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RE-EXAMINING SCIENCE COMMUNICATION:
MODELS, PERSPECTIVES, INSTITUTIONS

A question of dialogue? Reflections on how citizen science can enhance communication between science and society

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Abstract

Citizen science is a transdisciplinary approach that responds to the current science policy agenda: in terms of supporting open science, and by using a range of science communication instruments. In particular, it opens up scientific research processes by involving citizens at different phases; this also creates a range of opportunities for science communication to happen This article explores methodological and practical characteristics of citizen science as a form of science communication by examining three case studies that took different approaches to citizens' participation in science. Through these, it becomes clear that communication in citizen science is *always* science communication and an essential part of "doing science".

Keywords

Citizen science; Science communication in the developing world; Science communication: theory and models

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Introduction

Knowledge and information permeate all areas of society [cf. Poltermann, 2013; Bittlingmayer and Bauer, 2006; Nowotny, Scott and Gibbons, 2001]. This process is largely dependent on communication of this knowledge and information. When it is scientific knowledge and information being communicated, we can describe this as science communication.

Science communication has shifted significantly in recent decades. From an early, widespread understanding that scientific findings were disseminated in a linear, closed pathway — from expert to layperson — there is now widespread acknowledgement of the need for more comprehensive and inclusive participation in science [cf. Massarani, de Castro Moreira and Lewenstein, 2017; Schäfer, Kristiansen and Bonfadelli, 2015]. For example, there has been a shift to open up science, from a linear model of knowledge transfer to a concept of science

communication that is built around dialogue-participatory models [cf. Hecker et al., 2018; Weitze and Heckl, 2016; Trench, 2006].

This shift can be seen as part of a wider socio-political restructuring of society. Since the 1960s, New Social Movements have been calling for institutions and decision-making procedures to be opened up, while also accusing them of inefficiency. Participatory formats help counter both points, and there has been progress towards this in many fields. For example, the introduction of Article 11 to the EU Treaty of Lisbon (2007), on the possibility of citizen participation in general and specifically in policy-making, is a significant step [cf. Cantauw, Kamp and Timm, 2017].

As a result of such progress, people's right to participate in scientific processes, and opportunities to do so, have expanded considerably. The idea of the 'active citizen' is now a central concept in the discourse on science and communication, and revolves around ideas such as exchange, reciprocity and inclusion of concrete and specific conditions of each situation [cf. Hecker et al., 2018; Weitze and Heckl, 2016; Schiele, 2008; Trench, 2006].

Science is a difficult field in which to implement participatory formats and contents, however. A major challenge is that it remains strictly regulated by hierarchical structures. Indeed, science has one of the weakest inclusion intensities when compared to other social subsystems [cf. Burzan et al., 2008]. This may explain the relative reluctance of science to demand openness, and the extent of the discourse around this issue.

Citizen science is one field in which this move towards more open and participatory scientific methods has been effective [cf. Cantauw, Kamp and Timm, 2017; Dickel and Franzen, 2015]. By actively involving non-professional scientists in different phases of the process, it has challenged these hierarchies. This has seen new and different sources and types of knowledge integrated into research processes, and wider interests being represented than might be found within the professional science community [cf. Vohland et al., 2021; Hecker et al., 2018; Serrano Sanz et al., 2014]. It has also created new channels for (science) communication to occur between science and society.

Drawing on empirical material from three citizen science case studies (outlined in Section 3), this article discusses how citizen science and science communication work together, and the benefits this brings. We consider the challenges that can arise in dialogue between researchers, citizens and other stakeholders, and from the integration of different forms of knowledge [cf. Hoffmann, Thompson Klein and Pohl, 2019; Lang et al., 2012]. We conclude that communication in citizen science is *always* science communication, and thus a necessary condition for carrying out science and understanding citizen science.

Citizen science as science communication

2.1 What is citizen science?

Citizen science describes a range of practices that integrate people "who are not full-time professionals in the field of related science, with or without the participation of full-time researchers" [Pettibone et al., 2018, p. 6; see also Haklay

et al., 2020; Franzen, 2016; Serrano Sanz et al., 2014]. This integration can occur at various phases of the research process: from the joint development of the research question, through project design and data collection, to evaluation and interpretation of results.

However, citizen science should not be understood simply as extending the scientific field to new, non-professional actors. It also renegotiates traditional legitimation and evidence practices, while maintaining reference to scientific rules and structures. Describing the conditions and situations in which science is produced, Knorr Cetina [1999] focused on the heterogeneity of knowledge production and developed the concept of 'epistemic cultures' as a way of understanding "arrangements and mechanisms [...] which, in a given field make up how we know what we know" [Knorr Cetina, 1999, p. 1]. Her focus was the diversity of methods, tools, argumentation and legitimation that comprise the production of science. Building on her concepts, we understand citizen science as a specific form of epistemic culture: one that has strong links to traditional science systems, but which also puts science up for negotiation and questions it.

In this understanding, citizen science is a concrete evidence of changes of the changes in science production observed in recent decades. Various analytical narratives describe these changes, and how they are changing the relationship between society and science: Mode 1/Mode 2 [cf. Nowotny, Scott and Gibbons, 2001], normal versus post-normal, and modern versus post-modern [cf. Gibbons et al., 1994; Gibbons et al., 2012]. Common to each of these is the argument that science production has changed as society and science have become increasingly intertwined. In contrast to the mode of production in Mode 1, science production in Mode 2 is characterized by conducting problem-oriented research in an interdisciplinary as well as transdisciplinary manner with the involvement of different actors [cf. Hartmann and Mietzner, 2018, pp. 62–63]. A unique feature of citizen science as an epistemic culture is the transparency of the research processes, and its inclusion of heterogeneous actors. The integration of diverse actors, knowledge bases and objectives in citizen science makes it necessary for its research processes to be open, transparent and comprehensible for all.

Traditional scientific methods and concepts often exclude from society information on research practices and characteristics [cf. Latour, 1999] and close knowledge processes in a "black box" [cf. Latour and Woolgar, 1979, p. 28]. Research methods and concepts are only mentioned in connection with the preparation of a study, with the focus being on presenting research findings and output, and less to the conditions, circumstances and practices that not only lead to the knowledge and results, but also significantly shape them. The process between input and output remains in the dark [cf. Latour, 1999, p. 373] and is closed in a black box [cf. Latour and Woolgar, 1979, p. 28].

By contrast, citizen science integrates diverse actors, knowledge bases and objectives, which makes research processes more transparent and comprehensible for all. It also opens science up to include the knowledge of new, non-professional actors, who, while often unfamiliar with traditional scientific processes, provide a different epistemic quality by applying new explicit and implicit rules and structures [cf. Dickel, Schneider et al., 2019]. However, this requires a change to research structures, to those that make knowledge with different epistemic qualities

visible, and that can integrate them on an equal footing. Our case studies present different models and formats, which open up research structures in favour of increased visibility for different knowledge stocks, and with the consequence of a renegotiation between citizens' roles from 'audience' to 'performance' [cf. Dickel and Franzen, 2015].

By opening up scientific processes, citizen science demands the inclusion of actors regardless of their performance records or formal qualifications. This does not mean that participation is unconditional, but that the barriers to entry are non-formal educational qualifications [Dickel and Franzen, 2015]. The distinction between certified and non-certified expertise [cf. Collins and Evans, 2002] loses some of its meaning in citizen science [cf. Dickel and Franzen, 2015].

However, this does demand increased negotiation between professional and non-professional participants: about the contents and methods used; about how knowledge is exchanged; about each participant's ability to provide inputs into research priorities and agendas.

This greater negotiation, and the closing of the gap between professional and non-professional actors, means that citizen science makes the creation and exchange of knowledge and information more inclusive and equitable, thus supporting the ambitions of the open science agenda. This can be described as an opportunity-based approach: "anybody can join a given project. [...] This openness is possible because in most [citizen science] approaches, "citizens" are an implicit category, a catch-all term synonymous with layperson or volunteer" [Pettibone et al., 2018, p. 223]. Importantly, and as our case studies demonstrate, this opening up of scientific processes also creates new ways to enhance science communication.

2.2 What is science communication?

The traditional understanding of science communication encompasses sharing of scientific knowledge and information, both to the public and across scientific disciplines. The focus, however, is often on public, media-mediated science communication, especially in relation to the communication and reception of research content in from the natural science [cf. Burns, O'Connor and Stocklmayer, 2003, pp. 185, 190; Gascoigne et al., 2010]. In recent years, another field of science communication has emerged: a need to speak 'to' the public and convey their knowledge and security, and to 'interact with' and involve them in scientific processes [cf. Bowater and Yeoman, 2013; Mejlgaard and Stares, 2010; Kurath and Gisler, 2009]. Citizen science offers new understanding of communication and interaction between actors involved in the scientific process [cf. Hecker, 2020] and can be understood as a development of science communication [cf. Lewenstein, 2016].

Science of science communication identifies several coexisting research traditions. These mark different phases of the field's development, while also accentuating the many goals of science communication. 'Scientific literacy' focuses on strengthening people's understanding of scientific processes and principles [cf. Bowater and Yeoman, 2013, p. 10; Logan, 2001, p. 137], while 'Public understanding of science'

and 'Public awareness of science' are concerned with increasing the public's appreciation of science in terms of empathy, goodwill and acceptance of scientific matters and concerns [cf. Bodmer, 2010, p. 152; Bowater and Yeoman, 2013, p. 13]. Building on these, 'public engagement with science and technology' involves more dialogue with, and participation by, the public in scientific debates: instead of speaking *to* the public, this approach focuses on interaction *with* the public, and their integration into scientific processes of knowledge production [cf. Bowater and Yeoman, 2013, p. 15; Mejlgaard and Stares, 2010, p. 546].

In this article we outline an extended perspective of science communication: our understanding includes both the presentation of results, the discussion of methods, the education about scientific contexts, but, and here we think the extension, science communication also includes the production of knowledge and its further processing, which puts a focus on the practices of science communication, on the negotiations and dialogical mediations, on the process. By doing so science communication can support opening the "black box" [cf. Latour and Woolgar, 1979] in which the doing of science is hidden.

2.3 How citizen science can enhance science communication

As well as supporting the need for greater openness and participation in science, citizen science also addresses some of the challenges in science communication. For example, instead of treating research and communication as separate areas that interact only at certain points in the scientific process, or reverting to the idea of research results and findings being disseminated only at the end of a project, citizen science considers communication as an integral throughout the research process. Building on this, we believe that effective science communication depends on the specific situation: which content is to be communicated, to whom and how? In practical terms, there is a difference between communicating around different topics; and between communicating with an existing community or reaching out to new and diverse actors, who may first have to be identified.

In particular, it challenges the idea of science communication as a one-way process, from expert to layperson. Indeed, opening up science to non-professional scientists requires, among other things, a fundamental rethink of competence structures, with the traditional roles of 'expert' and 'layperson' being redistributed and renegotiated. Instead, communication becomes a continuum, ranging from the integration of external actors into the mobilization of 'lifeworld knowledge' [reading according to Irwin, 1995], to an education theory argumentation [reading according to Bonney, 1996].

In the first reading, non-professional scientists are integrated into the research process as experts on a particular subject. This means that the 'classical' linear approach to communication, from expert to layperson, does not apply. Rather, a constant dialogue must be established between them. A challenge for most citizen science projects is sustaining the motivation of the participating actors over several phases of the research process, especially non-professional scientists. Science communication can play a role here, as demonstrated in our case studies. A second aspect in this first reading is the abolition of traditional hierarchical structures. The scientist remains an expert on the rules and structures of the science system, while

the non-professional scientist brings expertise on a specific topic. This places special demands on communication, requiring permanent dialogue between the different actors. As a result, a common vocabulary is established and the actors are addressed as a team with different competencies.

The second reading focuses on developing the skills of participating actors. Citizen science is a way of imparting scientific skills, which are key competences in the modern knowledge- and information-driven society. This approach puts different demands on communication: how to prepare and impart specialist knowledge and the rules and contents of scientific work, and how to do so in a way that enables actors to work in a professional and rigorous manner.

The case studies presented in the next section show how different citizen science projects can nurture this dialogue-based approach to science communication, often in unexpected ways.

Case studies of science communication through citizen science

3.1 Different approaches to communication in citizen science

Science communication in citizen science projects happens in varying ways, and often with differing objectives. Two common objectives are: (1) communication to ensure that a project succeeds; and (2) enhancing citizens' understanding and awareness of a scientific issue, and at times motivating them to act on that issue. The first can be characterised as 'outreach', and fits a more traditional view of what science communications is about. The second can be framed as 'dialogue', and is an under-acknowledged element of the new science communications paradigm.

Our case studies fall under these two framings. The first looks at 'science buses', which focused on an early stage of science communication: increasing people's access to science. It shows how citizen science is able to work effectively in different settings and demonstrates the importance of establishing connectivity to people's 'living world'. The second case study ‚the science-policy dialogues from the D-NOSES project on odour pollution, examines the particular challenge of reaching out to, and achieving engagement from, actors who have highly contrasting — or even competing — interests and priorities. It demonstrates how dialogue can deepen all stakeholders' understanding of the issue, and appreciate perspectives that differ from their own. The third case study falls under science communication as a form of dialogue, examining an ornithological project researching nightingales, explores the changing roles of individual actors over the course of a project, and how this influenced the form that science communication took in the project. While far from exhaustive, these case studies demonstrate what science communication through citizen science can be, which forms it can take, and the different impacts it can achieve.

3.2 Increasing public access to science: the DITOs science bus and the XperiLAB truck

Project name: Doing it Together Science (DITOs)

Duration: 2016–19

Budget: € 3.94 million

Financing programme: EU's H2020 programme

The DITOs project aimed to increase people's awareness of citizen science and 'DIY' science. The project's two science buses — the XperiLAB truck and the DITOs science bus — were a key element of this 'public engagement with science' strategy. By visiting schools and community sites across Europe, the project reached children and adults who would not normally come in contact with science activities.[1]

The XperiLAB truck is a long-term project created by the Royal Belgian Institute of Natural Sciences[2] that has been travelling to schools across Belgium, bringing playful and interactive science experiments to support existing education programmes. The participatory activities take place inside the truck at custom-designed consoles. The XperiLAB truck has a stated goal of teaching the inductive method to children, and all the consoles target distinct scientific concepts from different fields of biology, chemistry and physics.

Within the DITOs project, the truck was also used to disseminate the infrastructure for a citizen science project, by taking XperiBird[3] boxes to different schools. This is an educational citizen science project that monitors the nesting of tits at schools across Belgium. Each school hosts a bird box fitted with a camera to monitor the birds nesting, which the children can analyse. In this sense, the XperiLAB truck can be viewed as 'science communication on wheels', reaching those who may not otherwise visit a science museum.

The DITOs science bus, coordinated by the Waag,[4] was a one-off project created specifically for the project. Making 17 stops across Europe, at community centres, small towns, public festivals and museums, it aimed to bring ready-made science activities to people. It also asked them to contribute their own 'folk remedies and recipes', which the bus would then take along on its journey. The DITOs bus did not explicitly target deprived areas, but visited a range of different settings, where its expansive notion of knowledge enabled it to function with different audiences.

In Birmingham, U.K., this open-ended approach enabled the bus to reach an intergenerational and culturally mixed audience. During four workshops [see Nold, 2019], the participants were a diverse age mix: children, parents and elder members of the community. Their ethnic and cultural makeup was also highly diverse, including British people, as well as those from newly arrived and long-term ethnic communities. The ready-made science activities involved making yoghurt and sun cream from ingredients such as milk or beeswax. The mix of ages, combined with the 'homely' activities, created an atmosphere similar to a cooking lesson, with adults chatting while kids were playing rock-paper-scissors.

The science bus 'captains' used the activities to explain the physics behind sun-rays and the bacteria involved in yoghurt. Yet most participants had not come for a science lesson; they came because visiting the community centre was part of their daily lives. Others came because they wanted to take part for pragmatic reasons: for example, one mother explained that she needed sun cream that would not

[1] This case study draws heavily on Nold [2019], which used ethnographic observations to compare the two Science Buses. The author is also one of the authors of this paper, so these ethnographic observations function here as a case study for analyzing the relationship between citizen science and science communication.

[2] See: https://www.naturalsciences.be.

[3] See: http://xperibird.be/en/home.

[4] See: https://waag.org/en/home.

irritate her child, who was allergic to commercial sunscreen. Similarly, other participants wanted to make extra jars of joghurt to take home with them or give to friends.

This surprised the science bus captains, who perceived the activities as demonstrating scientific principles rather than being a prosaic part of people's everyday life. At the end of the workshop the local coordinator said that the science bus captains were role models that showed that 'normal people go to university — you don't look like nerds'. She explained that the area around the community centre was highly deprived, and local people didn't aspire to science; it was seen as something remote, and the people who carry it out as 'other'.

These vignettes illustrate how the science buses used different practices of science communication. The XperiLAB bus activities added a playful, interactive version of scientific experimentation: a model of science communication based on increasing public access to a defined set of known scientific knowledge. While, the DITOs science bus did not engage with a defined public, but worked with whoever came to its workshops. Furthermore, it used a looser concept of scientific knowledge, one that revolved around the notion of instructables: text and image guides that are created by people on online forums to share DIY instructions for creating projects for oneself.

3.3 Integrating heterogeneous knowledge stocks through dynamic science communication: the D-NOSES policy-society dialogues

Project name: Distributed Network for Odour Sensing, Empowerment and Sustainability (D-NOSES)

Duration: 2018–2021

Budget: € 3.16 million

Financing programme: EU's H2020 programme

Odour pollution is the second-most frequent reason for environmental complaints after noise, yet it is not a well-known or consistently regulated topic. The D-NOSES project[5] uses a co-creative citizen science methodology to address odour pollution, based on the Extreme Citizen Science [cf. Haklay, 2013] and the Bristol [cf. Balestrini et al., 2017] approaches.

The project established ten pilot studies across Europe, and in Chile and Uganda, to address the local odour issue(s) of a specific area or community. These pilot strategies implemented a communication strategy with three phases, although these were not necessarily applied in a fixed order: (1) engagement of citizens; (2) communication with engaged citizen scientists; and (3) engagement of and dialogues between quadruple helix stakeholders.[6] In all three phases, flexibility in the methodology ensured continuous adaptation to the needs of the engaged communities, regardless of their socio-economic background, religious affiliation, gender or cultural background.

[5] https://dnoses.eu/.

[6] Public authorities, industry, academia, and citizens.

In most cases, the pilot studies could not rely on existing networks interested in odours, as these do not generally exist. Initial engagement therefore required a targeted approach to find those personally impacted by odours. This outreach was supported by olfactory sticks with 'good' smells (e.g. lavender) and bad smells that imitate odour pollution (e.g. dimethyl sulphide, which mimics the smell of waste). This often provided citizens with a first conscious encounter with their own sense of smell and helped highlight the issue of odour nuisance. Communications materials about the project were also used in this initial stage, and were constantly adapted according to need. In the Barcelona pilot, for example, they were simplified to be more accessible for deprived communities with low socio-economic status, where many citizens found it difficult to understand the original materials.

After this initial citizen engagement, the communications strategy for each pilot was adapted to local needs and knowledge. In Barcelona, for example, local civil society organizations (CSOs) were already communicating through WhatsApp groups, so the pilot team joined these groups and used WhatsApp for direct communication with engaged citizens. Other channels (e.g. email, phone, Facebook) were also used to provide wider opportunities for citizens to access the topic and contact the pilot leaders. This shows how adapting materials and channels to local contexts can advance even unpopular topics within a diverse community.

Building on these initial outreach activities, the next phase focused on increasing access to information on the local odour problem, with the aim of encouraging participation to tackle it. In this way, the pilots sought to implement Principle 10 of the Rio Declaration[7] by empowering citizens to become drivers of change. Achieving real action requires the engagement of quadruple helix stakeholders who, in this context, mean representatives from industry and business, policymakers and regulatory authorities, academics and odour experts, as well as citizens and CSOs. Given these diverse actors, and their competing interests and agenda, it was essential to establish dialogue-based communication that treated all these heterogeneous knowledge stocks in an equal way.

In many situations, it would be normal to engage and introduce all stakeholders simultaneously to a topic. However, many stakeholder groups demonstrated a marked resistance to the topic of odour pollution — and especially to the inclusion of the public in discussions — out of fear of conflict with angry citizens (industries), worries that their neutral stance could be threatened by getting involved (policymakers), or lack of trust in the quality of citizen-collected data (academics). Interestingly, citizens often showed initial resistance due to a feeling of powerlessness.[8]

To address these issues, the D-NOSES pilot leaders first engaged each group of stakeholders separately. The most appropriate initial contact point was determined in each case, based on in-depth stakeholder analysis. As a first step, the pilot teams established the knowledge and concepts that each stakeholder group brought to

[7] See: http://www.unenvironment.org/civil-society-engagement/partnerships/principle-10.

[8] However, the experience of self-efficacy, or the perception of the self as an active and informed actor [Schneidewind, 2018, pp. 301 ff.] is a decisive driver for example the implementation of sustainability development goals.

the table, their interests in the matter, and the barriers or concerns that needed to be overcome. The project created a list of expected and experienced barriers and concerns, along with appropriate mitigation strategies and arguments, to support the pilot leaders. In this way, each stakeholder group was involved, one after the other, while making it clear that all stakeholders would be equally involved and were equally important for the project.

In some cases, industry actors were approached first, to bring on board the stakeholder with the greatest expected resistance. In other cases, initial contact was with a local policymaker or regulatory authority, because they had access to their community and knew them well. And in other cases, initial contact was with citizens (using the communication strategies described above) to build up enough pressure for hesitant policymakers and industry leaders to engage.

The stakeholders were then brought together for open and moderated discussions — so-called 'policy-society scientific dialogues', which D-NOSES defined as every meeting or dialogue that involved policymakers or regulatory authorities, and public representatives. By bringing together heterogeneous knowledge stocks, such policy-society dialogues can can establish commitment among stakeholders and lead to a more accurate and widely supported definition of the problem at hand [cf. Bulkeley and Mol, 2003]. In the D-NOSES project, they provided an opportunity for finding common ground and establishing citizens' co-responsibility for issues and solutions [cf. Ponti, 2020].

As of May 2020, with many pilot studies still in their early stages, the D-NOSES project had organized 50 policy-society dialogues across nine countries, involving almost 400 citizens. The focus of these ranged from including the needs and views of citizens and policymakers in the pilot design, through understanding current procedures and regulations, to training sessions involving the use of olfactory sticks or collected smells from a known source to create a common base of knowledge around the topic of odours.

While these outreach activities do not fall within the typical boundaries of citizen science — no data on odour pollution is generated or collected, for example — this early focus on reaching out to stakeholders lays the foundations for a deeper engagement with the issue. Without this initial focus on outreach and dialogue, further citizen science actions (e.g. data collection on odour sources, policies to address these) would have a much-reduced chance of being possible or leading to positive changes. This confirms the need for communication to happen at every stage of the research process, even before the research, in a traditional sense, has even begun.

The D-NOSES project is still ongoing at the time of writing, but experiences to date show that approaches to science communication must be constantly adjusted to the needs and issues of the engaged stakeholder group. It also demonstrates how citizen science, even in a project's earliest stages, can facilitate communication between disparate stakeholders around a scientific theme: by acknowledging their concerns and hesitations, responding to these in a transparent way, and providing trusted spaces within which to discuss these.

3.4 Forschungsfall Nachtigall in Berlin

Project name: Forschungsfall Nachtigall (the Nightingale Research Project)

Duration: 2018–20

Budget: € 264,753 (BMBF, for 2018–19; in 2020, it was funded in-house by the Museum für Naturkunde Berlin)

Financing programme: German Federal Ministry of Education and Research (BMBF)

Forschungsfall Nachtigall illustrates the importance of building and maintaining communities for citizen science projects. Its overarching aim was to connect nature and culture through a charismatic songbird: the nightingale. As a modular, transdisciplinary project, it provided opportunities for people from different disciplines and modules to participate.

The first question was whether it was possible to create a nightingale distribution map in Berlin, with the help of an app and many untrained but enthusiastic citizens. Here, science communication took the form of 'traditional' dissemination, via TV programmes, radio interviews and newspaper articles. As well as explaining the scientific aims of the project, this media engagement played an important role in encouraging citizens to download the Naturblick App, developed by the Museum für Naturkunde Berlin, and participate in collecting song recordings and, through their associated global positioning system (GPS) data, the birds' singing and breeding locations. With the help of the app, it was possible for a broad audience to actively participate in data collection.

Unlike in many citizen science projects, participants were not able to contribute their own research ideas to the overall design and focus. The project had clearly defined scientific questions to pursue, such as: Where do nightingales breed in Berlin? Do they sing differently in Berlin compared to, say, Bavaria? However, although these questions were pre-determined by the project researchers, people engaged as the questions addressed issues that are important to many of us: how cities are urbanizing and are therefore no longer suitable homes for many bird and animal species; how birdsong — as in human speech — is a means of communication and thus dialects may form through learning processes over time and space.

The second element was more related to humanities: collecting memories and emotions from different regions of the nightingale's occurrence. The nightingale has a very wide breeding range, from Iran to the U.K., and its distinctive song plays a role in different cultures. Together with the project members, a small group of refugees (mostly from Syria) sewed a tablecloth of their nightingale memories. This project's aspect was approached in a very explorative way, with the aim of creating a 'common memory' of the nightingale.

The project did attempt to incorporate citizens' own research ideas on these related issues at workshops and BarCamps. Both were well received, and it became apparent early on that many of the participants using the app also turned up for onsite events at the Museum für Naturkunde Berlin. Although everything was kept open, a small 'nightingale community' quickly developed, without having

been explicitly planned as part of the project. This demonstrates an organic, unplanned form of science communication, in which communities gather around a shared interest and quickly achieve collective aims through individual ambitions and personal relationships. Further community events, such as guided tours of the museum's bird collection and evenings in the museum garden, helped to strengthen this group's cohesion and commitment to the project.

Traditionally, the ornithologist community in Germany and worldwide is strongly male dominated. Interestingly, the project events were attended by a large majority of women (many with 70–100% female participants). As all project staff in the project were female, this may have been an effective way of providing role models for interested female bird lovers. This hints at a further strength of citizen science as a form of science communication: personal interactions and direct communication with scientists allows for stronger identification not only with the topic, but also with scientist role models.

Reflections on citizen science as a communications tool

Citizen science is a diverse, evolving field of practice. In light of this, it is unsurprising that the opportunities it provides for science communication are similarly wide ranging. Yet engaging and integrating non-scientific actors in research processes also poses special challenges for communication. From the case studies described, we draw several lessons about science communication through citizen science.

4.1 Science communication must connect to the reality of people's lives

A frequently held thesis, and commonly given practical advice, is that scientific communication should be less formal [cf. Franzen, 2016; Dickel and Franzen, 2015]. One way to informalize science is to make it relatable to people's everyday lives; this can create a new 'way in' to science and scientific processes, by showing how science can help negotiate "real-world problems" [Brundiers, Wiek and Redman, 2010]. This opens up Latour and Woolgar's "black box" [1979] and creates synergies with citizens by actively involving them.[9]

The science buses showed that people take part in citizen science for practical reasons that are related to their everyday life, such as seeking a solution to a problem (e.g. the need for allergy-friendly sunscreen) or to make something useful (e.g. a gift for friends). Participants' motivation doesn't always come from a curiosity about science or a desire to gain knowledge, or even the specific scientific question being addressed by a project. By responding to a range of different motivations, citizen science can offer a range of 'starting points' for getting involved in science. The key is to use science to create narratives and stories that connect to those of the participants' lives.

This requires flexibility in communications approaches. As the science buses case study notes, there was clear surprise among the science buscaptains when they saw that participants' interests and motivations were not what they had expected — the

[9] To actively involve stakeholders in transformation and sustainable development, the Wuppertal Institute has developed a Transition Design Guide. Among others the methods presented are dedicated to socially relevant implementation [Liedtke et al., 2020].

key lesson is that they did not let this derail the project, or try to influence participants' reasons for taking part. Furthemore, as the comparison of the two science bus examples shows, the scenarios and settings in which science communication takes place are also relevant, as they influence the choice of communications formats, and especially the narratives used.

This need to make scientific questions and procedures relevant to people has been documented elsewhere as a criterion for motivating participants in citizen science. For example, Senabre Hidalgo et al. [2021, p. 12] note that "the methodological approach should focus on addressing real-world problems [...] regardless of its potential academic impact [...] research must be done with people and not on or for people". Co-created projects that succeed in connecting with the everyday questions and problems of potential participants have an increased potential to change public attitudes [cf. Pandya, 2012].

4.2 Effective science communication needs to be flexible

Science communication is not just about what information is shared; it is also a question of the channels used to do this. The D-NOSES case study illustrates that science communication cannot be static, but must be constantly adjusted to the needs of, and issues raised by, the target community or stakeholder group. While this is true of all approaches to science, the co-design elements of citizen science inherently offer this flexibility. Further, the case study shows that these approaches can — and should — differ from community to community, and from project to project.

The project's experiences so far also show the importance of adapting this during a project to ensure that it connects to the everyday reality of the actors. The integration of external actors and communities always means a debate about how to access the field. This question of how to reach the various interest groups is integral to the success of the project. Further, the case study shows that these approaches can — and should — differ from community to community, and from project to project.

Depending on which actors are to be addressed, and the dynamics and structures of each community and their social situation, there are different approaches and possibilities for communication. A prerequisite for successful communication — in essence, reaching the right actors, who then act on the information and knowledge — is understanding their ways of functioning and communicating. In addition, communication with a community must be an ongoing task, which happens throughout a project [cf. Mcleod, Scheufele and Moy, 1999] and which changes depending on how the relationships between the actors develop. There is little analytical literature on the role of community-appropriate communication in citizen science or community-based research, although indications of the role of communication strategies as field access can be found in the case studies in this article, or in the social science literature on field access and empirical research.

4.3 Openness is needed to balance different stakes and stakeholders

As Section 2.1 describes, citizen science demands the participation of non-professional actors at different stages of the research process. When involving

heterogeneous interest groups, there needs to be an exchange of motivations and interests to reach a consensus on what knowledge and information the research should achieve. Science communication therefore means communication and translation of these heterogeneous knowledge stocks. As our case studies show, this can be achieved through dialogue.

For such dialogue to be possible, the actors must have a common vocabulary, one created and shared by the constellation of actors involved. The case studies presented here illustrate some of the range of actors that a citizen science project can bring together: (organized) civil society, scientists, political decision-makers, representatives of the business community. Each constellation of actors evokes a specific mixture of motivations, interests, knowledge and time courses, and these must be brought into the research process [cf. Schade et al., 2021; Groom et al., 2019].

The D-NOSES project shows that, for this to happen in practice, it is essential for dialogues to be openf. In this project, the coordination of the talks, and the collection and documentation of prior knowledge and attitudes, was the responsibility of the pilot project managers, who used one-on-one talks to find out in advance what was driving the various stakeholders, the doubts they had and what obstacles they faced. The mediation and translation work was then designed on this basis, taking the form of an in-depth stakeholder analysis [D-NOSES Consortium, 2020]. By contrast, an unprepared confrontation between stakeholders, without a moderated concept, would overwhelm all actors [cf. Young et al., 2014].

4.4 Communication should go beyond the traditional 'teaching-learning' relationship

The Forschungsfall Nachtigall project documents the dynamic development that a project, a question or a cooperation can take on within the framework of citizen science — if the actors become fully involved with, and feel engaged by, the process.

At the start of the project, volunteers' participation was clearly defined in the task of recording nightingales' songs and helping to build up a database. The interactive and communicative structure of the project, however, made it possible for them to formulate their own research questions and interests.

Furthermore, the project's workshops and BarCamps created a space for dialogue that was not limited to a one-off event, but was a feature of the project at regular intervals. These regular exchanges between participants resulted in two concrete outcomes. On the one hand, the frequency of the events built up a community, which in turn provided space and time for the development and articulation of people's own ideas and questions. What becomes clear is that the integration of citizens in research processes, and in particular the inclusion of non-scientific actors in the development of questions and methodology, requires sustained communication.

To put it another way: it takes more than one attempt to break up traditional science communication structures and establish new ones that are based on

equality. It is a matter of negotiating the roles in a project, and distributing them between experts and laypeople. At the start of the Forschungsfall Nachtigall project, the distribution of roles was clear: the scientists are the experts who explain the research question, and who prescribe and guide the methods used [cf. Bromme, Jucks and Rambow, 2004]. But, over the course of the project, these attributions changed. When the cultural significance of the nightingale came to prominence during dialogues between actors, the volunteers became the experts. This change in roles means a different approach to the construction of knowledge [cf. Hitzler, Honer and Maeder, 1994]. In such cases, everyday knowledge becomes epistemologically relevant for answering a research question [cf. Hitzler, 1994]. Furthermore, the joint discussion of the methodological procedure and contents contributes to the critical reflection of the science system [cf. Wanner et al., 2018].

As well as practice and time, breaking up traditional science communication structures requires the establishment of a stable community, one that functions as a trustworthy communication space. In this case study, the project organizers decided to take up the ideas generated in the dialogue formats as prompts for the project's future direction and activities. As mentioned, this was not planned, but citizen science, specifically the involvement of external actors in science processes, can lead to such dynamic project developments — if the flexibility is there. While communication must be planned and adapted according to the respective needs of stakeholders, maintaining a degree of flexibility, such as open spaces for dialogue, allow the focus of a project to shift, or its scope to expand and develop.

Conclusions

5.1 Communication in citizen science is always science communication…

The empirical case studies presented here demonstrate some of characteristics of citizen science that are necessary conditions for successful science communication. Citizen science can make scientific topics relatable translate them into questions related to people's everyday lives. By focusing on the processes, rather than just outcomes, citizen science presents a dynamic and flexible approach to communication, one that is oriented to a project's context and open to changes in this context. And citizen science (often) results in successful science communication because it views teaching and learning in different ways to traditional science communication perspectives.

In particular, citizen science offers a conceptual framework for practically implementing the need for dialogue and exchange in science communication. In this way, it formulates a special understanding of knowledge production, seeing it not as originating exclusively within an academic-institutionalised space, but as transdisciplinary, heterogeneous and situational [cf. Nowotny, Scott and Gibbons, 2003]. At the same time, it is clear that citizen science has a specific understanding of science communication: one that is process-oriented and does not assume communication is a result of scientific endeavour, but a necessary accompaniment to the whole research process.

As stated, citizen science opens up the research process to external actors, and our communication in citizen science projects therefore always takes place between heterogeneous actors from different backgrounds. As such, it is always science communication, as all actors are learning from those outside of their peer group

and usual network of contacts. As our case studies demonstrate, this approach to science communication deviates from the traditional, top-down transferral of knowledge, moving instead to participatory communication that shares scientific knowledge and information that is co-created by different groups and shared within and between them, in new and, at times, unexpected ways.

The opening up of research processes in citizen science also opens up new opportunities for science communication. On the one hand, the target groups for science communication are introduced to new roles. On the other, research processes and procedures become more visible and understandable through citizens' active involvement in them. In this way, citizen science adds perspective to research processes and thus demands a process-oriented concept of communication.

However, efforts to integrate people without a traditional scientific background will not work unless accompanied by a clear commitment to sustained communication. Even in the joint research processes inherent to citizen science, communication and the exchange of knowledge and understanding must be established again and again. Constant and sustainable communication, and monitoring of the impacts of this communication, should be a requirement for citizen science projects.

There are also special requirements for science communication within projects. To ensure that the heterogeneous actors are integrated as equally and transparently as possible, communication must establish appropriate, open structures that are based on equality. These must focus on the specific needs, interests and motivations of each set of actors.

The challenges that the open science policy agenda poses to science can only be solved with and through effective science communication. Opening up science to citizens and other stakeholders is, above all, a communications task: providing open and transparent structures and spaces does not, by itself, achieve interaction and the inclusion of external actors in scientific processes; they need to be brought into these structures and spaces.

The case studies show that communication, in the form of science communication, is an integral part of the transformation of the scientific context [cf. Ramirez, 1999]. If the aim is to connect the sub-areas of science and civil society in a new and different way, suitable structures are needed. But communication between science and society is also needed, which — as this article argues — is always science communication.

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