Biodiversity Mapping as Participatory Science Communication

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Introduction

Over the last 20 years, citizen science has been understood as either democratized citizen science (Irwin, 1995) or contributory citizen science (Bonney, 1996). The present paper will argue for a third understanding—citizen science as participatory science communication (Metcalfe, Riedlinger, & Pisarski, 2008). We propose the following definition of participatory science communication (Hetland, 2020):

> Participatory science communication is based on the one hand on participatory processes, and on the other hand on boundary infrastructures, media and interpersonal communication, which facilitates a dialogue among different stakeholders, around a common science communication problem or goal, as well as accommodating local problems and goals as the participants learn, with the objective of developing and implementing a set of activities to contribute to its solution, or its realization, and which supports and accompanies this initiative.

So defined participatory science communication (PSC) move the focus of citizen science (CS) from doing science, be it either democratized citizen science or contributory citizen science, towards communicating science be it either for achieving scientific aims, contributing to environmental protection aims or other purposes. This is important since many participate in CS activities not primarily for contributing to scientific aims.

The present paper builds on four case studies of biodiversity citizen science activities carried out by the authors: (1) Interviews with 17 scientists at two natural history research museums in Norway concerning their own role in science communication (Hetland, 2019b). (2) Qualitative interviews with eight very active amateur naturalists using the Norwegian Species Observations System (SO) (responsible for submitting 2.4% of the total volume of records) and four boundary spanners who served as liaisons between knowledge production and knowledge infrastructures (Hetland, 2019a). (3) A crowd sourcing activity using an online portal to facilitate collaboration between staff at a natural history museum and a regional botanical society (Oswald, 2019). (4) A web-based survey about the use of the SO with 404 respondents (Hetland, 2020).

Consequently, two dimensions have been studied: 1) scientists – citizen science dimension and 2) identities – motivations dimension. The first dimension is in the project studied by two research questions:

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1. How do scientists at natural history research museums construct publics in museums' science communication?

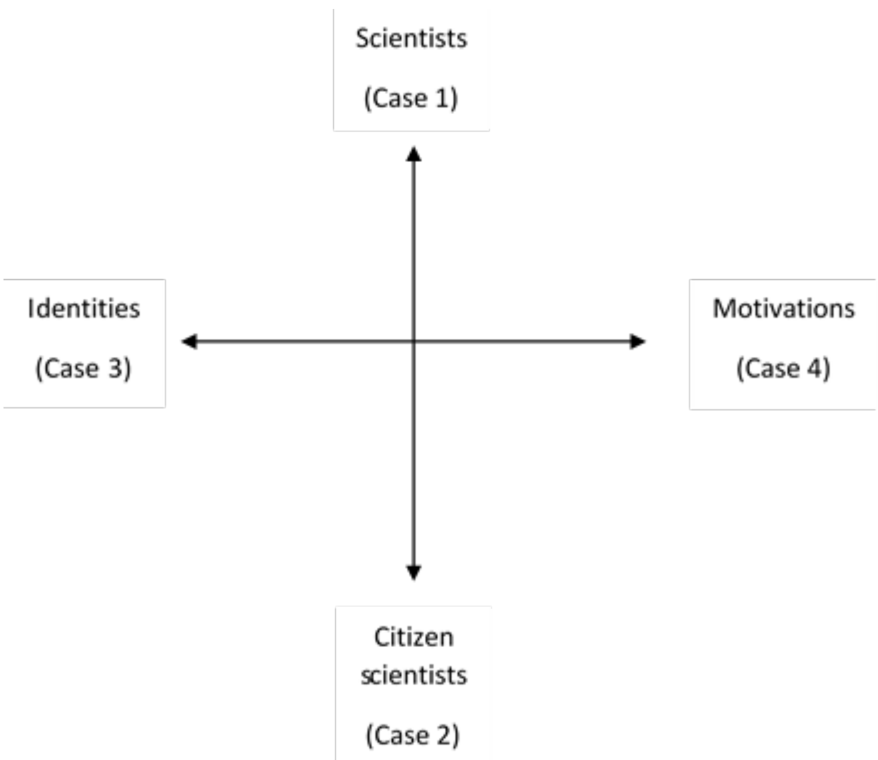
2. How do collaborators in a large CS project co-construct access, interaction, and participation?

The second dimension is in the project studied by the following two research questions:

3. What identities do amateur naturalists and scientists signal during collaboration through their choices of discourse? How do these identities support or undermine participatory science communication?

4. How do knowledge infrastructures such as Species Observation facilitate reciprocity and thereby participatory science communication?

Figure 1 illustrate how the four case studies are linked together (See figure 1).



Collaboration and communication between amateur naturalists and professional scientists is certainly not a recent phenomenon and has a long history in the natural sciences. Digital technology, however, has changed the scale and momentum of amateur and volunteer contributions to biodiversity mapping. The four cases suggest that well-functioning boundary infrastructures, including but not limited to digital platforms like SO, play an important role in facilitating the activities of participatory science communication. The cases also suggests that the success of boundary infrastructure rests on its ability to accommodate many smaller projects, and to facilitate reciprocity between professional scientists, amateur naturalists and other stakeholders.

Based on the case studies and the research questions we will in the following discuss how to understand the different aspects of participatory science communication.

Theory and conceptual framework

In their study of participatory governance arrangements, Braun and Schultz (2010) identified four major constructions of publics: the general public, the pure public, the affected public, and the partisan public. The general public refers to anonymous individuals; the pure public refers to concrete individuals, often "naïve citizens" as the subjects of education; the affected public are concrete individuals, including the authentic expert with firsthand knowledge of a specific area of life; and the partisan public refers to interest groups with knowledge of the landscape of possible arguments. This account "recognizes that there is not one public, but many publics that make up civil society, and it therefore recognizes that doxa is formed through participatory discourse" (Perrault, 2013, p. 26). There is evidence that, even where outreach activities are presumed to use other models, the dissemination model serves as their backbone (Brossard & Lewenstein, 2010; Stocklmayer, 2013). Stocklmayer attempted to map the science communication field by asking three basic questions about communicating any scientific material: from whom, to or with whom, and to what end (Stocklmayer, 2013, p. 27). Based on these three questions, she mapped science communication as a "space" in which various actors communicate. Amateur naturalists have a long history of involvement in biodiversity mapping (Conniff, 2011).

Fleck is responsible for introducing the concept of *Denkkollectiv* (thought collective) to describe how scientific knowledge is produced under certain conditions of collective thought. He also introduced the concept of *Denkstil* (thought style), which describes a particular style of thinking (Fleck, 1935/1979). Fleck outlines his collective scientific thinking in four circles, where the two inner circles are known as esoteric and the two outer ones as exoteric. In the first inner circle, one finds a small group of research experts; in the second inner circle, one finds professionals. The third circle contains a large group of scientific laypeople, while the fourth and outermost circle contains the general public. Most importantly, Fleck conceives the operation of these circles as a system based on a democratic exchange: When developing policies, policymakers position themselves within a specific civic epistemology or in "culturally specific, historically and politically grounded, public knowledge-ways" (Jasanoff, 2005, p. 249). Jasanoff's (2004, 2012) research illustrates that co-production is an important democratic element in many Western societies. Two components here are crucial: Empowerment and scope of choice (Perrault, 2013; Pielke, 2007). According to Jasanoff (2005, p. 255), "(c)ivic epistemology refers to the institutionalized practices by which members of a given society test and deploy knowledge claims used as a basis for making collective choices." Anne Secord claims that "aspects of working-class botanical practice become clear only in the light of artisanal notions of skill" (Secord, 1996, p. 379). Sometimes, exclusion was what caused the division, and "despite the public rhetoric of inviting the ordinary people, they were marginalized from some of the events, which were reserved for the elite" (Nieto-Galan, 2016, p. 59). Using simple Linnaean principles of classification also excluded people (Secord, 1996). Nieto-Galan points out that, decades ago, Ludwick Fleck stressed that "scientists become experts through a long process of learning in which for years they have been students, laypeople, audiences and active agents in classroom culture, in the exchange of opinions between teachers and students" (Nieto-Galan, 2016, p. 118).

When building knowledge infrastructures for CS (Bowker, 2000; Bowker & Star, 1999; Karasti, Millerand, Hine, & Bowker, 2016a, 2016b; Star, 2010; Star & Griesemer, 1989) reciprocity is an important driver (Mauss, 1950 (2002); Sahlins, 1972). A comfortable, respectful atmosphere is important for facilitating opportunities for reciprocity (Kramer & Wells, 2005). Reciprocity highlights a crucial element of CS: A personal relevance for different publics participating in CS (Frewer, Howard, Hedderley, & Shepherd, 1999). Boundary objects refer to elements that link various groups and interests. Star and Griesemer (1989) defined boundary objects as temporary agreements by different actors and groups on how to relate to a given situation. They describe how a standardized method in natural history for collecting, conserving, marking, and describing finds functioned as a boundary object between amateurs and researchers in what was a research subject among researchers and a subject for hobby activity, exercise of an occupation, or environmental protection among groups of the public. In other words, they establish agreement about what are points of contact in common. Boundary objects are negotiated agreements that contain different interests but, at the same time, open up for slightly different practices. The boundary objects create a dialogue among various interests, handling stability and ambiguity simultaneously (Wells, 1999). In this way, boundary objects permeate borders at the same time as the established practice is continued. Boundary work occurs when people contend for, legitimize, or challenge the cognitive authority of those who control knowledge production including the question of gender (Brenna, 2016; Rogan, 1998)—and the credibility, prestige, power, and material resources that attend such a privileged position (Gieryn, 1995). However, disagreements are also an important part of science, be it among professional or amateur scientists (Meyer, 2018). Studying Norway's largest CS project, access, interaction, participation (AIP model) (Carpentier, 2012, 2015) provide a conceptual framework to build bridges between contributory and democratized CS. Furthermore, public participation in biodiversity mapping creates large amounts of data in a short time, and the concept of *apomediation* represents a new strategy of validation (Eysenbach, 2008).

Scientist

Most scientists consider themselves as a central part of their own science communication because they can share enthusiasm and passion. The scientists perceived science communication as an important part of their professional identity; often, highly personal variation was the norm, and each had developed their own science communication niche or space. Closely linked to their research activities and personal preferences, these niches have consequences for how science communication develops. Several interviewees perceived public visibility with a certain ambivalence. Only one was a "celebrity scientist," with a high level of mass media visibility; most had a low to moderate profile and understood science communication mostly in terms of dialogues with specific publics. Several commented that this dialogical aspect was very important simply because only dialogue could provide a meaningful answer to Stocklemayer's question "To what end?" However, this also means that a lot of science communication remains unseen to colleagues, the research field, the institutions, and society at large. Interestingly, this study does not sustain the claim of Brossard and Lewenstein (2010) that the dissemination model (by Brossard and Lewenstein called the deficit model) serves as the backbone of science communication. One important reason is that this study focuses on the scientists and their diversity of science communication activities, while Brossard and Lewenstein's (2010) study focused on rather formalized communication channels (web-based newsletters, conferences geared towards minority communities, television documentaries, and radio programs). It is quite likely that studying science communication from the scientists' perspective will give a more nuanced picture of the role of the dissemination model as well as a broader picture of how scientists think about science communication.

For several of the scientists, science communication was determined not by incentives, but rather by long engagement and a sense of reciprocation to different publics as well as the amateur community. Consequently, several of the scientists had their own group of followers, or "science communication constituencies," and their science communication depended on those prioritized publics and their own personal engagement. This broader vision must include the relevance of science communication as an important quality assurance device, as most scientists ask themselves Stocklmayer's (2013) three basic questions: from whom, to or with whom, and to what end. Underlying these three basic questions is the key issue of relevance. The present study identified four more general science communication publics (see Table 1).

Table 1. Types of publics constructed through museums' science communication

	Practices and settings	Scientists' drivers	Speaking position publics	Designated outcome
The general public	general dissemination activities often by mass media channels	credibility, science identity, tenure	anonymous individuals, but also initiating feedback and dialogues	public appreciation of science, visibility, creating attention, conveying knowledge and process
The pure public	exhibitions, collections, open days, local venues	personal rewards, broaden their interests	concrete individuals; naïve citizen as subject of education, children	public engagement with science, educating citizens, transforming attention into caring
The affected public	amateur naturalist, amateur organizations, collectors and observers, directly or by social media	involving the public in doing science	concrete individuals; the authentic expert	critical understanding of science, building collections, educating the expert, knowledge exchange, knowledge building
The partisan public	organizations influencing knowledge building and agenda setting	funding, collaborating partners, partaking in knowledge and policy development	interest groups, political organizations	critical understanding of science, participation in shaping new knowledge and new policy

Adapted from Braun & Schultz 2010: 414

Dissemination activities with general publics. Braun and Schultz (2010) state that general publics are constructed mainly through opinion polls. For museums' science communication, general publics refers to the whole inventory of possible publics often approached through different mass media channels, sometimes reduced to a smaller repertoire of prioritized publics – like children, families, and senior citizens. Although general publics are traditional, well-known, and recognized publics, they encompass a series of individual adaptations, including direct communication and communication through different media channels—usually, a mix of both. The scientists perceived these dialogues as invisible, hidden from the institutions and from society at large. Ingelfinger's rule was followed in general; however, emphasis was also placed on the importance of process and the idea that it might also be important to communicate with both fellow scientists and the general publics at the same time. Although lay knowledge is sometimes associated with ignorance, conspiracy theories, or similar factors, none of the scientists referred to such problems in their interactions with different publics. The one exception was their concern that, at a more general level, evolutionary theory is losing ground among some sections of the general public.

Dissemination activities and dialogues with pure publics. Braun and Schultz (2010) state that pure publics are those encountered in specific participatory arrangements. For museums' science communication, pure publics are those actively engaging in museum exhibitions, open days, and botanical garden arrangements. They are there as individuals and their main qualification is the interests that motivate them to come. As for Braun and Schultz' (2010) study, they do not necessarily have any prior qualifications within natural history. Creating enthusiasm is perceived as very important by the interviewed scientists, as is the ability to communicate broadly. Children as publics engaged several of the scientists, both because 10- to 12-year-olds reflect the general understanding of the ideal public and because children often have low status in the context of science communication.

Dialogues with affected publics. Braun and Schultz (2010) state that affected publics are first hand experts that are affected, directly or indirectly, by the issues at stake. For museums' science communication, affected publics can be seen as long-lasting companions. As long as museums have existed, affected publics have contributed to natural history museum collections, gardens or scientific activities. Affected publics are heterogeneous groups of amateur naturalists. Hence, amateur naturalists have a long association with natural history museums, and recent developments have revived that relationship. However, the interviewed scientists noted some differences between professional and lay knowledge. First of all, professionals were seen to have a deeper understanding than amateurs of the dynamics of science—the ever-moving research frontier. As professionals also have access to important resources such as laboratories, professional science becomes less accessible when it moves from the field to the laboratory. On the other hand, when traditional professional knowledge, like floristic and faunistic knowledge, departs the center stage of professional knowledge and moves to a less prominent position, amateurs find a space where they can thrive. Because of the limited resources available for fieldwork, professional science is more concerned with general knowledge and less with local knowledge. On the other hand, amateurs develop extensive local knowledge that professional science sometimes needs. Consequently, lay knowledge or amateur knowledge usually conforms with scientific knowledge. However, some amateur naturalists also like to pursue aesthetic values or seek respect as an amateur naturalist by being first, doing the most, and/or being "best" in one way or another. However, this competitive element is not unfamiliar to science, either (Conniff, 2011). Aesthetic values may simply relate to the enjoyment of natural beauty or to the beauty of a well-designed collection. In general, affected publics were seen to create a need for extensive dialogue, often around the topics perceived as hidden from institutions and society at large.

Dialogues with partisan publics. Braun and Schultz (2010) state that partisan publics consist of organizations that hold strong opinions of the issues at stake or have particular interests. For museums' science communication, the oldest partisan publics are friends of the museum. In recent times, amateur societies have become important groups, as have public authorities such as Norwegian Biodiversity Information Centre (NBIC) etc. Dialogues with partisan publics are perceived as important because partisan publics provide resources for research and implement policies of relevance to biodiversity development. The scientists again perceived their dialogues with partisan publics as being invisible, or hidden, from the institutions and from society at large.

Citizen scientist

A study of access, interaction, and participation was conducted to attempt to answer the following research question: How do collaborators in a large CS project co-construct access, interaction, and participation? The results are summarized using the AIP model (Table 2).

Table 2. Co-constructing: Access, interaction, and participation

	Access (Presence)			
	Technology	Content	People	Organizations
Production	Species Observation System (SO)	More than 20 million biodiversity records since 2008	More than 12,000 contributors and 160 validators	Collaboration between amateur societies, SABIMA, and NBIC
Reception	User friendliness of SO	How to access (unstructured) relevant content; the problem of skewing	How to access the producer-content matrix	Organizational structures to provide feedback to (e.g., NBIC)

	Interaction (Socio-communicative relationships)			
	Technology	Content	People	Organizations
Production	Mapping 10 species groups	Produce new content (e.g., ranking lists)	Co-producing content, enhancing knowledge, prioritizing certain tasks	Co-producing meta-content (e.g., Species Maps, Red List, Alien Species List)
Reception	Using SO to receive content, planning recording activities, identifying "white spots"	Producing information (e.g., private diaries) and accessing species information	Consuming media together (e.g., identifying important tasks)	Discussing content (e.g., validation, openness)

	Participation (Co-deciding)			
	Technology	Content	People	Organizations
Production (and reception)	Co-deciding on/ with technology (e.g., new versions of the system)	Co-deciding on/ with content (e.g., the temporality of knowledge, the challenge of validation)	Co-deciding on/ with people (e.g., the 5 principles of participation, inclusion/ exclusion)	Co-deciding on/ with organizational policy (e.g., conducting environmental citizenship)

In the following subsections, we will discuss how access, interaction, and participation are co-constructed.

Access
Amateur naturalists and their societies, together with scientists and public authorities, have acted as strategists, formed alliances, mobilized resources, and built infrastructure for contributory CS with Norwegian Biodiversity Network (SABIMA) as an important driver. Access is a precondition for joining the ranks of records, contributors, validators, and institutional actors. Co-construction took place in the amateur societies, thus arguing strongly for a service like the SO, using the Swedish Artsportalen as their model and convincing the public authorities that such an infrastructure would be mutually beneficial. Hence, to secure stability and innovation, it is important to secure long-term funding by enrolling public authorities. At the same time, the contextual circumstances were favorable, and biodiversity concerns were placed on the agenda by a heterogeneous group of actors.

Interaction
The movement in science from the field to the laboratory widens the gap between professional scientists and amateur naturalists. Nonetheless, amateur naturalists continue to contribute much local knowledge. The hierarchal structure of professional scientists and amateur naturalists is also different. The former considers being a respected researcher within his or her discipline to be important, while the latter considers being a respected naturalist as important and has a limited tolerance for ignorance. Furthermore, the individual knowledge strategies of the amateur naturalists emphasize local patches and favorite species-groups.

Among the validators, there is a general claim that contributing your own records and validating the records of others are very distinct categories. When one is contributing one's own records, one is driven by intrinsic motivation. It is fun and interesting, and it is quite all right that the work is voluntary, but it is important that the contributions are taken seriously and reciprocated. Examples of such reciprocation include digital diaries, resources to aid recording activities, ranking lists (even if they are much debated), learning possibilities, new collection strategies, and a system of validation. All of these are examples have a high personal relevance (Frewer et al., 1999). When validating the records of others, one is driven by the extrinsic motivation of doing a necessary job for the community. It is, in the long run, somewhat boring and takes time away from doing what one likes the most. Consequently, the activity should be looked upon as a traditional market relationship—it is a job for which one should be paid. Thus, while the SO reciprocates to the amateur naturalists in a highly relevant manner, it does not do so for its validators.

Independently of each other, all five of the validators interviewed in this study are quite clear on this issue. The validators take part in a co-construction of knowledge that they sometimes experience as tiresome. In the past, they could use their own expertise to validate a record, but now they must enter into a dialogue with the contributor. Furthermore, while specimen collection has a long history among amateur naturalists, this history is broken by a change in the way collection is valued. Unskilled amateurs or "hopeless people" do not contribute, and several of the interviewees desire an easier way of expelling them. However, expelling participants violates the most important general principle guiding the SO, which is that everyone may contribute, regardless of their skills. Consequently, it is sometimes difficult to maintain a comfortable and respectful atmosphere within the SO, and this frustrates some of the participants (Kramer & Wells, 2005) and disagreements are also an important part of science, be it among professional or amateur scientists (Meyer, 2018). The heterogeneity that Secord (1994) found among amateurs is still there, even if the class aspect is downplayed; skills are currently growing in importance. In this respect, one find circles of interaction similar to those Fleck described (1935,1979).

Skewing partly results from people following their own interests or only going to their favorite places without considering the interests or needs of science. At the same time, these amateur naturalists might be concerned with the environment in their favorite location. This version of generalized symmetry (Sahlins, 1972) is also encouraged by knowledge politics, giving priority to species on the Red List and the Alien Species List, thereby producing meta-content. However, the SO also provides an opportunity to identify "white spots" and thereby select new and important places to record. Generalized symmetry is also noticed when young amateur naturalists are enrolled. The more experienced ones see this as an important element to sustain the community of amateur naturalists, but the recruitment is problematic in many respects. One can help the younger amateur naturalists more, but they may be overbearing in their ignorance. However, one can feel rewarded when said amateurs begin to participate in validation discussions. Personal relevance is high when it comes to generalized symmetry.

Balanced or symmetrical reciprocity (Sahlins, 1972) is the most apparent version of reciprocity when studying biodiversity mapping. On average, each of our interviewees collected 1,575 different species and submitted 58,000 records. Such work, generally, is not done solely for the common good. More often, it is done for personal reasons—such as instilling order among their own observations or making use of the SO as their own field diary—which in turn makes them visible to the community of fellow amateur naturalists and helps them achieve status as a knowledgeable and experienced amateur naturalist. Personal relevance here is also crucial. This knowledge may be useful in assisting others in validation work. The SO practices a form of openness that is sometimes experienced as problematic and consequently, several Facebook pages have appeared. Furthermore, comfortable, respectful atmosphere is important for facilitating opportunities for reciprocity (Kramer & Wells, 2005). However, the SO does not always accommodate these opportunities, according to some of the interviewees.

Sahlins (1972) also explored the concept of negative reciprocity, which is characterized by the attempt to get something for nothing. Many of those concerned with negative reciprocity think of it as a form of theft. Some harvest data from the SO for their own gain, unconcerned about giving something back. An example of this is the illegal hunting of protected species, although this sometimes becomes the *legal* hunting of the same species, since public authorities allow their hunting if a protected species attacks domestic animals or appears outside of their zone of protection. In this sense, the SO could be misused to identify places where both legal and illegal hunting could be done, which most amateur naturalists find predatory. Thus, they invent their own protection schemes by either not recording the sightings of such species or by being vague about the exact location of such sightings. Other activities that the participants in this study perceived as negative reciprocity include the form of validation that leads to a feeling of being pilloried or open for ridicule.

Participation

Most amateur scientists understand that they are partaking in a huge communal undertaking and that the value of contribution is quantifiable, as they can provide a picture of Norwegian biodiversity. However, the quality of this view rests on their ability to avoid skewing and collect well-validated data. The difference between professional and lay knowledge is primarily a question of different collection strategies and validation methods. Both professional and amateur naturalists emphasize that knowledge should be correct and validated. However, the methods for collecting unstructured and structured data are quite different. One reason for this not being an overly problematic situation is the differences in goals between the two types of naturalists. While scientists aim to provide something of scientific value to biodiversity, most amateur biodiversity mappers are more concerned with environmental citizenship. Simply put, their *Denkstil* (Fleck, 1935,1979) may be different. However, the ability to build and sustain the infrastructure also illustrates that participation is power enacted from the bottom-up. The inclusive style of participation and co-production also underlines important democratic traditions (Jasanoff, 2004, 2012).

Identities

Case description. This case study focused on the pilot of an online citizen science project, organized by a university natural history museum in Norway and involving volunteers from a regional botanical organization. Activities took place over six months in 2017, and were organized as a part of a university-led research project about participation and digital technologies in cultural institutions.

The museum had previously developed and piloted an online portal for citizen science, and, with support of the museum's public relations staff, mobilized online volunteers (and some members of the museum staff) to transcribe labels for a collection of African moss specimens. In the second pilot, detailed in this case study, the museum and a university researcher decided to recruit a specific group of volunteers rather than opening the task to anyone online. Both museum staff and the researcher were interested in exploring the feasibility of improving the quality of geographic data about herbarium specimens by matching recruited volunteers with collections material from their region.

This research aim is in line with recent suggestions that knowledge of the geography (Ellwood et al. 2015: 389) and organisms (Merckx et al. 2018) represented in a museum's collection could result in higher quality volunteer-created metadata through crowdsourcing. Naturalists, genealogists, local historians, and other "amateur-experts" these authors suggest, could make important contributions to natural history digitization projects with their knowledge of biology and geography. Outreach to organizations that amateur-experts participate in has been suggested as a strategy for recruiting individuals with potentially relevant knowledge (Ellwood et al. 2016: 8; Merckx et al. 2018: 46).
A museum staff member contacted two regional botanical societies and members from one of the societies agreed to participate in January 2017. Once members of the botanical society had agreed to participate, the pilot involved four activities: (1): In May 2017, three museum staff members lead an in-person workshop for 12 society members, providing an overview of the online task and time to work on the task and ask questions; (2) from May to September 2017, society members completed the majority of the task in the online portal; (3) in September 2017, eight society members and three museum staff met at the museum to discuss society members' experience with the online task; and (4), following the discussion, two museum staff members gave a "backstage" tour, showing society members physical specimens from the collection.

Data collection and analysis. The collaboration between the botanical society and the natural history museum during the pilot was documented through video recordings of in-person activities. The decision to video record these activities was informed by interaction analysis (Hall & Stevens, 2015), a qualitative method in the learning sciences. Video recordings allow researchers to repeatedly view interactions among participants, and compare their interpretations of participants' interactions with other researchers. Analysis of the video data, ongoing at the time of writing, has been guided by the research question: What identities do amateur naturalists and scientists signal during collaboration through their choices of discourse?

Shared organizational experience and knowledge. The botanical society members' understanding of what could or should be accomplished in collaboration with the museum staff was articulated with reference to the past experience of the botanical society as a collective. For example, during the first meeting with museum staff, a society member described a previous project in which biodiversity data

from the museum's collections was incorporated into a regional flora atlas maintained by society members. In apparent frustration, the society member explained to the herbarium curator that although they made corrections and improvements to the museum's data, the society's corrections were never made publicly accessible because of stipulations from the museum about information from the collections should circulate. By drawing on a specific example from the organization's past, the anecdote underlined the challenges of collaborating with the museum, and countered the herbarium curator's more positive view of what could be accomplished in the current citizen science pilot.
The botanical society members' collective experience with biodiversity in their region was similarly referenced during the group's "backstage" visit to the museum's herbarium. During the visit, society members and the herbarium curator looked at herbarium pages containing a species of wild orchid collected from the group's region. The society members explained to the curator that, although the herbarium includes relatively few examples of the orchid, and the curator himself never seen the orchid in the wild, in recent years society members have found the plant in their region in at least two locations. They went on to suggest that the society could provide additional physical specimens for the herbarium, a suggestion to which the curator responds positively. By referring to their local experience with a particular species, the society members introduce the possibility that collaboration between the museum and the botanical society may expand beyond the activity initially planned in the citizen science pilot project.

The above examples from in-person interaction between the botanical society members and museum staff suggest that the botanical society members approached the collaboration with the museum in terms of a shared organizational history and shared experiences of regional biodiversity and. These shared experiences or knowledge, however, did not mean that society members were always in agreement about what the organization could or should contribute. One society member, for example, emphasized to the herbarium curator that another member's knowledge of regional geography was "unique" and that it would be unreasonable to expect that all society members could contribute to the project with such detailed knowledge. She then went on to remind those present of another society member, and the difficulty that member would have had performing the task the group had completed as part of the pilot.

The preceding excerpts from the data suggest that although botanical society members contributed individually to an online citizen science pilot project and have access to knowledge that allowed them to contribute to the project in different ways, members also approached the collaboration with the museum in terms of an organizational identity, based on an organizational history of collaboration with the museum and shared experiences of biodiversity in their region.

Motivations

Boundary infrastructures like the Norwegian SO link a large variety of actors— be they volunteers, dedicated amateur naturalists, amateur societies, scientists, and environmental authorities—facilitating collaboration in Norway's largest CS project. More importantly, anyone can participate, whether a newcomer with only one recorded sighting per year or a veteran with several thousands. Some of the more skilled veterans may of course find the different levels of expertise a challenge; however, most of them recognize the value of this inclusive participatory principle.

We started by asking how knowledge infrastructures such as SO facilitate reciprocity. A new knowledge infrastructure's success rests on its ability to accommodate many smaller projects within the larger one. These range from projects of single volunteers or amateur naturalists following their individual interests in natural history, to larger projects by scientists, amateurs, and environmental authorities cooperating across disciplines and organizational boundaries, to even larger national projects, including the Species Map, the Red List and the Alien Species List. Among the smaller projects, standards and validation activities can be found. Consequently, knowledge infrastructures resemble Trojan horses, with a unified exterior and a multiplex interior. The boundary objects constituting SO represent different interests and open up for slightly varying practices (Bowker, 2000; Bowker & Star, 1999; Star, 2010; Star & Griesemer, 1989). The layering of boundary objects into knowledge infrastructures creates a form of irreversibility marked by a constant flow of incremental innovations as e.g. several private initiatives to make an app indicate. Consequently, the frustration that several users experience is caused by the fact that boundary infrastructures often have a dual mission; they aim to handle stability and innovation at the same time. This duality is also apparent in the user answers, some ask for more innovation while others ask for more stability.

As important aspects of studying reciprocity, three subquestions have been asked. First, who are the participants and what drives them? Three out of four are men. One interesting question is if infrastructures for natural history appeal differently depending on gender (Brenna, 2016; Rogan, 1998), and it seems that biodiversity mapping at present appeal mostly to men. We are not able to discuss this question further based on the available data. The users are mostly well educated; about three out of four have higher education. They represent a steady user group; about one out of two has been using SO for over five years. More than one out of three use SO every day. Consequently, they represent a competent and dedicated pool of free labor, mapping Norwegian biodiversity. How does the infrastructure facilitate reciprocity? The two most important reasons for using SO are to "contribute to biodiversity knowledge" (88%) and "keep track of my own sightings" (53%). However, summarizing the emphasis on individual outcomes and comparing these with collective outcomes show both as having more or less equal importance. The emphasis on individual outcome also reflects the importance of personal relevance, which also underline the importance of reciprocity when building knowledge infrastructures

Second, what does participation mean? Three out of four use the resources provided to enhance their own expertise, thereby providing answer to Stocklmayer's question "to what end"?' (Stocklmayer, 2013, p. 27). Many users are members of one or several amateur societies and participate in different activities to enhance their own skills as field naturalists. About 39% contact scientific institutions to obtain help or submit specimens. Validation is a crucial issue that concerns many users. The organized network of validators prioritizes the species included on the Red List and the Alien Species List. For the rest, apomediation is central (Eysenbach, 2008); however, many comments indicate that it works only to a certain degree, and much of the material is never validated. Many users find this issue troublesome; however, an important group also perceives the validation as Sisyphean. It is never ending, and what is done will never meet everyone's satisfaction. One way of rephrasing the quality is illustrated by the claim; the quality is in the quantity.

Finally, how does SO encourage participation and the building of expertise? As mentioned, Mauss (1950/2002: 50) describes three crucial obligations in a gift economy: "to give, to receive, to reciprocate." The users give their sightings, SO receives the sightings and some are validated, and SO reciprocates the gift by facilitating individual projects within the knowledge infrastructure for every user (if they so prefer). Consequently, there is multiple level of reciprocity and gifts. The responses obviously show much appreciation for such reciprocation; some respondents wish for even more tailored reciprocations for each user. Regarding how the respondents use SO, the two most frequent user forms are "Submit sightings" (96%) and "Look at today's sightings" (72%). However, summarizing the emphasis on either uploading or downloading information reveals that 37% focus on uploading, while 62% emphasize downloading. Uploading information highlights the act of giving, while downloading information stresses SO's ability to reciprocate in a relevant manner. All in all, SO contain bundles of rights and obligations for those who participate. Furthermore, ranking list may be experienced as an important form of visualizing reputation and consequently as a symbolic return gift in one specific version of credibility cycles.

Concluding discussion

Building on Braun and Schultz's (2010) four major constructions of publics, this study confirms that the four publics are also useful for understanding museums' science communication. Museums' science communication addresses the four main publics: general, pure, partisan, and affected publics, and the importance of dialogue is common to all of them. At the same time, these scientists perceived such dialogues as being unseen by either institutions or society at large. Consequently, most of what they do under universities' 'third assignment' is experienced as surprisingly unrecognized. Apparently, this is not a recent phenomenon but, rather, has characterized science communication in natural history research museums for perhaps as long as they have existed. Individuals may of course be members of all the mentioned publics depending on role and context. Hence, communicating with publics is not only a question of "good," "bad," or "average" but is also a matter of addressing different publics in a relevant way. For that reason, in addressing the quality challenge, greater attention should be paid to what is relevant for these different publics. Scientists seem to prioritize relevance as a primary quality assurance device when addressing different publics in museums' science communication.

The AIP model has strong analytical capacities (Carpentier, 2012, 2015), providing a framework of understanding the rather vague concept of participation in a more systematic manner that differentiates between access, interaction, and participation. By this differentiation, it is also easier to build bridges between contributory CS, where access and interaction signify presence and socio-communicative relationships, and democratized CS, where participation signifies co-deciding. Consequently, building bridges is crucial to include power in our understanding of citizen science where access and interaction are characterized by unequal distribution of power, while participation have a more egalitarian distribution of power where one has to establish rules for handling disagreement.

The limitations of the study is that none of the many at the long "tail" were interviewed, the same goes for those perceived as "hopeless people". However, it is unlikely that including them would have changed our understanding of access, interaction and participation. For future comparative research it would be very useful if one within citizen science studies took the AIP model into use and thereby facilitated a systematic approach to studying access, interaction and participation.

In the third case study, the organizational identity of botanical society members, which emerged in spite of the fact that the online citizen science project was structured in terms of individual contributions, suggests the need to further explore the involvement of existing groups or institutions in a citizen science project, whether those groups be members of a university research lab organizing the collection of biodiversity data by volunteers, or a community organization enlisting the services of a 'professional' scientist to document environmental hazards in their community. These findings about the prevalence of institutional identity in citizen science collaborations is particularly relevant in light of the findings from the other cases, including professional scientists' sense of the invisibility of their science communication to the institutions they work for, and the position of validators within other science institution and the species observation portal.

We have identified several elements that seems crucial for a definition of participatory science communication:

1) Open participation;
2) Participation involve all levels of skills and intensity;
3) Boundary infrastructures that facilitates dialogues and add-on-communication-forums supporting the activity;
4) Purpose include both large national and international projects as well as participants own individual projects;
5) Purpose are also multidimensional, including both scientific aims, environmental protection aims as well planning aims.

Building on those findings we have proposed the definition launched in the introduction.

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