEORY AND PRACTICE

How Citizen Scientists See their Own Role and Expertise: An Explorative Study of the Perspectives of Beekeepers in a Citizen Science Project

RESEARCH PAPER

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ABSTRACT

The mission and definition of citizen science are vividly debated. One of the crucial aspects contested is who has the agency to define it; another is how precise a definition can and should be and how much these definitions are reflective of the heterogeneity of practices and perspectives subsumed under the label citizen science. In this paper we draw attention to how citizens themselves actively construct their own roles within a project in relation to both their histories and the project's scientists. Drawing on a set of in-depth interviews with participating Austrian beekeepers in the INSIGNIA project, we show how even within a small, relatively homogenous sample of participants, there is considerable diversity in how the citizen scientists see their roles. We explore how citizen scientists articulate a different set of relations towards science, their own practice as beekeepers, and their desired role in the project. In conclusion, we discuss the implications of our findings for academic reflection on citizen science as well as practical implementation for citizen science projects.

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INTRODUCTION

The emergence of citizen science, the active involvement of non-scientists in processes of scientific knowledge production, is one of the most important developments in the relationship of science to the public in recent decades. Scholars (see Irwin 1995; Vayena and Tasioulas 2015; Ottinger 2016; Kennedy and Cavalier 2016) have suggested that citizen science has the potential to transform science by creating innovative ways for more inclusive, participatory forms of knowledge production and policy making—for the natural sciences as well as for the social sciences and humanities (Heiss and Matthes 2017).

The definitions and practices subsumed under the umbrella term citizen science are highly diverse, and this diversity has been increasing because of the growing popularity of the concept in research practice and science policy. Eitzel et al. (2017) as well as Haklay et al. (2021) provide detailed overviews on the different definitions and terms used for both practices and participants, pointing to the importance of language in framing how citizen science is understood and conducted. Some recent contributions have criticized the absence of a homogeneous definition (Vayena and Tasioulas 2015; Heigl et al. 2019), arguing a clearer concept is necessary, particularly for potential citizen participants. In response to Heigl et al. (2019), Auerbach et al. (2019) warn that too narrow of a definition of citizen science would both exclude important parts of contemporary practice and hamper the creativity and innovative potential of a citizen science grounded in its heterogeneity. This position resonates with different approaches for mapping citizen science (Eitzel et al. 2017; Haklay et al. 2021). At the same time, other authors acknowledge that citizen science currently is defined largely by scientists and policy stakeholders (Heigl et al. 2019; Haklay et al. 2021), which leaves space and a lingering need for more contributions considering "how people involved in projects themselves interpret the meaning of terms" (Eitzel et al. 2017, p. 16).

Our argument resonates with this point by aiming to contribute to understanding how citizens see their own involvement and expertise in relation to science. While authors have proposed a range of both different typologies of citizen science projects and their participating citizens (see Vayena and Tasioulas 2015; Haklay 2013; Strasser et al. 2019), citizens' own perspectives have received relatively little attention in the academic debate (for exceptions, see e.g., Füchslin, Schäfer and Metag 2019; Kam, Haklay and Lorke 2021; Kimura and Kinchy 2019; Russell 2014). In other contexts, citizens' conceptualisation of their own role has been shown to be of key importance for understanding the deeper dynamics of public participation in science (Felt and Fochler 2008), making this gap even more surprising.

Here, we report an exploratory qualitative analysis of the perspectives of beekeepers participating in an EU-funded citizen science project. Beekeepers are a quite peculiar kind of citizen scientist. Beekeeping is a specialized craft, which entails knowledge-based expert practices and discourses that, to a high degree, are independent of scientific knowledge production. Scientific research on honey bees enjoys a long history of collaborative projects with beekeepers, but only recently has the concept and terminology of citizen science been applied (Brodschneider et al. 2019, 2021; Woodcock et al. 2022).

We show that even in a small sample of relatively homogeneous participants, there is considerable diversity with regard to how citizen scientists conceptualise their own expertise, relating it to both the wider project and the expertise of the scientists. In conclusion, we discuss the implications of our findings for the academic reflection on citizen science as well as for the practical implementation of citizen science projects.

STATE OF THE ART

Citizen science emerged as a concept in the 1990s. The coining of the term is accredited to both Alan Irwin (1995) and Richard Bonney (1996), although their original understandings of the term vary quite considerably. This initial variance created important, long-lasting multiplicities in understandings and implementations of the term "citizen science," and differences in contemporary citizen science practices (Cooper and Lewenstein 2016).

Irwin's (1995) vision of citizen science was one of democratization of science (i.e., more democratic, participatory science). He called for a science both for and by citizens, the practices of which included more space for the concerns of citizens and the production of local knowledge. While some argue the participatory ideals presented in Irwin's work are relatively absent in the contemporary practices associated with the label (Strasser et al. 2019), a few modern scholars strive to incorporate these ideals, from citizen science's ability to increase the responsiveness of science to societal concerns (Martin 2006) to its capacity to challenge scientific norms (Kennedy and Cavalier 2016).

In contrast, Bonney's concept of citizen science concentrated on the contributory power of citizens, in particular on how citizens and science could benefit from citizens acting as data collectors. He envisioned citizen science as both a tool for the promotion of the public's understanding of science and a means for the public to participate more in institutional scientific research. Most present-day uses and implementations of citizen science tend to follow Bonney's contributory interpretation of

the notion more closely than Irwin's, although current practices subsumed under the term of citizen science remain heterogeneous.

Within the past decade, citizen science has continued to grow and diversify (see Kullenberg and Kasperowski 2016), which some argue can be attributed to the flourishing of digital information and communication technologies (Vayena and Tasioulas 2015; Sharma et al. 2019) as well as the increasing acknowledgement that citizens are able and should participate in the political and scientific processes by which they are affected (Haklay 2018). Despite its rise in popularity, the term lacks a widely held definition. The proposed definitions range from succinct, general ones, like Ottinger's (2010), "knowledge production by, and for, nonscientists" (p. 245), to more concrete, list-like descriptions—meant to generate standardization—created for use in evaluation and policy frameworks (see ECSA 2015; EC 2014).

Like its definitions, the practices subsumed under the term remain heterogeneous. Because of this flourishing diversification of citizen science practices and projects, Strasser et al. (2019) argue it is "still unclear whether the very diverse practices subsumed under that heading [citizen science] form a coherent whole, let alone a cohesive social movement" (p. 53). However, this apparent lack of clarity about the diverse practices has not gone unnoticed. Many scholars and practitioners of citizen science have proposed a wide range of different typologies (or ways of classifying) in order to both classify and suggest different forms of citizen science (see Bonney et al. 2009; Haklay 2013; Vayena and Tasioulas 2015; Cooper and Lewenstein 2016; Haklay 2018; Strasser et al. 2019).

Ranging from crowd-funding to participant-led research, Vayena and Tasioulas's (2015) typology classifies citizen science into four categories based on different combinations of citizen involvement and collaborative work occurring between the citizens and the scientists of a project. Haklay's (2013, 2018) typology focuses on four different levels of participation intensity in citizen science projects, from the base level of crowd sourcing to extreme citizen science. Haklay asserts this typology is meant to be value free with no level of citizen science more desirable than another. Contrasting both typologies, Strasser et al. (2019) propose a typology that identifies five distinct types of citizen science knowledge production practices with the hope of moving away from trying to discretely categorise citizen science, and towards capturing "the greater diversity of participatory practices" (pp. 55–56).

Scholars like Haklay (2013, 2018) and Strasser et al. (2019) call for a more contextualised understanding and valuing of citizen science projects and their practices in which levels of participation are balanced with the participants' needs. Yet, how the participants themselves see their roles in citizen science projects, regarding their own knowledge and expertise in relation to science, continues to be under-studied. Books and articles written by citizen scientists about their experiences (e.g., Russell 2014) provide fascinating insights but are obviously limited to a very small and specific set of citizen scientists. Academic contributions have studied the motivations and context of some citizen science movements in much detail (e.g., Kimura and Kinchy 2019), or have focused on the demographics of the participants and their direct motivations (Domroese and Johnson 2016; Füchslin, Schäfer and Metag 2019; Golumbic, Baram-Tsabari, and Fishbain 2020; West, Dyke and Pateman 2021; Wam, Haklay, and Lorke 2020). In most of these studies, how the citizen scientists construct their own role in the project—in particular in relation to science—remains implicit and not the central focus of attention.

Prior research in science and technology studies (STS) has shown that citizens are highly reflexive actors in their interactions with science (Wynne 1992; Ottinger 2016) and that analysing how they conceptualise their own role and expertise in relation to science is crucial for understanding the dynamic of science/public interactions. Several studies have demonstrated citizens oftentimes are more attentive to and knowledgeable of local factors, and when included in the scientific process, the respective research can be seen as a collaborative sense-making process (Wynne 1992; Callon and Rabeharisoa 2003; Wynne 1992). Further, it has been shown that citizens have complex perspectives on public participation in science and their own role in it (Felt and Fochler 2008). In resonance with these findings, a consideration of citizens' perspectives of their role within citizen science has much to contribute to a deeper understanding of the overall phenomenon of citizen science.

METHODS

The empirical work performed for this paper was part of the European Union (EU)-funded pilot project entitled **cItizeN Science InvestiGatioN for pestIcides in Apicultural products**: Environmental Monitoring of Pesticide Use Through Honey Bees, with the acronym INSIGNIA, which was a two-year (2019–2020) consortium of scientists and citizen science beekeepers across 12 European countries. The project aimed to develop a protocol for citizen-science environmental monitoring of both plant biodiversity and pesticide contamination through non-invasive sampling devices in honey bee colonies. Starting with four different sampling methods in the first study season in 2019, two

promising methods were further tested in the second study season (Brodschneider et al. 2020).

The role of the citizen scientists in the wider project was to test and use novel non-invasive sampling methods to analyze pesticide contamination as well as botanical origin and biodiversity of the pollen collected. The first season of the project ran from April through September, 2019, with the first introduction of the sampling devices occurring in the 17th week of 2019 and the last sampling occurring in the 37th week for a total of 10 sampling rounds. The citizen scientists were provided with material and instructions by the scientists in an instructional booklet that led the participants through the entire sampling process.

The intent of the booklet was to include all the information necessary for the beekeepers to install the monitoring devices and take the samples, that is, to become the main knowledge transfer instrument within the project If any questions did arise, the beekeepers were to contact their country coordinator. Except for a poorly utilised mailing list, there was no pathway created for the beekeepers to talk amongst themselves. Thus, the structure produced a clear linear transfer of knowledge from scientist coordinator to citizen scientist participants, who were expected to give feedback focusing on usability of the sampling devices and not necessarily on project design. The linear mode of knowledge transfer from scientists to beekeepers, coupled with limited feedback expectations, was acceptable for some participants while contested by others.

The sampling was conducted every two weeks, with the participants receiving replacement devices via the post. The participants were supposed not only to return the collected samples for the intended analysis but also to report back on the usefulness of each device and any problems encountered (Gratzer and Brodscheider 2021). While beekeepers reported any problems they faced during the sampling season, the project design remained fixed throughout the entire season for maintenance of scientific rigour of the analysis of the four devices developed for year one (Figure 1).

Part of the first season of the project also involved an explorative social science study, wherein we interviewed the four Austrian participants of the first project season to better understand their experiences in the project as well as to examine how the citizen scientists conceptualize their role(s) within a project in relation to their own perspectives. As only a small number of citizens per country (4) participated in the first project season, that small number still represents the totality of the overall project participants in Austria. Initially, similar interviews were planned in other participating countries; however, due to logistical problems, this could be done only to a very limited extent. These logistical problems included delays in recruiting to the overall project as well as language issues. We are not including this data here because the additional interpretative complexity due to the differing contexts would outweigh the analytic gains from a larger

Figure 1 An INSIGNIA scientist inserting one of the monitoring devices tested at monitoring hives. Picture taken by Bieszczad April 2019.

sample size. Rather, we aim to go in depth in studying the perspectives of these four citizen scientists.

Two qualitative, semi-structured interviews (Silverman 2015) each were performed with the citizen scientist beekeepers at the start of the 2019 sampling season (April) and towards the end of the sampling season (September). Following semi-structured guidelines, the interviews were conducted to focus on providing the citizen scientists space to unfold their narration. The interviews lasted from one and half to two and a half hours each and were conducted in the participants' homes, often coupled with tours of their apiaries and less formal discussions. The interviews were digitally recorded, while the tours and less formal discussions were documented in fieldnotes. All participants agreed to being interviewed and written informed consent was obtained. Participants were guaranteed that the data will only be used in pseudonymized form. The design was not approved by an institutional review board (IRB) because this was neither legally required, nor requested, nor common practice for qualitative social science studies of non-vulnerable populations at the time.

The semi-structured interviews followed an interview guideline, which insured consistency between the interviews, but additionally created a flexible space for the beekeepers to explore topics important to them. A translated English copy of the interview guidelines are provided as supplementary material in Supplemental File 1: Questionnaires.

The interviews were fully transcribed and coded in an inductive coding approach based on a grounded theory sensibility (Charmaz 2006) and a thematic coding approach (Rivas 2018). Interviews were initially processed in an open coding approach in order to both preserve respondents' meaning and systematize the data. Thematic analysis was then used to group the resulting codes into code groups representing the most salient themes in the interviews. Initial analysis was done between the first and second interview round. This initial analysis showed strong differences between the citizen scientists' role perception and their relation to the project. This led to the decision to focus analysis on these aspects and to use comparative coding techniques to further explore these differences. Along a grounded theory sensibility, results of the first analysis informed the interview approach in the second interview round. The transcripts of the second interviews were then coded using the codebook developed in the first interview round, but allowing for new codes to emerge for themes not covered in the initial code scheme.

Interviewing and coding was done by the first author. The analysis was supervised and reviewed by the other authors.[1] A codebook of selected codes and their corresponding descriptions is provided in Supplemental File 2: Codebook.

The interviews were conducted in German. For this publication, the quotes used have been translated to English language by the authors. A pseudonymized[2] version of the original transcripts is provided in Supplemental File 3: Transcripts.

FINDINGS: FOUR PERSPECTIVES ON BEING A CITIZEN SCIENTIST

Despite their highly different roles, the four beekeepers in our sample had elements in common: all were male, from mid 40s to early 70s in age, Austrian, and financially independent from beekeeping (Table 1). They all showed an eagerness for participation and for the acquisition of knowledge about their bees, particularly because the results of the sampling analyses were anticipated as having practical relevance for the management of their colonies. They have all participated in scientific studies previously, seeing themselves as more engaged than the typical beekeeper. Lastly, each of their lives are deeply enmeshed with the communities and temporalities of beekeeping, with the tending of their bees playing a central role in their lives.

Additionally, the four beekeepers shared one strong motivation for participating—access to pesticide residue and botanical source analysis (i.e., testing). They were, to varying degrees, worried about the health of their colonies and their potential contamination by pesticides. Yet,

BEEKEEPER PSEUDONYM	ANTON	MATTHIAS	WERNER	HELMUT
Beekeeping experience (yrs)	21	12	15	31
Participation in other honey bee citizen science projects	Yes, many	Yes, three	Yes, two	Yes, one
Type of beekeeper	Hobbyist	Commercial	Hobbyist	Hobbyist
Teacher of beekeeping	Yes	Yes	No	Yes
# of Colonies	10 to 12	60 to 70	Approx. 50	Approx. 30

Table 1 Comparison of Austrian Citizen Science Beekeepers interviewed for the INSIGNIA project, 2019.

outside of projects like INSIGNIA, the costs for laboratory analysis are high, often too costly for beekeepers to afford on a regular basis. Anton explains: "The long-term effects of [pesticides] is difficult to detect for a beekeeper, a normal one, no? Or not at all, because I can only detect it if I have the lab test results? And a test cost for pesticides around 500 euros, no?" Further complicating the matter is the lack of governmental support for the testing for pesticides in colonies in Austria, with Anton explaining that sending samples to the appropriate ministry will only end in "the sample rotting somewhere along the way and will in no way lead to results." With no proper and reliable governmental system to turn to, beekeepers become reliant on such projects.

Whilst problems and concerns of the four beekeepers were communicated to the scientists, regarding both the sampling devices and the potential harm they may cause to the bees, the project structure's consistency requirement limited the available space for incorporating feedback on the broader project design.[3] The beekeepers were all aware of their limited capacity to affect change in the experimental structure or knowledge production process during season one. They all mentioned their main role in the project (to varying degrees) was that of sample collectors. Nevertheless, we show below that how each defined their roles in detail was quite different.

WERNER

Werner has a family history in beekeeping, but he is relatively new to the practice. In comparison to the other participants, he has the least amount of formal training. He joined the project because he is concerned about his hives being contaminated by pesticides, particularly those sprayed by a neighbouring Christmas tree farmer. He hopes the results of the analysis will confirm this belief.

Werner seems to hold the least amount of confidence in terms of his knowledge and ability to contribute to the project. He does position himself as subordinate to the scientists, having something to learn from them. This stands in contrast to the other participants who see themselves more as equal partners with the scientists. As a result, Werner feels he is neither on the same level as the scientists nor able to critique their choices. When asked if he reads scientific articles, he replies, "It is a bit hard, they are mostly in English, no? And, I mean I struggle through, but for pages on end, I am too dumb."

Like the other participants, Werner is hopeful science will be able to provide answers to the question of the cause(s) of the poor health of some of his hives, However, at the same time he harbours suspicions about scientific autonomy, shows ambiguity about which sources are trustworthy, and suspects that a lot of studies on the phenomenon are biased because they have been influenced by industry's interests. He reflects, "I believe that many [studies] are bought, no? I mean, I can't figure out the difference with my background knowledge, no?"

Like the others, Werner struggles with gaining access to testing for his hives. Werner sees scientists as more knowledgeable and able to potentially provide answers to his problems of potential contamination through the testing of his samples. For him, his role is apparent. He states, "[my] role. That I believe is relatively clear. I will take the ten probes from the three colonies." Through this statement one can observe that Werner sees his role as a taker of samples, not as someone who is assisting the scientists in any more active role. His stance fits with how he perceives himself as not very knowledgeable on scientific matters. He does not feel like he is doing science, but rather providing the samples with which the scientists can do science.

MATTHIAS

Matthias runs a small business selling his honey. Despite having a job outside of beekeeping, he gives the impression throughout our interview that he sees himself as much more of a commercial beekeeper than a hobbyist, which stands in contrast to the other three participants. Matthias does not think that environmental pollution is necessarily the biggest threat to beekeeping. Rather, he stresses beekeeping requires experience, knowledge, and training, and that the recent trend towards "lifestyle beekeeping" damages the work and reputation of more professional beekeepers.

Similar to Anton and Helmut, Matthias also is embedded in the Austrian landscape of beekeepers and has a lot of experience working with scientists, something Werner would not claim. Like all the beekeepers, he does not claim the label of scientist for himself. However, Matthias does position himself as an important actor in the project. In his view, he is providing the project with high-quality data and material—a great benefit to the scientists. He even goes so far to select test hives that are strong, healthy, and located in an area of high biodiversity, something he thinks the scientist will appreciate. Being able to do so is the result of a strong, formalized training and the resulting expertise.

> "I think, scientists have the big advantage of having my beekeeping in the background and at least one to two colleagues that are profound beekeepers, because they regularly need material for experiments, be it honeycombs, be it brood, be it pollen, be it bee mass, whatever, and it works that those are available if someone is taking care and if someone is familiar."

In this position, Matthias remains in a separate, yet non-subordinate role in relation to the scientists, unlike Werner who takes on a subordinate one. Like Werner, Matthias sees himself as a sample provider, but the difference lies with the expertise he sees himself bringing to the project. To Matthias, the exchange is simple: he provides high-quality samples to the scientist in exchange for test results in return. His role self-conceptualization can best be seen when the perceived agreement has been broken in Matthias's eyes. When asked about how the sampling season has gone so far in his second interview, Matthias replies:

> "Way too time-consuming. In total, including the drive time to my test colonies, it's taken two complete days to do all the sampling, and I still haven't gotten any results so far, so if the results aren't somehow proportional to the effort I am putting in, then I won't be taken part next sampling season."

In working on the project, he sees himself as capable of understanding scientific instruction and thought but does so passively in comparison to Helmut and Anton. For example, he neither challenges the scientists' instructions or knowledge, nor compares his own knowledge to that of the scientists. Instead, he sees their knowledges as complementary, but distinct—Matthias's about beekeeping and the scientists' about the science of bees. These two roles remain separate—two separate bodies of expertise connected by a sample exchange, working independently but cooperatively for the purpose of the project. Matthias and Werner both maintain a strict separation of roles throughout the project. Like Werner, Matthias does not criticize the experimental design, stating: "[about] that, I cannot judge, I am a beekeeper, not a scientist." Epistemic authority is given to the scientists as they hold the knowledge to properly judge what is and is not relevant to obtain the data the project demands. He sees his role in the project as "simply provid[ing] data." This means that I am the one in the field who tries to get as many reasonable samples as possible to evaluate them in the laboratory."

For Matthias, this is how the project should be, with skilled beekeepers providing data for the scientists, who then analyse the samples in the laboratory, and in return the beekeepers receive analyses of their colonies. Unlike Anton, who shows interest in being more active in the knowledge production process and Helmut who would like the scientists to use his input more, Matthias seems satisfied in his role, seeing the beekeepers and scientists as experts in their own right, with their corresponding roles for the outcome of the project.

HELMUT

With more than 30 years, Helmut has the longest experience amongst the project's participants. Well-known in his community, Helmut has a long history of teaching beekeeping, traveling throughout Austria to give lectures. He does not believe one person can be an expert on all beekeeping topics, unlike Matthias who saw himself as the expert of beekeeping. Instead, he mentions that often when asked questions by his students, he connects them with other experts on the topic at hand, taking on a coordinating role, a knowledge broker of sorts. The level of knowledge of "normal" beekeepers is very important to him. Relating to the exchange within the project, he states: "I would wish for this more regularly, well and not only with beekeepers like myself, that are very interested, but that an approach will be found between science and the normal beekeeper."

Helmut has confidence in science's ability to solve problems, believing it has the power to uncover the truth, unlike Werner who remains sceptical about its motivations. Simultaneously he is acutely aware of the unique perspective his experience affords both the project and him. Helmut does not merely view himself as a provider of high-quality data, like Matthias, but rather as someone with a holistic understanding of beekeeping as well as the complex interplay of actors in the project.

> "I can imagine, because scientists work mostly in a very narrow field or something and a beekeeper sees this probably more holistically, I can quite imagine that there could be a more intensive interesting conversation, so not that there would come new scientific findings on the part of the beekeeper, but perhaps this holistic view could then also be scientifically useful, yes."

Although Helmut trusts the knowledge of the scientists, he sees science and scientists as highly specialised and, thus, positions himself in relation to their knowledge as offering a more holistic view to the scientists, which enables him to help scientists see the broader situation. This conceptualization of expertise contrasts Matthias's separate-but-equal understanding in that Helmut sees himself also as a potential conversation partner that influences scientists' wider perspectives. He understands his knowledge of beekeeping as allowing him to offer input on how to improve the sampling devices and optimise the process so that "It is also easier, a beekeeper, who is maybe not so interested in scientific things, can easily apply it and still get a verifiable result." Helmut sees himself as a knowledge broker and a translator between science and the world of "normal" beekeeping. For him,

the potential flow of knowledge is bi-directional, unlike for Werner and Matthias. Scientists may learn from a more holistic perspective, and beekeepers may profit from the results of scientific projects. Accordingly, dialogue within the project and amongst other participating beekeepers is of particular interest to him and, like Anton, Helmut would like more space for productive interactions in the project.

ANTON

Anton is the most invested of the four beekeepers, and is the most scientifically orientated. Now retired, Anton's professional work included taking environmental measurements, something which carried over into his daily beekeeping practice. For years, Anton has employed a rigorous daily methodology, recording various features of his colonies, even designing his own computer program to track the trends in his data. When collecting data for the project, he goes beyond what was asked of him by the project coordinator. He states:

> "I have had relatively much experience, I mean in the practical application of measurement systems, etc, etc, and therefore it was a bit convenient for me, it was interesting and I'm generally a bit curious and want to know everything, no? and always want to get to the bottom of things, that's roughly how it always was and still is, even though I'm in my 70s."[4]

Anton, like Helmut, is also an established expert in the Austrian beekeeping landscape, and has even given talks to Parliament based on his own measurements. He is an important person of reference for both scientists and peers alike in his community. He actively tries to nudge other beekeepers to test their hives for pesticides more regularly. Like with Helmut, and in contrast to Werner and Matthias, we see Anton as an active and important mentor in his respective beekeeping community.

In many ways, Anton's positioning towards science is ambivalent. Although he employs systematic measuring techniques himself and is conscious of his own strong knowledge base, he has high regard for science, whose knowledge he gives authority over his own. He positions himself as someone who works personally with scientists yet does not have the same ability to know scientifically, that is, judge studies or make knowledge claims about scientific findings, similarly to the other beekeepers.

While Anton is not claiming the role of a scientist, he does put himself on eye-level with the project's scientists, as he has the ability to draw upon his own experiential knowledge and has been following both the scientific and political developments related to bees and pesticides in Austria for the past two decades. Anton always highlights that the scientists ask him to participate, showing that he sees himself in a way as a colleague of the scientists. When he talks about the project, the phrase he uses is that "we research." This positioning differs from both Matthias and Helmut, who do see themselves as equals to the scientists, but do not see their role as taking part in the research process. Still, Anton's position is closer to that of Helmut's than Matthias's and Werner's, as both Anton and Helmut see their role in shaping the knowledge outcomes of the project as bi-directional with the scientists.

Of the participating beekeepers, Anton is the most critical of the project's experimental design, for example the sampling times. Based on his knowledge of the flight radius of his bees, the local climate, and local farmers' practices, he would suggest measuring at different moments in the year:

> "I have complained a couple times … I have also criticized the sampling intervals, because in the fall I don't need to take any samples, because it's nonsense, it is money out the window in my opinion, every 14 days, especially during this time, the current project is a bit late, because here the time for spraying is in spring and they are already spraying away."[5]

Among our participants, Anton was the person most closely aligned with the idealized notion of a citizen scientist, in a more Irwinian sense of the term (Irwin 1995), that is, citizens producing knowledge both outside and alongside of science on their own initiative to help tackle controversies that science alone cannot solve, such as colony loss.[6] From the project, he receives knowledge about his bees (potential contaminants); testing, which he could not afford on his own; and an outlet for his scientific curiosity. Yet, Anton also voiced a slight frustration with the project, and somewhat cynically described his own position within the project as that of a "relatively cheap co-worker." This can be interpreted as Anton's wish to have been included more in the actual experimental design and to be in more of a dialogue with the scientists.

DISCUSSION

Our exploratory analysis has shown that even within one project in which the participating citizens were arguably not highly diverse in terms of gender, age, and reasons for participation, there is still a high degree of diversity in how the citizen scientists conceptualized their own role and participation in relation to science. Of our four participants, one, Anton, conceptualised himself as an active producer of knowledge and data in his own right and, hence, a close

colleague of the scientists; one, Matthias, as a different and complementary kind of expert to the scientists; one, Werner, as their mere assistant; and one, Helmut, as a knowledge broker providing a more holistic perspective to science's narrowly focused one. In terms of their self-conceptualisation and the way they relate to science, our four participants, thus, present very different types.

Most existing typologies of citizen scientists classify participants based on the nature of their involvement in a project (Haklay 2013; Vayena and Tasioulas 2015). Despite the differences we found in our interviews, due to the similar activities performed throughout the project, such typologies would classify each of our four participants similarly. All of them describe themselves as being in a data collector role, which both Haklay (2013) and Vayena and Tasioulas (2015) would label as crowd-sourced participation, a form of participation in which citizens act as sensors and data-gatherers without providing interpretation or input to design. In the knowledge/engagement matrix by Haklay (2018), the project and its participants would be characterised as high-knowledge/high-engagement. However, the beekeepers' perspectives on this differ more. While Werner might see himself as only following instructions and hence "low-knowledge," the other three participants stress their own expertise, placing themselves in the "high-knowledge" category, though in quite different ways. While Matthias sees his expertise as separate from the scientists, Anton and Helmut assess their expertise in relation to science.

The significant difference between the participants lies in where their desired levels of engagement fall within the extant categories. Both Werner and Matthias are quite content with the "crowdsourcing" level of engagement, while Anton and Helmut clearly desire a higher level of engagement with the possibility to interact with the scientists and influence the research design. The relation between actual and desired level of involvement for each of the participants strongly corresponds to the participants' own self-perception and their perception of the relation between citizens' expertise and science. Helmut and particularly Anton's self-perception resonates with an Irwinian (1995) concept of citizen science in which citizens are seen as capable knowledge producers, while Werner and Matthias accept a much more categorical division between scientists and non-scientists, along the lines suggested by Bonney (1996).

As implied from our findings for research and practice, we suggest that every citizen science context will likely harbour heterogeneous perspectives and the potential tensions between them. Any effort to standardise how citizen science is defined will need to acknowledge and reflect this irreducible complexity. If it fails to do so, it risks excluding certain viewpoints and damaging the democratising quality of the overall idea of citizen science. What follows from this is that any definition should set minimum standards while also explicitly leaving room for situated meanings of citizen science. In addition, projects should encourage an active discourse on the meaning of citizen science among scientists and citizens—ideally a discourse that embraces citizen science's heterogeneity.

Our findings also relate to the literature on citizen scientists' motivations (cf. West, Dyke, and Pateman, 2021; Füchslin, Schäfer, and Metag, 2019). All our participants share a complex motivational mix between egoistic (focused on their own welfare) and altruistic (focused on the welfare of others) motivations for participating in the project and its activities (West, Dyke, and Pateman, 2021). However, altruistic motivations, such as contributing to the well-being of bees and the environment, fostering scientist-beekeeper interactions, or supporting science, are much stronger with Helmut and Anton as those participants also see themselves as knowledge producers. For Werner and Matthias (who view science as producing knowledge), egoistic and instrumental values are of much higher importance (e.g., gaining knowledge in particular on the status of pesticide contamination in their pollen). These values are present to such a degree for Matthias that he describes his relation to the scientists as an exchange of work for knowledge.

Our study also describes a particular kind of motivation that has not been as well characterised thus far: In absence of action by regulatory agencies, citizen science projects can act as a unique access point for particular forms of knowledge and testing. Depending on the respective participant, gaining access to testing can be motivated egoistically or altruistically.

For the practical implementation of citizen science projects, a heightened sensibility to the diversity of citizen perspectives and motivations can be of benefit. Our findings resonate with the arguments of both Haklay (2013, 2018) and Strasser et al. (2019) that citizen science projects will benefit from offering different levels of participation to meet the different expectations on the side of the participating citizens.

Our findings demonstrate not only the value of a citizen science project offering different levels of participation but also the challenges involved. As we have shown, sometimes the roles desired by the participants conflict with the roles assigned to them by the project. In particular, frustrations were often expressed by those participants desiring a higher degree of involvement in the design of the experimental protocol as well as by those wishing for more lateral forms of communication within the project, despite describing their relations with the scientists as very positive. This variance in constructed roles shows that

organizers of citizen science projects should offer citizens a relatively wide range of different forms of participation on different levels, and, ideally, organizers would consult with participants about their desired level of participation at the beginning of the process. In addition to this, organizers should also reflect on the finding that certain benefits, such as access to pesticide testing, will have different meaning to participants depending on their motivations and self-perceived role.

LIMITATIONS AND FURTHER RESEARCH

While the sample size is a clear limitation of our study, the diversity observed in even this small sample may serve as inspiration and a starting point for further studies exploring citizen scientists' perspectives. In particular, it would be interesting to compare citizens' perspectives between projects characterised by varying levels of citizen expertise. Beekeepers may be seen as a relatively knowledgeable group of citizen scientists, but given the complexity of contemporary societal perceptions of science, there is reason to assume that less specialised citizen scientist populations might have highly diverse viewpoints as well.

CONCLUSION

Much of the literature on the role(s) of citizen scientists within a given project takes into consideration the project specificities and the intended role(s) assigned to the participants. However, our exploratory study shows the great variance present within a single project when one focuses on the participants' own construction of their roles. Our study shows the value of attending to the self-perceptions of the citizens as well as to differences between their actual and their desired level of participation in the project. Both facets are under-represented in much of the extant literature. We suggest actively acknowledging this diversity in citizen science practice, by offering different levels of participation, for example, will improve the quality of involvement in citizen science projects.

NOTES

1 Member checking of the analysis by the participants was not done.

2 In accordance with the Informed Consent for the project, all details that could potentially lead to an identification of the participants have been removed from the transcripts.

3 Some of their feedback was however valuable in planning the second season of the project.

4 All quotes have been translated from the verbatim German language transcripts.

5 This interview was in early April, 2019, before INSIGNIA's sampling season had begun.

6 Colony loss is a general term used in the melittology and beekeeping communities to describe the phenomenon of whole, sudden colony death or illness, the exact reason for this trend is unknown but widely believed to be a culmination of many environmental and anthropogenic factors. The term is often associated with colony collapses disorder (CCD), for more information see Suryanarayanan and Kleinman (2017).

SUPPLEMENTARY FILES

The Supplementary files for this article can be found as follows:

- **Supplemental File 1.** Questionnaires. DOI: https://doi.org/10.5334/cstp.501.s1
- **Supplemental File 2.** Codebook. DOI: https://doi.org/10.5334/cstp.501.s2
- **Supplemental File 3.** Pseudonymized transcripts. DOI: https://doi.org/10.5334/cstp.501.s3

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COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR CONTRIBUTIONS

Bieszczad: conceptualization, methodology, investigation, data curation, analysis, writing – original draft, writing – review and editing.

Fochler: conceptualization, methodology, validation, writing – original draft, writing – review and editing, supervision.

Brodschneider: conceptualization, validation, resources, writing – review and editing, supervision, project administration, funding acquisition.

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