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Infrastructuring Digital Citizen Science:

analysing a commercial app development platform

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♦ For Renate ♦

1 Introduction

It is a mild day in the fall of 2018 in a quiet corner of Vienna. A tram stops and out hop a group of students. They join their colleagues and their lecturer Sascha Dickel at the gate of the Zentralanstalt für Meteorologie und Geodynamik (ZAMG)[1]. None of them have been here before. But most know this institution as provider of weather forecast data in Austria. Today however the group has a different interest. They meet scientists who talk about their experience with involving the general public in science, a practice also known as citizen science. I am part of this group. And this is one of the initial inspirations for my master thesis.

The first presentation is about the Citizen Science Network Austria[2], which aims to promote the approach, quality and visibility of citizen science in Austria. Starting in 2017 it now involves 45 institutions who are connected to citizen science in varied ways such as research, education, activism or funding. The coordinators of the network, Daniel Dörler and Florian Heigl, bring in a wide range of citizen science projects[3] from their home institution, the University of Natural Resources and Life Sciences (BOKU[4]), and build on their personal experience of running the mobile app Roadkill[5] to collect data about animals killed in traffic.

ZAMG is one of the members of the Citizen Science Network Austria and they have broad experience with citizen science[6] related to weather, climate, geophysics or the environment. They train volunteers to become Trusted Spotters[7] who provide observations to improve damage forecasts and warnings for extreme weather events like avalanches, black ice, lightening, hail, storms or floods as weather stations are not able to cover impact on the ground. ZAMG also involves schools to work on issues around earthquakes, glaciers, geomagnetic field and climate research. Their earliest records of volunteer observations dates back to 1851 in the field of phenology which is a form of applied climate research that involves recording blossoming cycles of plants and studying shifts in the timing over the years.

In his presentation Thomas Hübner from ZAMG mentions that the tradition of certain professions like teachers and clergy to contribute phenological observations has dramatically declined. As the field of phenology depends on sustained long-term observations ZAMG looked for ways to attract new contributors. They started cooperating with schools using a mobile app to submit observations

[1] https://www.zamg.ac.at, last accessed: 16.12.2022
[2] https://www.citizen-science.at/en/network, last accessed: 16.12.2022
[3] https://boku.ac.at/en/citizen-science/projekte, last accessed: 16.12.2022
[4] https://boku.ac.at, last accessed: 16.12.2022
[5] https://roadkill.at/en/, last accessed: 16.12.2022
[6] https://www.zamg.ac.at/cms/de/forschung/citizen-science, last accessed: 16.12.2022
[7] https://www.zamg.ac.at/cms/en/research/citizen-science/tsn-austria, last accessed: 16.12.2022

containing the type of plant, the phenological phase and the location. Eventually ZAMG opened participation in their Naturkalender[8] app to the general public.

I leave the excursion impressed by the broadness of citizen science activities these institutions carry out. And with my special interest in digital citizen science I note that both projects, Roadkill and Naturkalender, use apps to integrate volunteers in their scientific activities. Both apps are developed with and running on the Spotteron[9] platform which maintains an extensive website. Spotteron also seems like a relevant actor in the field of citizen science being mentioned in the footer and the imprint of the Citizen Science Network Austria Webpage and maintaining a portfolio of national and international projects. This is where a rough idea for my master thesis project emerges: I want to analyse the website of Spotteron to find out what kind of citizen science they promote. And so I did. Here is how I present my results in this thesis.

Chapter 2 gives an overview of related scientific literature in the area of citizen science and digital citizen science. This includes the distinction between democratized and contributory orientations in citizen science and a discussion on the use of the term citizen science for historic practices as well as on the variety of terms used for similar practices and actors involved in them (section 2.1). It contains typologies to position digital citizen science projects and activities and discusses motivational issues including potential tensions between volunteer and project goals (section 2.2).

Chapter 3 provides more background on the Spotteron platform, organisation and collaborations before presenting the focus of my research namely how Spotteron imagines collaborators and their contributions when building their digital citizen science infrastructure.

Chapter 4 introduces digital infrastructure as central concept to make sense of Spotteron. Information and knowledge infrastructures studies provide a fruitful conceptual ground and empirical material related to digital citizen science (section 4.1). Platform, app and social media studies address levels which are relevant for Spotteron, who develop citizen science apps with social media functions based on their core platform (section 4.2).

Chapter 5 describes the methodological approach of this thesis. Beyond the core of qualitative document analysis of the webpage text this involves interviews, autoethnography, visualisations and quantitative experiments (section 5.1). I introduce my main empirical material, the website, considering structure, perspective and fluidity (section 5.2) and described how I stabilised and analysed this large corpus of texts (section 0).

Chapter 6 presents the results of my empirical work. It starts with a broad overview of the framing of main actors and their contributions: Spotteron as platform provider who develop features as well as

[8] https://www.naturkalender.at/, last accessed: 16.12.2022
[9] https://www.spotteron.net/, last accessed: 16.12.2022

app customizer who design participation, their partners as app administrators who use data to solve issues and the citizens as social media users who contribute spots within a community (section 6.1). The collaboration of Spotteron and their partners in designing a citizen science app is the starting point for an app-based citizen science perspective (section 6.2). Next is a phase where data is collected with the help of the app. Social media functions are central in the latest version of the Spotteron app and these introduce new practices and impact existing ones (section 6.3). Finally, broader perspectives need to be considered to make sense of Spotteron, such as moving from an individual app perspective towards a platform view, considering personal motivations of citizen scientists and understanding Spotteron apps as part of a broader research project carried out by partners (section 6.4).

Chapter 7 connects the findings to existing literature (section 7.1) and uses Spotteron as illustrative example for introducing visual tools which are proposed for further research beyond this case (section 7.2). These allow to assign contributions to individual and multiple collaborators as well as illustrate the involvement of multiple collaborators in different project phases.

Chapter 8 derives conclusions for practitioners from the main findings and proposes further research for academics. With this my master aims to be an entry point to digital citizen science for academia but also beyond. After all, digital citizen science as practice involves a varied crowd including technologists, scientists and citizens.

2 Literature: Towards digital citizen science

Citizen science is a popular label in science policy, funding and research. The common core is inviting public participation in scientific knowledge making which is a longstanding interest of Science and Technology Studies. Establishing a common understanding about what citizen science is and what it should be is an ongoing debate involving discussions from many perspectives (Haklay et al., 2021).

The founding of the journal "Citizen Science: Theory and Practice" in 2014 and Special Issues on citizen science in the Journal of Science Communication (Lewenstein, 2016; Weitkamp, 2016) and Science and Technology Studies (Kasperowski & Kullenberg, 2019) demonstrate persisting academic interest.

Although the latest edition of the STS handbook (Felt et al., 2017) does not include a separate chapter on citizen science the broad use of the term with some prominent focal points becomes apparent with appearances in every fourth chapter (9 out of 36) related to issues such as arts, social movements, epistemology, documents, urban studies and most strongly in the chapter on environmental justice (seven times) and science communication (four times).

The first section of this thesis chapter presents important academic work around citizen science. This includes introducing central framings of citizen science, hinting at the plurality of disciplines, practices and participants that are related to citizen science as well presenting systematic approaches that aim to establish order in this varied field.

More recent work in STS is interested in the way digital technologies are employed for citizen science. These can comprise project websites, catalogues, social media, apps, wearables, sensors, drones, data analysis and mapping tools, virtual and augmented reality and open data (Mazumdar et al., 2018). The *Journal of Science Communication* recently published a special issue to discuss design standards, methodological approaches and empirical findings around user experience in digital citizen science (Skarlatidou et al., 2019).

The focus of the second section of this thesis chapter is on conceptual work around digital citizen science and empirical findings that describe what happens when social and technological aspects meet in digital citizen science platforms.

2.1 Citizen science

The start of academic discussions around citizen science in Science and Technology Studies are commonly attributed to Irwin (1995) and Bonney (1996). Their use of citizen science refers to different motivations.

Irwin (1995) introduces the term citizen science in academia to value both scientific and public perspectives in knowledge making. He suggests it contains science *for* citizens and science *by* citizens.

The former is science that addresses interests, needs and perspectives of citizens. The latter appreciates active knowledge-making of non-scientists.

Irwin encourages a more nuanced, balanced and productive relationship between science and the public. He suggests balancing scientific and public needs to allow further self-reflexivity for knowledge making instead of a simplistic framing of science as progress and critical voices as ignorant. This involves openness to consider science from the point of view of citizens rather than from that of the scientific establishment. According to Irwin expertise should be put at the service of the public. He makes his case in relation to environmental issues where he positions citizen science as a way of active citizenship. Irwin claims that sustainable development needs social learning involving science, technology and public groups. His recommendation to make science more receptive to citizens can be seen as policy-oriented and deliberative.

Bonney (1996) builds on his experience in the long-standing collaboration between amateurs and scientists in ornithology. He describes citizen science mainly as citizens contributing to science thereby acquiring new skills and a deeper understanding of science. Bonney's approach highlights participatory and educational aspects. Bonney also participated in creating typologies for citizen science starting with a differentiation between contributory, collaborative and co-created projects with different degrees of involvements of citizens from limited to data collection, to participation in several steps of knowledge creation to joint design of research activities (Bonney et al., 2009). This was later extended to include contractual projects where communities task scientists with investigation and collegial contributions where citizens carry out research independently (Shirk et al., 2012).

Cooper and Lewenstein (2016) suggest the terms democratized citizen science (Irwin) and contributory citizen science (Bonney) to distinguish these background ambitions. Democratized citizen science aims to open up science to be shaped by the public whereas contributory science starts from a narrow focus on public crowdsourcing of data. They suggest that these two views can build on each other. Contributions can extend beyond data contributions which then supports democratizing ambitions. This happens when citizens do more than collecting data and scientist do more than working with it.

> *"The 'democratic' definition represents a larger context in which the 'contributory' style of citizen science resides. The lowest common denominator to citizen science projects is the collection and/or processing of data. From that focal point, the collaboration between scientists and nonscientists can expand."*
>
> *Cooper and Lewenstein (2016)*

As an example for extending the cooperation beyond collecting data they use the Flint water study. This was initiated by a resident of Flint who was concerned about lead levels in tap water and asked an engineering professor for help. The initiative increased attention through crowdfunding, public water sampling and advocacy until finally political action was taken.

Cooper and Lewenstein suggest that although the term citizen science is relatively new there are historic practices following the spirit of involving the public in the scientific method. Before the professionalization of science towards the end of the 19th century all science activities could be considered citizen science. For crowdsourcing activities they include examples starting from the 18th century such as observations of the weather, meteors, tide or whales.

Strasser et al. (2019) offer a critical discussion of popular historizations of citizen science as reaching back to amateur science. They suggest that if citizen science means involving amateurs into scientific processes it does not make sense to extend the notion citizen science to amateur communities which existed before the institutionalisation of science which created the separation between experts and amateurs in the first place. The focus on amateurs also risks neglecting the involvement of the public in areas where no amateur communities existed before and opening of disciplines which were not publicly accessible such as experimental science which is carried out in laboratories with expensive equipment.

They also discuss caveats of popular promises of citizen science: democratization, science literacy and scientific breakthroughs. Although broad participation could be the aim of citizen science in practice not everyone desires to participate and there might be bias concerning educational and professional background as well as inequality of contributions. Citizen science projects which aim to foster learning about the content and the science process can be seen as connected to the framing of our society as knowledge economy which still affects educational policy. Instead citizen science projects often ask questions which might not be addressed otherwise and they offer space for intuition and bodily experience which question scientific ideals of objective, rational and disinterested knowledge. Therefore citizen science has the potential to redefine the process and the participants, the focus and the outcome of knowledge production which connects epistemology and politics.

Eitzel et al. (2017) discuss contemporary labels for citizen science and potential effects on practices and participants. These are based on practical experience of the 23 authors who are mainly academics or citizen science project leaders in the United States and Europe. At first they present the use of existing labels for citizen science activities within different contexts. They suggest that considering the context is essential to understand the meaning of labels as the same labels used by different actors could suggest very different things.

Eitzel et al. list potential historic predecessor terms such as Participatory Action Research and Community Action Research which they present as connected to social movements starting in the 1960ies and Crowdsourcing is included as potential alternative term at the beginning of the 21 century.

They illustrate variations of terms used in different disciplines. In health and environmental fields the label community-based participatory research with residents, neighbours and community members is prominent and in geography volunteered geographic information is the dominant term.

Eitzel et al. also present variations within a broader geopolitical, language specific and institutional context. The Arctic council[10] promotes the term Traditional Ecological Knowledge, Estonia uses multiple terms such as citizen science, amateur science and people science, Austria has a practitioner (Österreich forscht[11]) and an institutional platform (Zentrum für citizen science[12]) and the European citizen science Association[13] aims to promote a common understanding of citizen science.

They mention academic umbrella terms such as Public Participation in Scientific Research or Community and Citizen Science which aim to accommodate the wide range of participatory approaches which varying degrees of participation in different stages of the scientific process. However citizen science and more recently crowdsourcing are more prominently in use. Alternative labels for systematic investigation include analysis, monitoring or research which might align more with the motive of communities to convey credibility of their findings outside the classical science paradigm.

Eitzel et al. discuss potential implications of labels used for people involved in citizen science which highlight the variety of characteristics and motivations of participants. Specialised labels used for scientists include public scientist, civic educators, commercial scientist, credentialed scientist, academic scientist, professional scientist, researcher, scientist-activist or volunteer scientist. Since citizen implies a legal association of individuals with a state or city which is usually not an inclusion criterion for participation alternative labels are frequently used. General terms include collaborator, community, contributor, participant, partner or volunteer. Labels such as indigenous, traditional, local or lay knowledge holder highlight particular types of expertise. Prefixes such as non-scientists, non-credentialed, non-academic potentially devalue participants and their contributions by highlighting deficits when compared to institutional, credentialed scientists. Donor or human sensor may convey

[10] https://www.arctic-council.org/, last accessed: 13.12.2022
[11] https://www.citizen-science.at/, last accessed: 13.12.2022
[12] https://zentrumfuercitizenscience.at, last accessed: 13.12.2022
[13] https://www.ecsa.ngo/, last accessed: 13.12.2022

the connotation of limited involvement or consent of participants. Some projects use specific labels for their participants such as eBirders (eBird[14]), Zooites (Zooniverse[15]), Player (FoldIt[16]).

They propose several strategies for choosing an appropriate title. The first set of options follow a generality approach. One way is to use a general label and acknowledge that the terminology may not fit all audiences. Another one is to skip labels and focus on the skills necessary to contribute without making a distinction between different participants in order to show more recognition of volunteer contributions. The second set of options follow a specificity approach. This means connecting to the umbrella term citizen science but defining the meaning or including alternative more fitting labels. Contributors could be described according to the characteristics of their work or their role. The final recommendation is to find out how people call themselves and how they want to be called in this specific context.

Instead of engaging in labelling practices Strasser et al. (2019) focus on the variety of epistemic practices such as sensing, computing, analysing, self-reporting and making and their political implications. In a similar vein Schrögel and Kollek (2019) suggest joining the often disconnected academic discourses of participation in knowledge-making and science governance to develop a multi-dimensional model. They propose their participatory science cube as descriptive tool to visualize the position of participatory approaches and projects. The model modifies Archon Fung's (2006) democracy cube to contain normative focus, epistemological focus and reach as three axes. Each axis contains steps which are derived from a literature review of domain specific one-dimensional frameworks and ordered depending on the power balance between institutional scientists and the public. The resulting space allows to position activities between the extremes of closed traditional science and open activities such as hackers and makers which involve a broader public in problem definition and governance.

While this section uses the broader frame of public participation in research to position citizen science the next section zooms in on the specificities of digital citizen science.

2.2 Digital citizen science

A prominent model for classifying digital citizen science endeavours comes from Haklay (2013). His model stems from his interest in volunteering geographical information which plays a role in some parts of amateur science, community science and citizen cyberscience. Citizen cyberscience includes providing computing power through the internet (volunteered computing), producing data with the help of mobile phone sensors (participatory sensing) or carrying out classification (volunteered thinking).

[14] https://ebird.org, last accessed: 13.12.2022
[15] https://www.zooniverse.org/, last accessed: 13.12.2022
[16] https://fold.it/, last accessed: 13.12.2022

Haklay uses the degree of citizen participation as classification logic. His typology covers citizen participation from providing data to carrying out independent research. At the most basic level citizens volunteer computing or sensing resources but do not contribute cognitive power (crowdsourcing). The next level invites volunteered thinking involving interpretation of data (distributed intelligence). This also encourages project organisers to provide basic training and support learning of volunteers. As a next step citizens are invited to define the problem and participate in data collection (participatory science). This is a model that is often used in community science projects that aim at environmental justice. Citizens who are affected by environmental issues ally with scientists who perform the analytic work to support credibility of results. At the last stage volunteers are involved in problem definition, data collection and analysis (extreme citizen science). This asks for an egalitarian engagement of citizens and scientists where project organisers take on a facilitation roles and also applies to amateur scientists who carry out independent research.

He suggests that participant benefits might increase when aiming at the highest level of participation suitable for a project but avoids a blind normative pledge towards extreme citizen science. He invites to consider multiple simultaneous levels of participation and mentions that participants might look for more engaged forms of contribution with increasing experience in projects.

Franzoni and Sauermann (2014) suggest a classification logic that they apply on two levels: first they differentiate between crowd science activities and other forms of scientific work and then they classify volunteer contributions. Instead of using a hierarchical structure they identify pairs of key characteristics which they use to construct a classification matrix.

They suggest openness of project participation and openness of intermediate results as defining characteristics of crowd science projects. This allows differentiation between traditional science which is restricted to professional scientists and discloses final results in papers with the hope to be the first to discover something new, science with sharing of some intermediate results (such as data or logs – sometimes required by funding schemes) and innovation contests or crowdsourcing with open participation but restricted results.

For the classification of contributions within citizen science Franzoni and Sauermann suggest the key characteristics of nature of the task and required expertise of contributors. For tasks they combine complexity and structure which creates an axis from interdependent subtasks that are ill-structured to independent subtasks which are well-structured. For expertise they choose common human skills, specialised human skills and domain-specific skills. More complex and ill-structured tasks correlate with a higher specialisation of required skills. They present three project examples to illustrate the heterogeneity of crowd science activities.

Their first project example is FoldIt which started as crowdsourcing project using spare computer resources to run a protein folding algorithm and showing the ongoing work as screensaver. Some participants realised that there might be better solutions which led to the development of a web-based game which later also included codified solution strategies by participants and led to several co-publications. Sub-problem solving in FoldIt shows moderate complexity with reasonably isolated sub-tasks which require specialized humans kills such as spatial imagination.

Next they present Galazy Zoo which is a spinoff of an earlier project Stardust@Home that invites participants to classify objects in satellite pictures. This resulted in new discoveries and publications and further projects were created on a common platform Zooniverse with Galaxy Zoo Quench inviting participants to engage in further scientific activities including analysing, discussing and publishing. Distributed coding in Galaxy Zoo consists of well-structured independent subtasks that require common human skills.

Finally they introduce Polymath which solves mathematical problems in moderated collaborative discussions. It was initiated by a top expert mathematician Timothy Gowers who was joined by university professors, PhD students and school teachers. The experiment was successful and led to a publication using a group pseudonym. The Polymath model was adopted by other mathematicians for additional challenges and inspired the question-answer platform mathoverflow. Collective problem-solving in Polymath deals with interdependent subtasks that are ill-structured and require expert skills.

Franzoni and Sauermann discuss potential benefits and challenges of crowd science projects and recommend supporting measures. Open participation helps achieving high numbers of inputs which works best for well-structured tasks that require common human skills. Broadcast search allows to identify contributors with rare skills, interests in niche topics or those with potential solutions for specific problems. Crowd science allows to build on human strengths such as intuition, narrowing solution spaces and watching out for the unexpected. It also increases the diversity of different types of knowledge and geographic coverage.

They suggest organising crowd science starts with matching projects and people. Platforms with multiple projects are presented as potential efficient means of aggregating information about projects and disseminating them to an interested crowd. De-coupling tasks whenever possible through modularization supports broader participation. Flexible approaches to leadership beyond scientific expertise include facilitation skills, using emerging skills within the crowd or guiding through infrastructure design. Open disclosure of intermediate results allows temporary engagement of contributors and documents the knowledge-making process along the way allowing deeper verification and spin-off work. Documentation also transports conventions of work and problem solving techniques.

Franzoni and Sauermann discuss motivation as essential for sustaining ongoing engagement which is a challenge of crowd science projects. Intrinsic motivation increases when tasks are considered as interesting, challenging or gamification is employed. The interest in the topic can be addressed by providing further background, sharing project findings or allowing to create personal collections. Personal interactions enable social benefit which is central in collaborative problem solving but can also be fostered by including facilitators or through digital infrastructures. Motivation is high if personal stakes are at play such in finding a cure for a disease. Participants also value contributing to science and progress.

They recommend to support a broader set of motivations to attract new types of contributors such as professional scientists and firms which requires rethinking existing compensation scheme. Payment for essential contributions and key contributors or contractual mechanisms such as assigning different rights to different contributor groups might be a way to balance these currently conflicting motivations. The authors illustrate this with examples such as inviting non-competing scientists to work with data and get authorship on publications and allowing companies to use data and algorithms in their commercial products.

Lin et al. (2016) further explore human factors of citizen scientists in weather data collection through two different projects in the UK: The Old Weather Project involves citizen scientists in transcribing historic weather records of naval vessels on the platform Zooniverse, whereas the Weather Observation Website invites public contributions of weather observations in various formats such as text notes, photographs or readings from private weather stations. It displays this information alongside other types of weather information such as social media postings and includes a forum to foster exchange between project participants. This shows that there are varied ways to work with citizen scientists within the same project and thematic area, allowing to involve different publics with different interest, skills and equipment.

At the same time Lin et al. show that while digital citizen science infrastructure offers a channel for altruistic sharing of data whether or not this gets used depends on the degree of interest for the central topic. For private weather station owners it is an opportunity to extend their enthusiasm for weather observations and working with respective instruments (e.g. mounting, re-calibrating, checking accuracy). For Rasperry Pi tinkerers running weather stations is more of a chance to enhance their technical problem-solving abilities, understanding how to work with sensors and their device rather than producing and sharing standardized weather data. Also this community does not seem to identify itself with the label citizen science. In both communities available time is flagged as challenging to ensure constantly consistent data quality or engagement in data sharing.

Lin et al. discusses that emotional and experiential aspects of doing citizen science are sometimes overlooked when aggregating and integrating additional data. They use the example of weather information from ship logbooks which started with UK ships that participants felt connected to and then switched to US logs which felt unfamiliar and remote for the citizen scientists. Similarly while different project on the same platform might have the same technical infrastructure they might establish different forms of sociality which might pose a personal challenge when switching between projects. Lin et al. encourage to understand citizen science beyond a simple technical scaling approach but as involving the perspective of the local values and practices of communities.

Kasperowski and Hillmann (2018) connect to this by looking at the interplay of recruiting values and volunteer practices within the project Galaxy Zoo. They analyse conversations between volunteers and project staff when encountering visual artefacts in pictures which are an anomaly in the picture but no astronomical phenomenon and therefore outside the project interest. They apply the concepts of epistemic subject to analyse where Galaxy Zoo locates knowledge-making by volunteers as well as program and anti-program to contrast the core project focus on classification from alternative engagements of volunteers. Their empirical material are forum conversations between volunteers and project staff which are enriched with interviews and participant observation at project staff meeting. They describe a tension between the individual and collective as well as contribution and discovery orientations when participating in Galaxy Zoo.

The researchers describe that Galaxy Zoo invites individuals to make small contributions by classifying objects in astronomical pictures. This is done following a standard protocol which aims to let the volunteers see like scientists. The project also asks several participants to classify the same picture which creates a collective level of contribution. It is at this collective level that contributions are presented as reaching reliable scientific quality. The standard threshold is described as 40 classifications but the actual number varies from project to project and can be found in publications. When contributions are mentioned in the paper there is a collective reference to the project volunteers with a link to the webpage where individual usernames are listed.

Kasperowski and Hillman mention that Galaxy Zoo promises the chance of discovery. At the collective level this is done through aggregating many small contributions and analysing them to reach larger insights. At the individual level it means that volunteers have the chance to see pictures that no one else has seen yet thus being able to discovers something new. This encourages volunteers to investigate things which do not fit the standard classification protocol. Dutch schoolteacher Hanny von Arkel is a celebrated volunteer who discovered a new phenomenon that is named after her and she was included as co-author in several papers.

The authors present a standard interaction around optical artefacts derived from their analysis of forum discussions. When volunteers encounter visual artefacts they mostly ask what it is that they found. In most cases moderators respond with the factual statement that it is an artefact and sometimes they resist to get into deeper discussions even when prompted by volunteers. Within the community some volunteers demonstrate deeper knowledge about the mechanics of the production of the pictures or additional expert tools that could be used for verification. Kasperowski and Hillmann mention that for many online citizen science projects education is not the core focus but rather a by-product which also contributes to an increasing quality of contributions. The design of tasks is kept rather simple so that volunteers can start right away without the need for many instructions or a steep learning curve.

The cases in the empirical material are mainly US based university-driven digital citizen science initiatives. The discussions on contributions are focussed on those of citizen scientists. Therefore I suggest to study initiatives from other regions which involve organisers outside academia with an interest in contributions of all actors participating in the project.

3 Case and research questions: digital citizen science by Spotteron

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SPOTTERON is a well-known commercial citizen science platform in Europe. SPOTTERON has coevolved with the Austrian citizen science community since 2014 and offers several packages of website and app development and hosting, together with optional add-ons that focus on community services, interactive maps, and data quality. Over the years, SPOTTERON has developed a whole ecosystem of apps and functions, which is strengthened by its business plan. In this plan, add-on functions financed by one project are made available for free to all other projects that use SPOTTERON. Furthermore, SPOTTERON offers the creation of image and event videos. Today SPOTTERON hosts a wide range of projects that, in addition to Austria, now also come from Australia, Switzerland, and Sweden.

(Liu et al., 2021)

As site for my own investigation I focus on the digital citizen science platform Spotteron which is developed by a small company in Vienna. Their core business is developing customized apps building on generic features implemented on their platform. They sell this to clients from science and civil society who run participatory projects in Europe and beyond. The name hints at the core functionality of these apps: reporting observations with geo-locations, so called spots. It also connects with the figure of the spotter, the activity of spotting (e.g. trains, storms) and as a wordplay with the phrase “spot on”.

The initial idea behind Spotteron was a standalone app to remove litter in Nature. This was triggered by a personal experience in 2013. They found litter in nature but did not know where to report this. The idea was to develop an app that allows to document the littering with a picture, classify the type of litter, capture the location and report the sighting to the relevant authorities. At first this project was not realised because Spotteron could not find a partner to run the project.

The idea to establish a platform for citizen science apps came when reading about a university project that allows to report animals which are killed in traffic. Spotteron realised that the abstract functionality needed is more or less identical to what they had in mind for reporting litter: picture, location, classification. The project already had a basic website and some data but decided to launch a mobile app with Spotteron in 2015.

Spotteron work with a broad variety of partners. The first non-academic partners joined soon afterwards with an app for phenological research, i.e. studying climate change through comparing the flowering cycles of plants over the years. This started as a closed school project and was later opened for the general public and launched with several apps for different provinces. The litter reporting app was eventually launched in 2016 with an environmental protection partner. There are a few projects with a focus on social rather than natural issues.

In 2017 Spotteron introduced its social media approach. The aim is to create communities around the topics on the platform to increase motivation and quality of observations. As Spotteron puts a strong focus on protecting participants they did not integrate an external social media platform which collects user data but re-implemented a follower social network approach.

Spotteron maintain an extensive website which is available in German and English. The items appearing most often on the startpage are features, price and contact. This supports the overall impression that the website aims to attract new partners globally for commercial collaboration.

Spotteron also participate in international citizen science initiatives. On the national level they are connected to central actors in the area of citizen science such as the University of Natural Resources and Life Sciences Vienna for which they run the platform Österreich forscht! The platform leaders are engaged in discussions around standardization of citizen science and promotion of the platform (e.g. (Heigl & Dörler, 2017), (Eitzel et al., 2017), (Heigl et al., 2019a; Auerbach et al., 2019; Heigl et al., 2019b), (Heigl et al., 2020), (Liu et al., 2021), (Haklay et al., 2021)). Spotteron demonstrate their individual competence by participating in workshops, conferences and collaborating on books and articles (e.g. (Hummer & Niedermeyer, 2018), (Lemmens et al., 2021), (Ruefenacht et al., 2021))

In Europe (e.g. Science with and for Society[17]) and Austria (e.g. Top citizen science[18], Sparkling Science[19]) citizen science activities have also received dedicated funding.

My informant, the lead designer of Spotteron, expresses a strong and long-term personal attachment to nature and science and sees citizen science as a way for people to learn and thereby connect deeper to their environment. He identifies as citizen scientist and designer rather than businessman or scientist. Therefore some of the activities Spotteron carry out are pro-bono and they claim to use a flexible approach in their collaboration. Even though they provide fixed-price projects they aim to deliver what projects need as long as it is manageable in the suggested timeframe.

The platform approach which allows to serve a broad customer base and the strong connection to central actors in citizen science in several countries make studying what kind of citizen science Spotteron promote a case relevant beyond national boundaries.

[17] https://data.europa.eu/doi/10.2777/32018, last accessed: 14.12.2022
[18] https://www.fwf.ac.at/de/forschungsfoerderung/fwf-programme/foerderinitiative-top-citizen-science, last accessed: 14.12.2022
[19] https://www.sparklingscience.at/, last accessed: 14.12.2022

Spotteron promote their services through different channels such as youtube, Twitter, Instagram, their blog and webpage. I analyse the English version of the Spotteron webpage as basis to answer the following main research question:

How does Spotteron present citizen science through texts on their webpage?

In order to explore this broader question I suggest to investigate the following aspects:

How does Spotteron imagine

- *the main collaborators and*
- *their contributions*

when building their digital citizen science infrastructure?

The first part highlights that my research starts with the Spotteron perspective, the bullet points put a focus on human actors and their activities and the final part introduces the notion of infrastructure which I introduce in the next chapter and use a conceptual frame for looking at my empirical material.

4 Sensitizing concept: Digital infrastructures

The concept of infrastructure allows to study how citizen science as practice and digital platforms as technologies interact. Infrastructures are a well-established concept in STS going back to the study of built infrastructures and even before that as illustrated in the current STS handbook (Slota & Bowker, 2017). More recently interest on digital infrastructures is documented through the Fieldguide to digital STS (Vertesi, 2019).

The first section of this thesis chapter identifies conceptual work around early internet-based science collaborations from the late 90ies appearing under the label information infrastructures as relevant starting point. This includes methodological hints on how to study infrastructures.

Making knowledge through distributed thinking is central to digital citizen science platforms. Therefore I present empirical material on how infrastructures support knowledge-making, an area with ongoing engagement of scholars as the 2016 special issue on knowledge infrastructures in the journal *Science and Technology Studies* with four issues and fourteen papers demonstrates (Karasti et al., 2016), and on thinking infrastructures (Kornberger et al., 2019) which suggests studying how infrastructures shape our perception. As the empirical material deals with digital infrastructures more broadly I describe potential links to my focus on digital citizen science platforms.

The second section of this thesis chapter moves from the general notion of digital infrastructure towards concepts which are used as layers within my own empirical material. This includes literature which connects infrastructure, platforms and apps. A special issue on apps and infrastructure in the Journal *Computational Culture* (Gerlitz, Helmond, Nieborg, et al., 2019) demonstrates timely interest in this field. Since social media represents a popular approach to establish a community within digital citizen science platforms I also introduce work around the type of sociality supported by social media features.

4.1 Infrastructuring information, knowledge and thinking

Much of the STS work on digital infrastructures builds on the conceptual basis established by Star and Ruhleder (1996) who studied the relationship between large-scale information systems and organisational change. They illustrate their notion of infrastructure by using examples of built infrastructures such as roads or waterpipes. An infrastructure thus is something that provides the base for an activity to happen. Cars travel on roads, water flows in pipes. It is however not a fixed concept but relates work practices and technology. While the cook needs water for their activities and therefore uses the infrastructure of pipes, for the plumber it does not offer infrastructural support but is the target of work. In that sense infrastructures are built to support other activities, resting patiently in the background until they are used.

Star and Ruhleder suggest that infrastructures share the following dimensions: embeddedness, transparency, reach or scope, learned as part of membership, links to conventions of practice, embodiments of standards, built on an installed base and becomes visible upon breakdown. I illustrate these dimensions with examples from digital citizen science which I understand as infrastructuring in the sense of co-producing knowledge production and digital technology (Table 1).

DIMENSIONS OF INSTRASTRUCTURES (STAR & RUHLEDER, 1996)	APPLICATION TO DIGITAL CITIZEN SCIENCE
EMBEDDEDNESS	+in activities e.g. collection or classification +using existing technologies e.g. web +using existing devices e.g. smartphones
TRANSPARENCY	+guiding users through workflows with Graphical User Interfaces +invisibly supporting tasks in the background e.g. data storage, creating notifications
REACH OR SCOPE	+beyond single user +beyond single sites (e.g. observations) +beyond single projects (e.g. platforms)
LEARNED AS PART OF MEMBERSHIP	+within a particular (virtual) community +user support
LINKS WITH CONVENTIONS OF PRACTICE	+"scientific" protocols for data collection or classification +demonstrations, tutorials, trainings +feedback channels
EMBODIMENTS OF STANDARDS	+connecting to external services e.g. open street maps +providing access through Application Programming Interfaces (APIs)
BUILT ON AN INSTALLED BASE	+citizen scientists +smartphone platforms +mobile networks
BECOMES VISIBLE UPON BREAKDOWN	+offline use +compatibility with devices and technologies

Table 1 illustrating infrastructural dimensions for digital citizen science

Star and Ruhleder (1996) suggest that in order for infrastructure to work the global and local level need to be aligned e.g. local practices are transparently supported by global technology. Bowker et al.

(2009) call to explicitly consider the distinction between technical and social solutions. In order to reach a match between technology and practices either of them could be adjusted.

In their work Bowker et al. focus on the influence of the internet on the nature and production of knowledge. They identify historical trends which support the rise of information infrastructures such as state statistics, knowledge workers and other practices and technologies that support dealing with large amounts of data which spread into work and broader society. Bowker et al. mention two examples of early digital science infrastructures: databases that built on the interest of the social sciences to quantitatively study society and of the natural science to create repositories, and electronic journals.

They consider infrastructure as public good with long-term orientation. Infrastructure includes technologies and organisations which create a network of resources for knowledge work. This view includes individuals such as designers, developers and users.

Bowker et al. suggest to study the social, valuation and ontological dimension of infrastructures. The social dimension includes mediation work that is necessary to align all elements of the infrastructure such as system, organisation and people. Infrastructure building is a continuous effort that simultaneously builds communities and systems. It needs to consider varying degrees of readiness of participants. Infrastructures require new roles some of which support participation, others perform invisible maintenance. Infrastructures which support long-term research need to align with different temporalities of funding and career schemes. The valuation perspective considers that it is essential who is involved in system design since the values become embedded in infrastructures. Dominant views might be reinforced, alternatives not included e.g. when developing classification schemes. The ontological dimension addresses that infrastructure needs to align with practices of knowledge workers in order to be accepted. Therefore it becomes important to understand current institutions and study the changes which are introduced through information infrastructures.

Studying infrastructures in practice requires focusing on relations between digital and human activities thereby bringing infrastructures back to the foreground which Bowker (1994) calls infrastructural inversion. Star (1999) describes common challenges and potential solutions in studying digital infrastructures ethnographically. Traditional ethnographic involves observing actors and their activities at a particular site. Digital infrastructures however involve multiple sites, large volumes of data and observing online traces rather than offline activities. This thus requires new approaches which are also relevant for citizen science.

Star suggests to look at the rhetoric level e.g. how the infrastructure is described by the designers, how they describe the actors involved and which aspects are not mentioned. This might include invisible work that is necessary to make the system work but which is not framed as essential contributions.

Star mentions that there are different ways to think about the alignment of digital and human practices. Infrastructure can be seen as an accurate representation of human activities, collection of digital traces about human activities, or artefact that has an impact on human activities. Star recommends that researchers are reflexive about which of these positions they use in their research. For my empirical work on digital citizen science I consider that digital tools do not work seamlessly in the real world. Therefore it becomes interesting to investigate how participants align digital with human practices. I will now illustrate with empirical work how practices and infrastructures co-evolve.

Star and Ruhleder's (1996) early work is based on ethnography with observations and interviews on multiple sites of a large-scale information infrastructure aiming to support a geographically dispersed community of biologists who study genetics of a worm and use it as model organisms to support the Human Genome Initiative.

They discuss conflicts arising while building the infrastructure related to and happening between different levels of context such as resources, coordination or politics. Star and Ruhleder suggest multidisciplinary development teams as potential solution, enabling mutual learning between users and designers such as to better align work practices and infrastructure design and providing technical user education in relevant contextual settings. They stress these kinds of collaboration also need new reward mechanisms.

Some of their findings are also relevant for digital citizen science such as considering differences between participants concerning technical knowledge, work rhythms, and motivations for participation.

Work rhythms and motivations also play a central work when Karasti et al. (2010) show that groups who build infrastructures align their work towards different timeframes. The researchers use their longitudinal involvement in a long-term ecological information infrastructure to study long-term orientations related to developing standards of developers from a national centre and site-based information managers. The first versions of the standard were established by developers at the central site as part of funded project work. The information managers then took this work up and amended the standard so that it could support their work practices and allowed for further evolutions.

Karasti et al. use the example of documenting standard units for observations to illustrate the different approaches. Project managers defined standard physical units (such as second, meter) but since ecological research mainly uses special units (such as EggsPerNest) they included custom units as open category. Information managers then developed a dictionary to collect all custom units in use at individual sites and a registry to promote best practices as overarching standard. This difference shows the tension between global domain-wide standards suggested by developers and local standards which accommodate site-specific approaches used by information managers.

Considering the temporal orientation they suggest that developers are working within project time, while information managers consider infrastructure time. The difference in the temporal orientation also became visible in the initial standard development where developers openly invited information managers to contribute. However the fast-paced rhythms of project work did not allow information managers to participate in practice.

For developers they suggest it is central to get deliverables done before their funded project ends to secure additional funding. They prefer developing cutting edge solutions and global solutions. This results in planning how to get from the present to the future with a short-time focus on tasks and a long-term perspective on project duration which is a few years.

They describe that information managers also aim at resolutions for their daily work e.g. introducing a dictionary which aligns with their current practices. In addition information managers consider the past legacy of their work when thinking about the future. Thus their focus is on sustainable solutions. For this they apply a continuing design strategy which allows to keep the system running but also evolve over time e.g. through defining global standards in their registry. Their long-term perspectives include decades of the lifetime of the infrastructure as well as several hundred years for experiments within their domain.

For digital citizen science infrastructure this encourages to look at how different temporal orientations of collaborators are supported by the infrastructure.

Jalbert (2016) encourages us to look beyond the digital infrastructure that supports knowledge creation on how different forms of organisation distribute power between participants. He presents two contrasting cases for water monitoring infrastructures. The NY Water Sentinels (NYS), *"a grassroots coalition of advocacy groups"* and the Three Rivers QUEST (3RQ) *"a large network managed by academic institutions"* (p. 26).

He notices that democratic governance and de-central empowerment can enable shifts in the focus of certain involved groups. In the case of NYS they started out with a focus on base-line data which was deemed "science at the local level". Over time this was rivalled with work perceived more political and activist-oriented such as landfill monitoring. While this shows autonomy within the network it also risks diffusing scarce resources and weakening focus. The issue of resources also played out in another shift of power. When NYS lost one of its main funding stream they decided to become an official part of the Sierra club. However integrating NYS into the larger organisational network also meant that additional reporting requirements, financial rules etc. influenced the flexibility of individual groups within the volunteer network.

Jalbert notices that 3RQ was set up differently from the beginning with three universities provided with funding to organize monitoring of their local river system within a common infrastructure. These universities also offered mini-grants to selected local monitoring organisations. Their dominant position meant that other partners who did not received funding were pressured to contribute data while they did not receive the same level of empowerment or appreciation. Contributions were put into different tiers reflecting the affiliation with the monitoring scheme. Also the focus on research did not reflect the agenda of some of the contributors who were more interested in local activism. As a response the tier scheme was changed to reflect the data collection methodology and not the affiliation with the monitoring program and separate funding and staff were introduced to work more closely together with local water monitoring organisations.

This research sensitizes us to different power structures fostered by organisational arrangements but also reminds us that knowledge infrastructures, and the relations between the technical, social, epistemological components they include, are not stable and can also be challenged and resisted. *"[I]t important to not only evaluate how [knowledge infrastructures] emerge, but also how power plays out in their emergence. What one finds is that [knowledge infrastructures], even when seemingly stable in their leadership and intended purpose, are indeed dynamic spaces where relationships of power are rarely settled."* (p. 39).

For digital citizen science this could hint at including flexible participation opportunities which provide space for growing engagement of interested citizens.

Infrastructure studies are also interested in the values that get embedded through design decisions. A prominent focus is standardization which can happen at different levels. Goëta and Davies (2016) show how seemingly technical open data standards affect access for particular user groups. While their work focusses on open government data aiming for greater state-transparency some of the sensitivities are also useful when looking at the relations between citizen, scientists and open data. Goëta and Davies look at three different standards: Comma-separated value (csv) as general purpose format operating only at the structure of the files and two domain-specific standards which specify potential data fields to be shared; one of them strictly defined and based on csv, the other one flexibly extensible using xml.

Goëta and Davies highlight that the adoption of a standard is sometimes already taken as quality criterion of a dataset although it does not necessarily say a lot about the content in the dataset itself. They illustrate efforts needed to implement open data standards by those who produce data and those who are responsible to provide it openly. Goëta and Davies claim that open data standards often aim for machine-readable data which makes that data tailored towards advanced users (i.e. with a high degree of technological competence) which excludes large parts of the population as direct users: *"developers who can reuse the data to create services, advanced users who can open the dataset and do basic analysis and the general public who are expected to benefit from the opening of data only via intermediaries"* (p.25).

This can be a critical issue for those citizen science projects who aim for citizens to be able to work with the data they have produced. Goëta and Davies include practical examples such as publishing data in multiple formats suitable for different user groups or providing specific tools such as visualizations or maps to work with the data to overcome those barriers.

Regarding maps Shavit and Silver (2016) show that geographical standards affect data collection practices and convey a particular understanding of the environment. They analyse how different conceptualizations of space were rivalling with each other during integrating observations into two different ecological knowledge infrastructures. They differentiate between *exogenous* and *interactional* space. Exogenous space focusses on representative and generalizable data. Therefore it standardizes space without regarding the objects of observations. One example would be to define regular squares within a grid defined by latitude and longitude. Interactional space defines space that is related to the interaction of the observed object with its environment e.g. defining territories around animals or plants.

Shavit and Silver argue that the current dominance of exogenous space in digital infrastructures needs to be balanced by more interactionist approaches. Furthermore, their empirical work suggests that the flexibility of interactionist representations of space might be more supportive of citizen science engagement.

These examples of empirical work demonstrate that the interactions which happen on infrastructures are shaped by many things such as temporal orientations of actors, organisational structures and standards. Next we zoom in on different layers of platforms with a particular focus on social media.

4.2 Platform, Apps and Social Media

Moving from infrastructure towards platforms Plantin et al. (2018) suggest to combine a focus on infrastructural and platform aspects of current digital tools. Specifically they recommend to combine the infrastructural perspective of how large systems develop over time with a platform focus on how this is connected to enabling specific forms of expression.

> *"[…] infrastructure studies provides a valuable approach to the evolution of shared, widely accessible systems and services of the type often provided or regulated by governments in the public interest. On the other hand, platform studies captures how communication and expression are both enabled and constrained by new digital systems and new media. In these environments, platform-based services acquire characteristics of infrastructure, while both new and existing infrastructures are built or reorganized on the logic of platforms." (p. 293)*

Plantin et al. also suggest that infrastructures and platforms aspects merge when services and technologies with public value are driven by commercial actors. With respect to digital citizen science this might relate to framings of democratizing science on a commercial platform.

They recommend including platform aspects such as "*programmability, affordances and constraints, connection of heterogeneous actors, and accessibility of data and logic through application programming interfaces (APIs)"* (p. 294). This approach integrates management and organisation studies about negotiating modularity and power in systems with a stable core which is extended through interfaces with highly variable components. It also draws on media studies around participatory media practices of Web 2.0 that focus on connection, programmability and data exchange in the production and remix of content within the affordances of platforms that are also influenced by technical, social and economic concerns.

Plantin et al. mention that platforms offer standardized interfaces which is convenient for users. With their ecological structure they might also integrate external tools such as maps for spatial representation. Collaborators can build on the platform code base, audience and marketing power of platforms. This comes at the price of increased lock-in that binds to designer conceptions of users and functionality, constant updates and reduced interoperability.

Looking at the relationship between platforms and apps often favours the power of platforms (such as app stores, development tools or mobile phones and their operating systems) as providing certain services that can be used in apps. This is also implicit when Gerlitz, Helmond, Nieborg et al. (2019) suggest potential analytical entry points: the physical level e.g. of sensors of smartphones, the (operating) system, the static code and the dynamic runtime level, the network level, the package level of app stores which also links to development tools and guidelines, and the level of in-app services such as authentication, monetisation, advertising, content-delivery and tracking. As focus for further research they suggest to *"attend to the technical and material dimensions of apps and infrastructures as well as the practices they support [and] refuse to simply 'follow' the app, the company, or the user; rather [being] attentive to imaginaries, intermediaries, the redistribution of value and economic power, the evolving relationship between user and data practices, the heterogeneity of data forms and formats, and [advancing] research practices and materials."*(p. n.a.)

Gerlitz, Helmond, van der Vlist et al. (2019) demonstrate that apps also have power to influence platforms. They investigate how app features influence social media platform practices. Their empirical work includes analysing descriptions and code of apps related to major social media platforms which they identified through semi-automated qualitative and quantitative approaches in the app stores.

Their findings include five types of changes in platform practices initiated by app features. *Intensification* follows the existing platform logic e.g. improving visual content before posting, adding inspirational quotes to posts or improving strategic audience engagement. *Reduction* means considering infrastructural limitations e.g. providing alternative clients which work well on weaker systems. Some platforms have taken this up and provide their own lite clients. Since the functionality is already adopted by parts of the users community this step is less risky than introducing a new functionality from scratch. *Revival* means bringing back discontinued features such as Twitters favourite icon instead of the new like symbol or integrating messenger back into Facebook apps. These approaches might challenge strategic platform decisions and might also introduce incompatible meanings of platform practices. *Instruction* might support learning about advanced features such as using special cameras or lenses or growing audiences but also include more mundane guidance such as explaining the basic snapchat interface, challenging the intuitiveness of its design. The last category is *transformation* which includes workaround through combining existing functionality. One example is enabling editing existing Twitter posts through combining deleting and creating a new post. This category includes a small fraction of apps which include new features such as downloading and saving content or repurposing existing functionality such as introducing dating practices by matching profile pictures or introducing a gender based username search. Some apps work alongside the official apps sharing content with it through system functions. Gerlitz et al. conclude that their work demonstrates ways of changing platform practices beyond using APIs and some of the changed practices might not align with existing framings or interests of the platform.

Staying with social media infrastructures Alaimo & Kallinikos (2019) describe how they infrastructure sociality. They state that humans engage in forms of sociality such as assuming an appropriate role or identifying with groups by making sense of social situations through multiple contextual scripts. They then argue that in social media logic social context is eliminated since scripts are substituted by user models, actions by data traces triggered by strictly governed interactions such as following, liking, tagging or commenting. It is not the content that is transported in the interaction but the encoded social data that is valuable for the platform operators. Alaimo and Kallinikos thus point to the instrumental logic of this engineering approach aiming at the economic benefit of platform providers. Forms of sociality such as similar users or recommended items are computed through aggregations, fed back to users to foster additional interactions and constantly refined through automated learning loops. Social media computations follow a flat ontology logic which does not differentiate between people, groups and other objects as all of them are aggregated data traces.

Gerlitz and Helmond (2013) illustrate these dynamics with the specific example of Facebook likes which they describe as valuable user activity that creates alternative relations between different pieces of content. They suggest that Facebook aims to spread its platform logics through external components such as the like button which integrates external content into the platform. This content is then shared within the social media network to encourage additional reactions in pre-defined formats such as liking and establishing relations between users and content. Gerlitz and Helmond suggest this as successor of a hit and link economy which calculated the value of content by number of user visits displayed on webpage counters and links that webmasters create between websites.

I suggest that for citizen science that employs social media logics a critical reflection on the different types of interactions is necessary. If likes are the only option the focus on positivity and network effects might hinder critical thinking and discussion which are part of validation in scientific work. Further investigation on how conceptions that are part of the social media work out in the area of digital citizen science are necessary.

Rather than looking at the technical affordances of platforms and apps Gillespie (2010) suggest to look at the discursive work of online content providers related to employing the term *platform* with various meaning.

> *" [...] 'platform' merely helps reveal the position that these intermediaries are trying to establish and the difficulty of doing so. YouTube must present its service not only to its users, but to advertisers, to major media producers it hopes to have as partners and to policymakers. The term 'platform' helps reveal how YouTube and others stage themselves for these constituencies, allowing them to make a broadly progressive sales pitch while also eliding the tensions inherent in their service: between user-generated and commercially-produced content, between cultivating community and serving up advertising, between intervening in the delivery of content and remaining neutral." (p. 348)*

Similarly some digital citizen science tools work with online content and describe themselves as platforms. Therefore I rephrase the above paragraph for such digital citizen science platforms:

[Digital citizen science platform providers] must present its service not only to [citizens], but to [organizers of citizen science projects such as universities and NGOs] it hopes to have as partners and to policymakers. The term 'platform' helps reveal how [digital citizen science platform providers] stage themselves for these constituencies, allowing them to make a broadly progressive sales pitch while also eliding the tensions inherent in their service: between [content generated by different communities and projects], between cultivating community and serving up [scientists], between intervening in the delivery of content and remaining neutral.

Starting from a dictionary definition Gillespie suggests that the term platform is used in four different ways: computational, architectural, figurative and political. The computational meaning of platform highlights the technical infrastructure support for designing and using applications. The architectural one refers to the physical features as flat surface while the figurative use highlights the open potential that this neutral stage offers and the political one refers to supporting particular positions. Gillespie also suggests that all these variations include ideological features of "being raised, level and accessible" (p. 350) which he connects to the rhetoric of the democratizing potential of the internet that also fits user-generated content and amateur expertise which connect to citizen science.

Gillespie describes that platform providers aim for a regulations that allow them to act as freely as possible while protecting them for liability so that they appear to support public interest. Their rhetoric is carefully chosen *"not only to sell, convince, persuade, protect, triumph or condemn, but to make claims about what these technologies are and are not, and what should and should not be expected of them. In other words, they represent an attempt to establish the very criteria by which these technologies will be judged, built directly into the terms by which we know them."* (p. 359)

For digital citizen science platforms this invites analysing communication of platform providers towards different constituencies. This is exactly what I do in my empirical work which I carry out according to the method described in the next chapter.

5 Method: analysing citizen science through webpage texts

This chapter presents my analytic approach in three sections. In the first section I refer to the methods used for the empirical work in this thesis including classical qualitative methods such as document analysis, interviews and autoethnography but also involving creative and quantitative experiments and I list my empirical material which is website text and interview transcripts. In the second section I introduce my main empirical material which is the Spotteron product webpage in order to provide further context for my empirical findings. The last section reflects on my personal process of doing research illustrating some of the messy issues that need to be dealt with before coming up with shiny final results. Returning to the beginning one of the important steps is to choose a site for investigation.

5.1 Analytic approach: integrating traditional, digital and creative approaches

I took the Spotteron webpage texts as the central focus of my empirical work. After capturing a static snapshot of the webpage texts (for more details see 5.3.1) I used thematic analysis (Braun & Clarke, 2006) to document how people who are described as interacting with the platform ensure that the platform and citizen science project work.

I started by coding active verbs which mark specific contributions. At a later stage I included contributions that were not directly mentioned but included in passive formulations or otherwise indicated.

As a next step I looked to whom these activities are assigned. This helped me identify the main social actors Spotteron, partners, citizen scientists and ways they are addressed in the text with alternative labels (e.g. users). While some of the contributions were clearly attributed it also became clear that some contributions involve collaboration between multiple actors.

To better grasp the broader context beyond main social actors I employed a text frequency analysis with a focus on nouns (for more details see 5.3.2) on the text corpus. Looking at nouns this identified additional elements which I clustered into infrastructural, organisational and legal issues.

I used visualisations as thinking tools trying to depict structures that are described in the texts. In addition to tables I produced illustration for the empirical part which show the different levels of the infrastructure and actors around them and I generated graphical analytical tools like collaboration (Figure 30) and involvement profiles (Figure 31) which aim to be useful beyond this case (7.2). For all graphical elements I applied a consistent colour coding scheme: Spotteron and their platform are presented in dark blue, partners and their apps in light blue, observations in yellow and social (media) interactions in green. For features, users and citizen scientists the colour varies depending on their contribution or association with a particular infrastructure level (Figure 1).

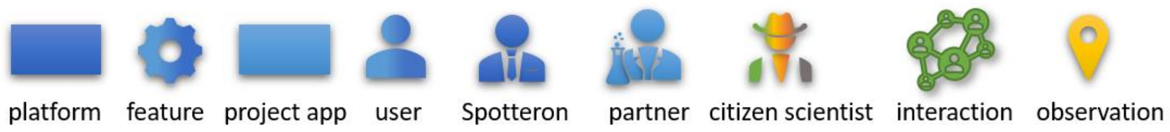


Figure 1 visualizing contributors and infrastructure

In order to include a practical perspective I also carried out auto-ethnographic experiments using a Spotteron app and exploring the related open dataset (6.4.2).

I carried out two semi-structured interviews (Silverman, 1993) with one individual from the Spotteron core team to reduce potential researcher bias and ensure a higher validity of results. Both interviews were carried out in a neutral meeting place and fully transcribed. The first interview was before my analysis so that Spotteron can present their approach to me with a rather fresh mind. This interview was coded in the same manner as the webpage. The second interview offered Spotteron an opportunity to comment on my preliminary findings. This also included interactive experiments. I presented an alphabetic list of most often used nouns as stimulus material to my interview partner and asked for selecting and explaining the most relevant words which are relevant for successful Spotteron projects. I also used visual tools I developed as part of my empirical work and asked my interview to draw their version of involvement of different contributors throughout the phases, explain the results and then contrast it with my version to support reaching mutual understanding.

Table 2 gives an overview of the different texts used in my empirical work. It quantifies the substance of the webpage and also shows that interviews produced material of comparable scope. For quotes of empirical material in this thesis [I1] and [I2] are used as reference for interviews and for webpage quotes the related section is indicated (e.g. [About > How it works]).

SOURCE	DATE	LOCATION	DURATION	TEXT	FOCUS
INTERVIEW1 [I1]	2019/01/29	Café	2:12	133673 characters (incl. spaces and timestamps), **23273 words**	organisation, concept and approach
INTERVIEW2 [I2]	2020/02/11	Café	3:17	151541 characters (incl. spaces and timestamps),	validation of findings

				27329 words	
WEBPAGE [SECTION]	2019/04/19 + update check from 2019/06/15	Web	-	138067 characters (incl. spaces), **21720 words**	text analysis

Table 2 texts used as empirical material

The next section presents my main empirical material, the webpage, in more detail.

5.2 Making sense of the website

There are many potential ways to get in touch with Spotteron ideas. They write publications, create promotion material and they publish on social media, their blog and a product website. I choose the Spotteron webpage[20] as the centrepiece of my analysis which means working with text that is publicly available, can be obtained without researcher intervention and has performative effects on reality as well as provides rich content for in-depth qualitative analysis (Silverman, 2014).

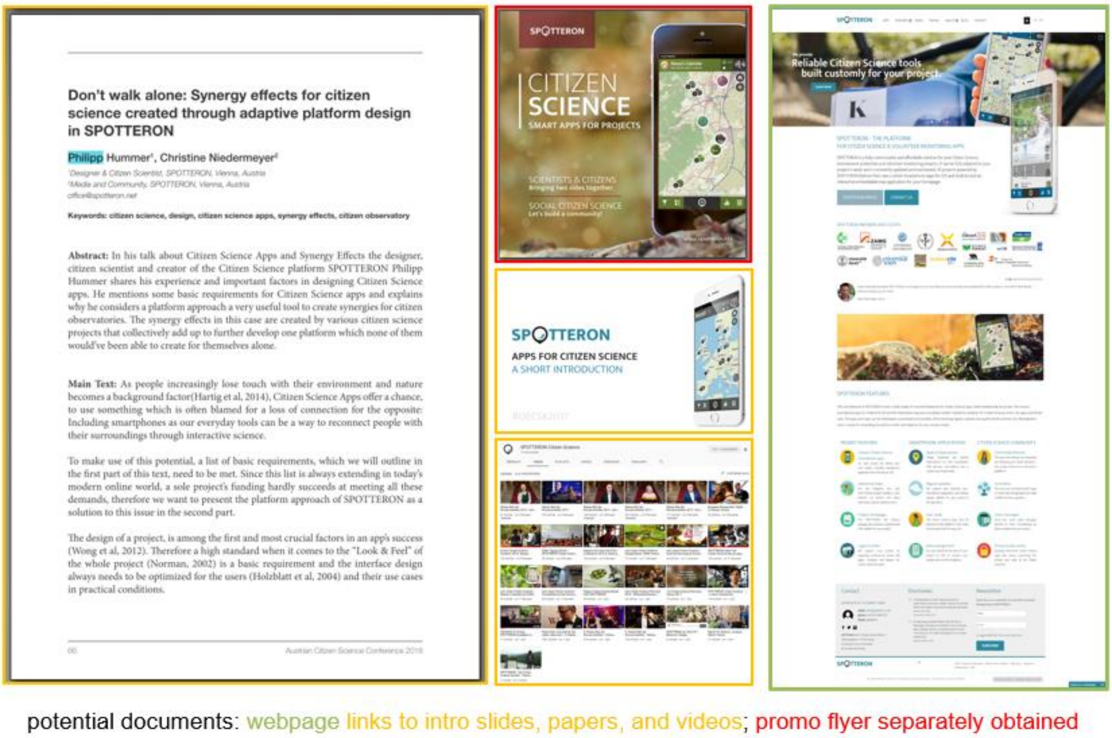


Figure 2 choosing the website as central empirical focus

The Spotteron webpage contains extensive material about the platform, positioning it at aiming to support partners interested in science, environment or social topics to create customized apps for

[20] www.spotteron.net, last accessed: 13.12.2022

digital participation. They describe generic features such as submitting observations, connecting citizen scientists with social media functions and broadcasting messages to all citizen scientists in individual projects through push messages. These features are customized for individual projects regarding graphical design, data capturing dialogues and potentially developing new functionalities. Spotteron presents this out-of-the-box approach as efficient and transparent with fixed package prices.

5.2.1 Structure

Even though the analytic approach in this thesis is on text rather than visual analysis it is important to understand the structure of the webpage in order to identify the prominence of certain elements. I focused my structural analysis on the landing page as this is the main entry point into the webpage and thus aims to present and link to most important items. This page features a header menu for main navigation and a footer section which presents contact information and updates and includes links to legal and technical information around the platform which is a common approach for most pages of the Spotteron web presence. Specific elements of the landing page are a slider gallery which transports key messages and links to related pages. Below it is a short intro with unique text describing the Spotteron platform which is followed by buttons linking to price and contact information. The next block presents logos of key partners followed by a testimonial slider. Next comes a picture slider with impressions of the app (smartphone or computer outdoors) which is followed by overview content related to Spotteron features (Figure 3).

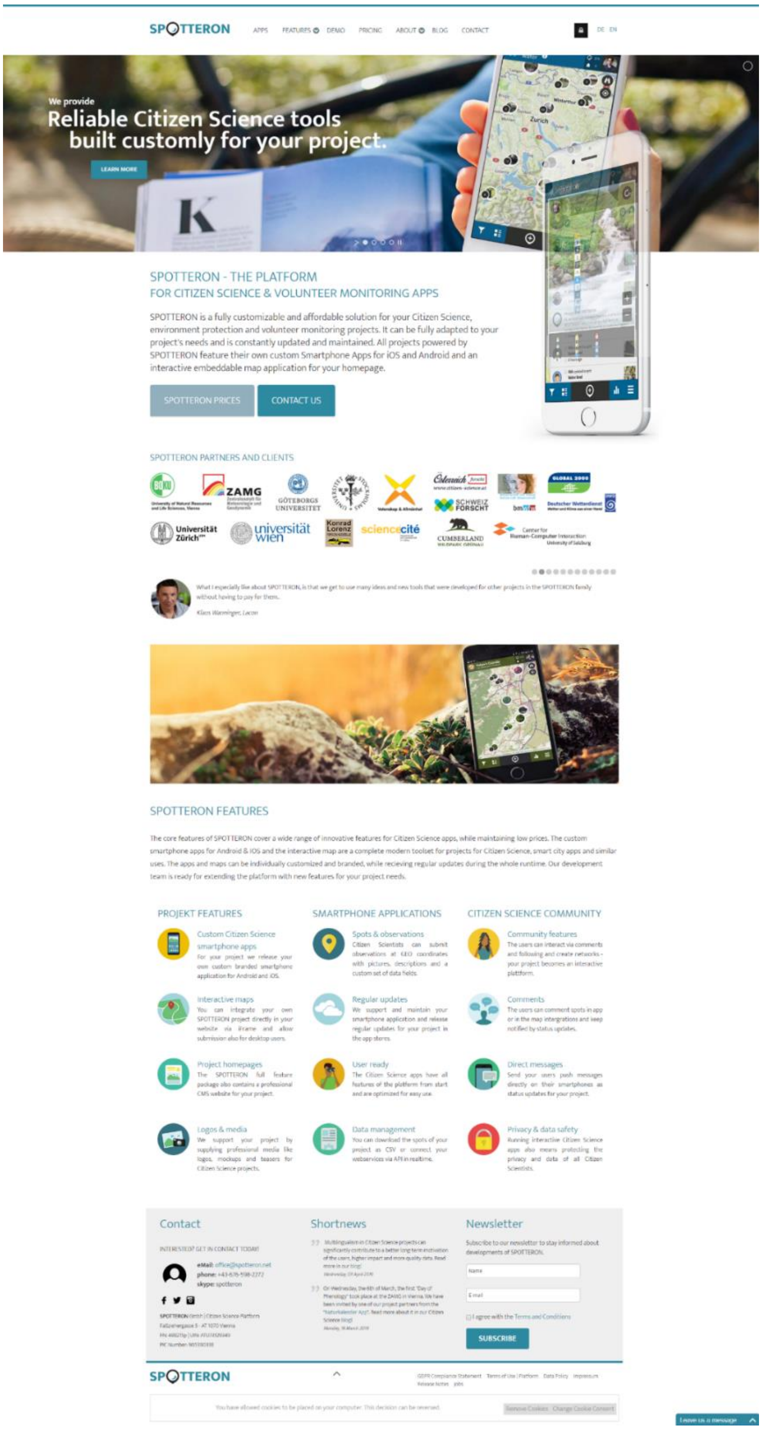


Figure 3 Spotteron landing page

The main navigation section *Apps* shows the spectrum of projects which use Spotteron, *Features* are presented as a way to support these endeavours, *Prices* as adjusted to project needs, *About* presents Spotteron, the respective partners and the impact through papers and publications.

Assuming that the more often certain elements are referenced on the landing page hints at their overall importance I looked which sections are referenced either through links or included directly as content. I went through the blocks from top to bottom and checked which sections are referenced. I consolidated sub-feature sections with the main feature section (indicated by asterix) and included the footer items contact and shortnews as content, as these are not links but direct content (using brackets for both special cases) (Table 3).

ELEMENT	MENU	SLIDER	BUTTON	CONTENT	FOOTER
APPS	+				
FEATURES	**+**	**(+)**		**+**	
*CUSTOM SMARTPHONE APPS		+			
*COMMUNITY FEATURES		+			
DEMO	+				
PRICE	**+**	**+**	**+**		
ABOUT	+				
BLOG	+				
(INTRO)				+	
CONTACT	**+**		**+**	**(+)**	**+**
FORUM	+				
LANGUAGE	+				
PARTNERS		+		+	
TESTIMONIALS				+	
SHORTNEWS				(+)	+
NEWSLETTER					+
GDPR STATEMENT					+
TERMS OF USE					+
DATA POLICY					+
IMPRESSUM					+
RELEASE NOTES					+
JOBS					+

Table 3 website element analysis (most prominent elements bold)

What this analysis suggests is that the sections *Contact*, *Price* and *Features* appear most prominently on the landing page and are thus considered key content within the overall set of pages.

One limit of this quantitative focus is its strict focus on the landing page. With this it does not cover further strategies used on the Spotteron website to present important messages to the readers. One example are repetitions. Sometimes whole sections are repeated in different places with no or only slight variations. These broader level repetitions are not the core of this thesis as they do not contribute to answering the research questions. They are partly considered through an analysis of most frequent nouns (5.3.2). The centre of gravity of the analytic work is qualitative analysis of the overall content in relation to the research questions.

5.2.2 Perspective

Most sections are written from the perspective of Spotteron. The author of the texts is hidden, appearing as anonymous narrator. This indirect voice provides a distanced stance which enables projecting objectivity into the promotional texts. This position is consistently used, even for pages which could address partners using a personal and direct voice such as *Contact*, *Team* or *Blog*. When addressing actors, they are mostly aggregated into organisations or groups of people. Although framed and curated by Spotteron, the *Testimonial* section is an exception to all this, including individual partners and their voices.

A very high-level abstraction of distribution of responsibilities may be read as: “We”, Spotteron, maintain a platform with generic functionalities. “You”, partners, get customized mobile phone apps to run you citizen science project. “They”, users, submit observations and exchange via social media functions. The interview roughly confirms this as rough split of work with a stronger emphasis on the scientific and organisational work of partners and hinting at additional nuances which are explored in the empirical part of this thesis.

> *“[..]when considered very roughly and very blurry, then we provide the tool and the functionality and the service, as mentioned before. The university creates the environment for the project, so: what kind of questions are asked, what should the outputs be etc. And also for example the work with the public in this case. The dissemination most of the part. And the citizens provide the activity, on the data but also on the activity on the interaction level.” [I2]*

5.2.3 Spatial and temporal limits of the analysis

The focus of my analysis is on publicly available website content which excludes activities in the forums where Spotteron interact with all the projects, the projects share ideas with each other and sometimes within their teams.

> *“When you log in and every partner, every project, every citizen science project and every partner of every citizen science project (laughs) has a user account. We*

create them for them. And then you have access to the forum. And in the forum we have this sections for projects. People communicate. Also a little bit with each other. But also I give you a good example. Apple had new requirements, again (laughs). So we needed to translate all the app permission dialogues, otherwise they won't release the apps anymore. So what we need in this case. We can do it in German and English. But we have projects in Dutch, Italian, Slovenian, French. Then we write into the forum that we need this content. Every partner gets an e-mail that there is a new forum post. And the partners contribute their translations in this case. So with new features we need this organization because simple, you know, time is the crucial resource. And here we can communicate to all projects on a direct level. But still have it centralised in a way. That we don't write ten e-mails, or fifty e-mails, we just write one post and everybody gets it. And the beneficial part also here is that the project teams can reply. And sometimes - it does not happen very often, but sometimes also - they have interactions with each other. Ideas, or e.g. [name] from [project] did share some code of the R software thing where they put statistics onto the website with the API of Spotteron and everybody can use it. So they share stuff a little bit. And that's a very, very important, nice section. " [I2]

Another decision was to focus on parts of the website which are rather stable. This excludes social media communication which happens outside the website and the blog which follows a regular update cycle.

"Yeah the blog is our core element which changes all the time. We write, we try to write four blog entries a month, once a week. Sometimes it works, sometimes not. It depends on the workload. But in general the blog is our central hub for keeping everybody up-to-date. And also it is always linked with the social media dissemination" [I2]

However, still even the webpage content used in my analysis are in constant flux, thus it is important to consider the temporal situation of my analysis which is based on material from 2019 and 2020 (Table 2).

“A website since years, it is not a new thing, but a webpage is always based on a content management system. That means everything is in constant change. So, for example, this section we separated at one point in time into world-wide and regional projects. Because there were too many to have a first overview. It will for sure be changed in the future. There will, I guess, some days filters where you can select your country and see which projects are active in your country. Or things like that. Perhaps your interest, your topic. But that's important to mention because it is never a constant state. And it changes really frequently. More on a smaller scale, but also with new sections.” [I2]

5.3 Practice report: analysing websites

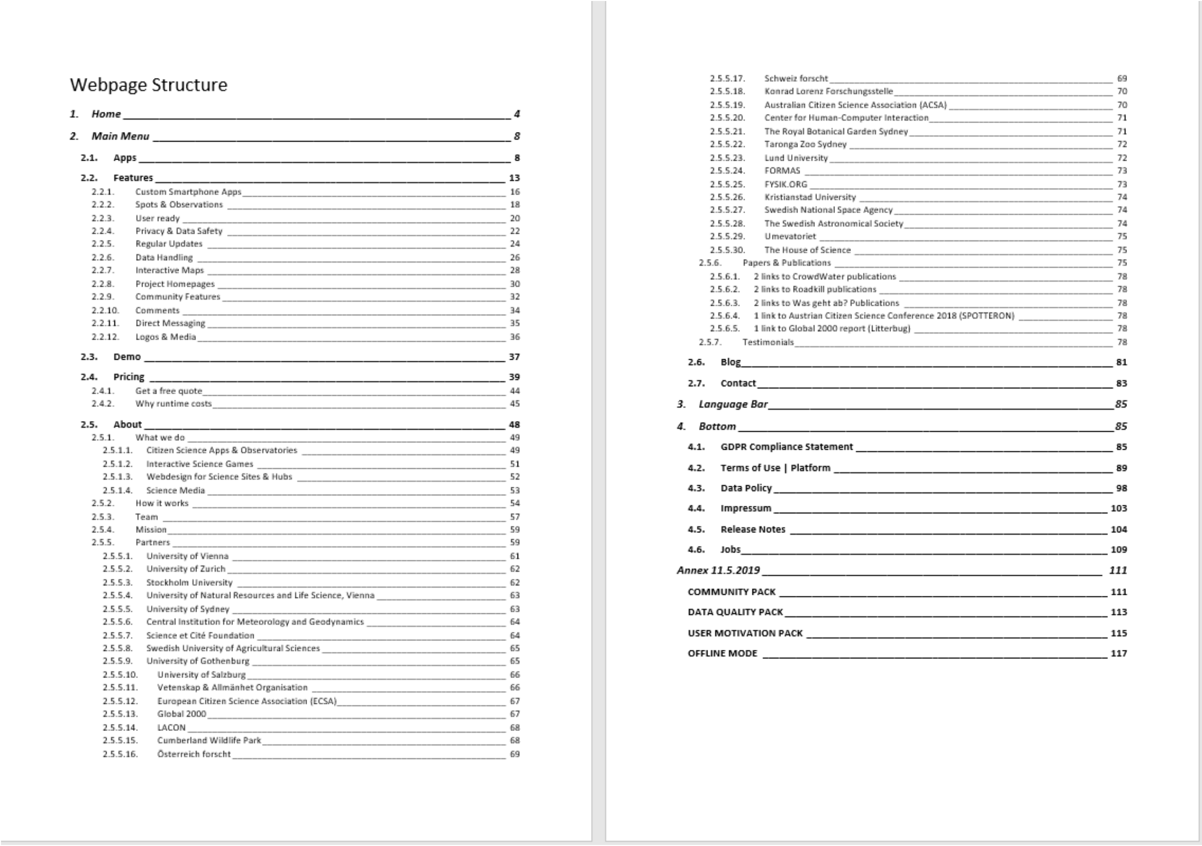
This chapter presents a reflexive account on how I dealt with some of the challenges of analysing the Spotteron website in practice. I attempted to tackled the fluidity of the website content by capturing the text in a stable document and addressed the text volume of websites by supporting the central qualitative approach with quantitative experiments. There are also experiments which did not work out such as an attempt to identify central topics by automatically counting the links to individual pages. Therefore this limited selection of issues aims to demonstrate how a research approach that sounds straightforward produces a lot of messiness before final results are cleaned up.

5.3.1 Turning a website into a document

The Spotteron web links text, pictures, videos, blog entries and interactive resources such as project apps. Shankar et al. (2017) make it clear that delimiting the field in digital document studies is essential and they also mention a potential distinction between fixity and fluidity. I decided to focus on text content of the product pages. I excluded the blog section as I assume it to be updated regularly and potentially addressing a different audience. The constant flux of the webpage also showed when a few month after my initial analysis I realised that part of the structure of the website had meanwhile completely changed. While finishing up work on the thesis I also found a link to a new beta website for citizen scientists[21].

As the product pages are also not completely static I preserved structure and content of the webpage for analysis by combining screenshots and full page texts in a Word document. I created a Table of Content resembling the navigation structure on the webpage (Figure 4).

[21] https://www.spotteron.app/, last accessed: 23.12.2022



Webpage Structure

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2.5.5.5. University of Sydney 63
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2.5.5.8. Swedish University of Agricultural Sciences 65
2.5.5.9. University of Gothenburg 65
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2.5.5.11. Vetenskap & Allmänhet Organisation 66
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USER MOTIVATION PACK 115
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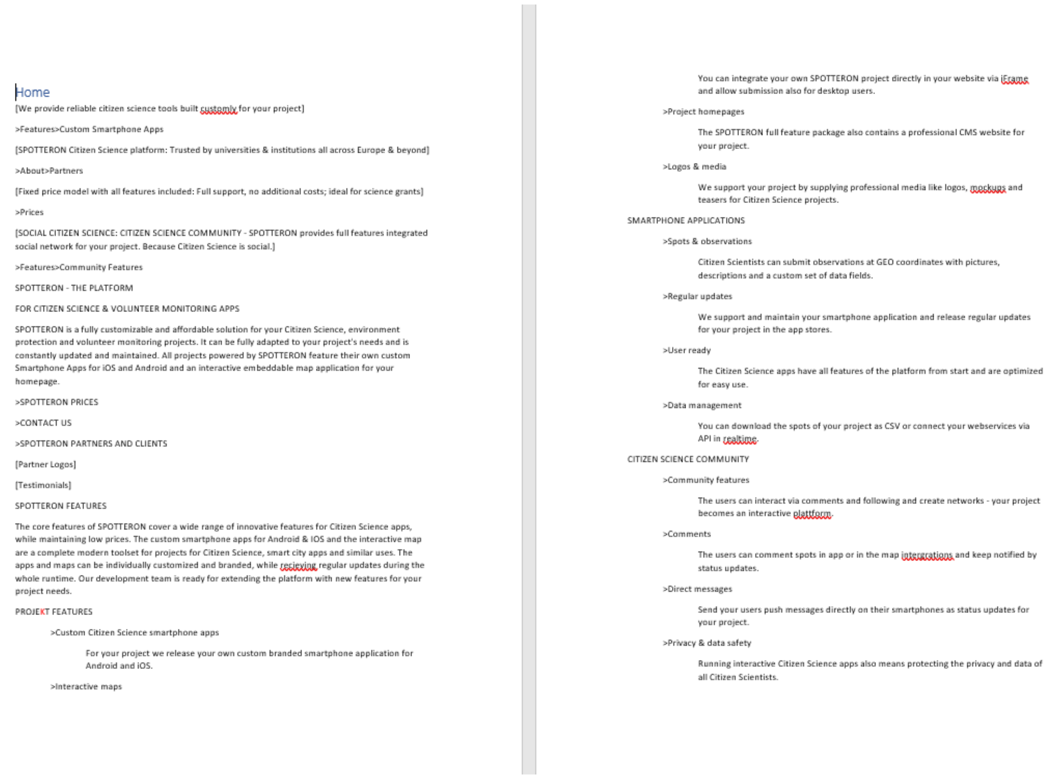
Figure 4 mapping the website structure through hierarchical headings

I created a second version with alternative texts to represent graphics and their position within the texts and transcribed text elements in graphical elements such as banners to include them in the text analysis. I highlighted links and skipped exact repetitions in teaser texts which link to detailed content pages (Figure 5).



Home

[We provide reliable citizen science tools built customly for your project]

>Features>Custom Smartphone Apps

[SPOTTERON Citizen Science platform: Trusted by universities & institutions all across Europe & beyond]

>About>Partners

[Fixed price model with all features included: Full support, no additional costs; ideal for science grants]

>Prices

[SOCIAL CITIZEN SCIENCE: CITIZEN SCIENCE COMMUNITY - SPOTTERON provides full features integrated social network for your project. Because Citizen Science is social.]

>Features>Community Features

SPOTTERON - THE PLATFORM

FOR CITIZEN SCIENCE & VOLUNTEER MONITORING APPS

SPOTTERON is a fully customizable and affordable solution for your Citizen Science, environment protection and volunteer monitoring projects. It can be fully adapted to your project's needs and is constantly updated and maintained. All projects powered by SPOTTERON feature their own custom Smartphone Apps for iOS and Android and an interactive embeddable map application for your homepage.

>SPOTTERON PRICES

>CONTACT US

>SPOTTERON PARTNERS AND CLIENTS

[Partner Logos]

[Testimonials]

SPOTTERON FEATURES

The core features of SPOTTERON cover a wide range of innovative features for Citizen Science apps, while maintaining low prices. The custom smartphone apps for Android & IOS and the interactive map are a complete modern toolset for projects for Citizen Science, smart city apps and similar uses. The apps and maps can be individually customized and branded, while recieving regular updates during the whole runtime. Our development team is ready for extending the platform with new features for your project needs.

PROJEKT FEATURES

>Custom Citizen Science smartphone apps

For your project we release your own custom branded smartphone application for Android and iOS.

>Interactive maps

You can integrate your own SPOTTERON project directly in your website via iFrame and allow submission also for desktop users.

>Project homepages

The SPOTTERON full feature package also contains a professional CMS website for your project.

>Logos & media

We support your project by supplying professional media like logos, mockups and teasers for Citizen Science projects.

SMARTPHONE APPLICATIONS

>Spots & observations

Citizen Scientists can submit observations at GEO coordinates with pictures, descriptions and a custom set of data fields.

>Regular updates

We support and maintain your smartphone application and release regular updates for your project in the app stores.

>User ready

The Citizen Science apps have all features of the platform from start and are optimized for easy use.

>Data management

You can download the spots of your project as CSV or connect your webservices via API in realtime.

CITIZEN SCIENCE COMMUNITY

>Community features

The users can interact via comments and following and create networks - your project becomes an interactive plattform.

>Comments

The users can comment spots in app or in the map intergrations and keep notified by status updates.

>Direct messages

Send your users push messages directly on their smartphones as status updates for your project.

>Privacy & data safety

Running interactive Citizen Science apps also means protecting the privacy and data of all Citizen Scientists.

Figure 5 preserving webpage content and substituting pictures with alt texts

All these transformations do not occur naturally but require active decisions and developing rules to ensure a consistent and systematic approach.

Having a stable text-only version of the website ensures that citations can be traced back to a source and allows to start analytic work. Besides the qualitative core of my analysis I employed quantitative methods as sensitizing and verification means such as word frequency analysis which is presented in the next section.

5.3.2 Making the digital count

I used word frequency analysis to extend beyond the focus of my qualitative analysis on social actors. For this, I first made a wordle but then realized that this is only partly useful as it does not consolidate variations of the same word (such as singular/plural e.g. project/projects or verb/noun e.g. use/user). It still helps to highlights specific words such as data, science, citizen, project (Figure 6).

Figure 6 Wordle of most frequent words on the webpage

For a more detailed analysis I had a look at the top 100 word appearances and chose those, which seemed specific (not general words like “the”, “and”, “your”). Then I looked for variations in the full list of words (see column ‘sum of variation’ below which indicates how many different variations exist – of course typos also induce artificial variations). I tried to combine related words into larger categories (red in graphic below) but felt that this proves quite tricky (e.g. university/science does not belong together when talking about citizen science; use and user should not be combined as use has become a general word but user is rather connected to technology). However it still shows that data, information and content are very prominently used and if we agreed that these are related they together constitute a very prominent position in the speech used on the webpage. Also on a more general level there are words which are very specific and others where a lot of alternatives exist (thus making them less likely to get a high count and thus appear in my 100 count list). Still I feel that the initial idea to look at the commonly used words might prove useful when looking at which actors are most often mentioned and which labels are assigned to them.

main occurences consolidated	Sum of occurrence	Sum of occurrence2	Sum of variation	Sum of variation2
_not specific or not amongst top 100	**15185**	**80.17%**	**3055**	**92.10%**
#N/A	15185	80.17%	3055	92.10%
data/information/content	**437**	**2.31%**	**14**	**0.42%**
data	259	1.37%	6	0.18%
information	109	0.58%	4	0.12%
content	69	0.36%	4	0.12%
user/use	**315**	**1.66%**	**28**	**0.84%**
user	189	1.00%	13	0.39%
use	126	0.67%	15	0.45%
project	**314**	**1.66%**	**8**	**0.24%**
project	314	1.66%	8	0.24%
app	**302**	**1.59%**	**23**	**0.69%**
app	302	1.59%	23	0.69%
science	**240**	**1.27%**	**4**	**0.12%**
science	240	1.27%	4	0.12%
citizen	**221**	**1.17%**	**6**	**0.18%**
citizen	221	1.17%	6	0.18%
SPOTTERON	**196**	**1.03%**	**8**	**0.24%**
SPOTTERON	196	1.03%	8	0.24%
map/spot/observation	**173**	**0.91%**	**23**	**0.69%**
map	82	0.43%	10	0.30%
spot	54	0.29%	7	0.21%
observation	37	0.20%	6	0.18%
personal/custom	**113**	**0.60%**	**12**	**0.36%**
personal	67	0.35%	6	0.18%
custom	46	0.24%	6	0.18%
platform	**103**	**0.54%**	**6**	**0.18%**
platform	103	0.54%	6	0.18%
new	**101**	**0.53%**	**9**	**0.27%**
new	101	0.53%	9	0.27%

Figure 7 word frequency analysis with categories

Only looking at individual words I noticed that project, app, data dominate the scene. The first human actor is "user". For citizen, science and scientist considering the context around the word is important since they might often appear in combined forms e.g. citizen science, citizen scientist. Further interesting actors are "partner" and "community" (52) or more technical platform, feature, map, spot, updates, smartphone. Also combining maps, spots and observations might be analytically useful as observations are linked to the physical world, they are transformed into spots (containing particular kinds of information) and then put on maps (thus mapping observations virtually in physical space).

Constructing these categories analytically reminded me of STS studies on categorization. While it seems an essential part of consolidating research results it is important to reflect potential implications of these decisions for the empirical results which are presented in the next chapter.

6 Empirical Part: infrastructural perspectives on digital citizen science

In this chapter I look into contributions of collaborators on different infrastructural levels. Section 6.1 provides an overall introduction to the framing of actors, which infrastructural level they are mainly interacting with and their main contributions. The next sections presents different infrastructural perspectives on digital citizen science. Section 6.2 has the business case of Spotteron as its starting point which focusses at the joint design of a citizen science app between Spotteron and partners. I extend the timeframe of individual project apps from initial design towards using the app for data collection, beyond the end of citizen scientists involvements. With a focus on the app, active contributions from citizen scientists are somewhat relegated in this story. This is compensated in Section 6.3 which takes a closer look at how the social media approach supports building communities around observations thus putting more emphasis on citizen scientists and their contributions. Section 6.4 considers broader perspectives of collaborators such as considering the perspective of the Spotteron platform, personal experience of citizen scientists, and apps as part of an overall partner project.

6.1 Overall framing of main actors and contributions

I start with a broad presentation of the main collaborators and their contributions as they appear on the Spotteron webpage. The main actors are Spotteron, partners and citizen scientists. Spotteron works with partners to develop custom smartphone apps which enable users to contribute observations and participate in a community. Spotteron lists broad areas of interest for academic and non-academic partners such as citizen science, environmental protection and social agendas. Users are not described more specifically, making them appear as potentially everyone.

Spotteron is identified as owner of the platform, developing and maintaining an infrastructure for digital participation which provides a common set of features that are customized in apps for project partners and users. Partners are presented as administrators of individual project apps running on the platform. Citizen scientists use features supported by the platform in individual apps which are connected to specific projects to contribute relevant location-specific digital observations and participate in a social media community assembled around the project issue.

While Spotteron presents itself as directly enabling partners, users are indirectly addressed: Spotteron enables partners and this enables users. This overall framing moves Spotteron closer to partners and increases the distance to users. In addition the term partner indicates a higher degree of (social) closeness, direct interaction and equality as compared to citizen scientist. Spotteron also employs the term user frequently, mainly addressing citizen scientists, which highlights a relation with a technical tool (an app in this case) rather than a relationship between social actors.

Looking at the abstraction level of the collaborator labels I suggest that they are aggregate social actors meaning they are composed of several individuals. Citizen scientist is an aggregate actor which is composed of diverse individuals without a common organisational background. Partners and Spotteron are aggregate actors, being composed of members of a particular organisation (Table 4). This description is at an abstract meso level of actor groups or organisations which hints at opportunities for micro level studies of interactions and variations within those aggregate actors in specific projects.

Partners and citizen scientists are abstract plurals i.e. they are taken on by specific but varying organisations and individuals in the context of specific digital participation projects. Spotteron invite a broad range of partners and activities. They invite academic and non-academic partners, interested in citizen science, environmental protection or social causes. The most common type of projects are organised by universities with a focus on natural science questions. For citizen scientists Spotteron aim even broader inviting everyone to participate. However they admit that it is mainly people who are already attracted to science who actually participate. The current actor labels are suitable for the case of Spotteron but for general use they can be further abstracted with a consistent focus that supports particular types of analysis.

For this thesis I suggest labels which link infrastructural levels with roles of the collaborators. Spotteron is platform provider and app customizer, partners are app administrators and citizen scientists are social media users. This relates to citizen science as digital infrastructure. It suggests that digital citizen science needs competency in all three parts of the compound noun: *digital* features are developed and digital participation is designed in the app by Spotteron, *citizen*s contribute spots in a social media community and *science* solves an issue with data from the app (Table 4).

	SPOTTERON		**PARTNERS**	**CITIZENS**
ABSTRACTION	specific organisation		abstract organisations	abstract individuals
INFRASTRUCTURE	platform	app	app	social media
ROLE	provider	customizer	administrator	user
KEY CONTRIBUTION	develop features	design participation	solve issue with data	contribute spots in community

Table 4 framing collaborators related to the infrastructure

Throughout this thesis I present my own tables and figures which illustrate important aspects. The details of the presentation are case-specific. However I will use abstract conceptual language which can be applied to other cases. This is an invitation for scholars and organisers of different participatory projects to further reflect on how different digital practices frame human participation.

6.2 App-based citizen science

HOW IT WORKS Running your own citizen science project on the Spotteron platform is easy. First, we provide a free quotation based on a project's description or a Skype call at first hand, which summarizes all the costs, including updates and support for your citizen science apps. After your decision, we work in collaboration with your [research] project to create the app's data structure and necessary assets like a project logo, icons, app store media and others.

ROADMAP We take care of your project's app development from the start. After the concept phase we start building your citizen science or volunteer monitoring toolkit and create custom design elements for your app. The whole process is done in close collaboration to have your apps optimized for your project's requirements. We put our 15+ years of experience in digital design and development at work to provide the best solutions and innovative features in an online mobile world.

Since Spotteron is built as a platform by concept, the time-frame for a new citizen science app release can be just around 4 - 6 weeks. After the release of your project's citizen science apps, we continue to provide updates and improvements during the whole run-time.
[About > How it works[22]]

Spotteron develop custom apps with partners based on their platform which is also the focus of their webpage. From the structure and content of the webpage I derived three phases in digital participation projects around Spotteron apps:

1. There is a design and development phase preparing the app (before app) with strong collaboration between Spotteron and partners, which is described on the webpage *How it works*.
2. Next is a digital participation phase enabled through the app (during app) connecting partners and citizen scientists. This is discussed related to *Features*[23], descriptions of other *Apps*[24] which are already on the Spotteron platform or with a legal focus in *Terms of Use*[25]. Spotteron

[22] https://www.spotteron.net/about/how-it-works, last accessed: 13.12.2022
[23] https://www.spotteron.net/citizen-science-app-features, last accessed: 13.12.2022
[24] https://www.spotteron.net/apps, last accessed: 13.12.2022
[25] https://www.spotteron.net/terms-of-use, last accessed: 23.12.2022

present a lightweight package within the *Pricing*[26] page that can be used to maintain web access after mobile apps are discontinued thus extending the participation phase.

3. Spotteron frames partner collaborations as projects which suggests they have a defined end point. The *Apps* site also includes finished projects which hints towards a phase after the Spotteron app project ends. A page for *Papers & Publications*[27] indicates that there are further activities which are related to but happen outside the lifespan of individual apps.

This sharp separation into three distinct phases is done for analytic clearness. In practice these phases might overlap e.g. design of the apps might be improved while data collection is ongoing or papers might already be published during data collection and not only after the app has been discontinued. The next sections describes these idealised phases in more detail bringing together collaborators, contributors and the infrastructure.

6.2.1 Designing a custom app

My analysis of the website shows that the design of the app starts with a feasibility check on how partner requirements can be met by the platform. For this partners use their domain knowledge to describe their project idea (light bulb icon). Spotteron brings in their understanding of digital participation. Project apps (light blue rectangle) run on the Spotteron platform (larger dark blue rectangle) and thus can use existing features (cogwheel icon in the top left corner of the platform). Financing is provided by partners (coin stack icon) within a fixed price package that includes custom design (palette icon). If partners need development (mobile phone icon) of additional project features (cogwheel overlapping with the app at the right side) additional funding will be required. Spotteron starts customizing the app (dotted line around the app rectangle). Partners care about promotion and recruiting participants to prepare the launch of the app which marks the transition to the next phase (Figure 8).

[26] https://www.spotteron.net/prices, last accessed: 13.12.2022

[27] https://www.spotteron.net/about/citizen-science-papers-and-publications, last accessed 13.12.2022

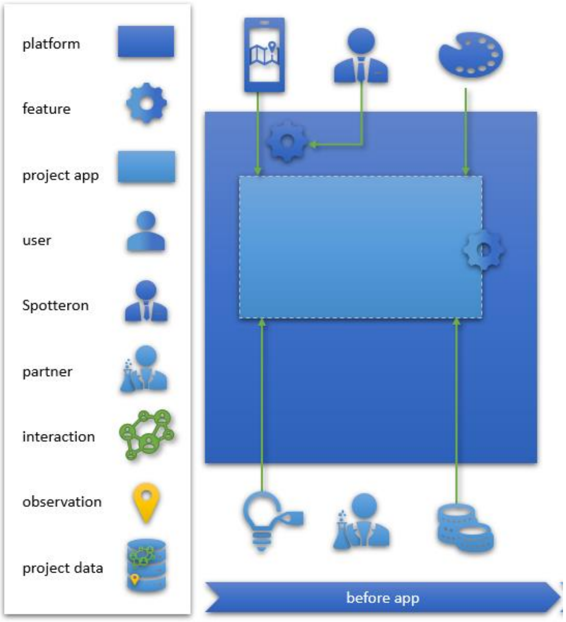


Figure 8 collaborator involvement "before app"

In the design and development phase Spotteron suggest close collaboration with partners. Citizen scientists are not directly involved at this point. However Spotteron claim to keep users in mind during design and development using their own experience as digital natives and active citizen scientists. Spotteron take the role of an app customizer which involves design and development work. Partners are presented as app owners who contribute their domain knowledge and financing (Table 5).

	SPOTTERON*	PARTNERS	CITIZENS
INFRASTRUCTURE	app	app	-
ROLE	customizer	owner	-
KEY CONTRIBUTIONS	designing, developing	knowing domain, financing	-

Table 5 framing collaborators during app design and development

Spotteron describe the setting in which they operate as fast paced, online and mobile word. Spotteron and partners enter a formal legal relationship as contractor and principal with the focus on customizing and maintaining an individual app.

Spotteron keep the thematic scope for partners broad. The main focus is that data is collected as geo location information which can be visualized as maps. partners and Spotteron use special expertise to determine whether the project fits with the Spotteron platform as part of *checking feasibility*. For partners this involves *knowing the domain* around the issue. This includes knowhow on the topic e.g. to identify research gaps and formulate related research questions as well as suitable methods in the field e.g. developing questionnaires, classifying observations, designing experiments. Spotteron stress that they do not interfere with the scientific focus of the project. Their focus is on technical feasibility and sometimes making recommendations how to open topics for broad participation. They claim to *understand digital participation* thus being able to keep users in mind and represent them as digital natives and experienced citizen scientists themselves.

Partners are responsible for *financing* a Spotteron fixed-price package depending on whether they want just a web application, include a mobile app or also need a webpage. In case partners require new features extra costs will be calculated. However the features are then shared through the platform with all other projects at no extra cost. Thus partners can also be seen as enabling new features for the platform. Spotteron position their decision to charge partners as ethical choice contrasting it with platform business models which monetize user data. Spotteron contribute by *developing* technological groundwork beyond single projects which they frame as in-kind contribution to a joint infrastructure development partnership. This includes a scalable server infrastructure or the social media functions. Spotteron frame their overall work as engagement for citizen science which goes beyond a business perspective also involving pro-bono contributions.

Developing an app means customizing the platform functionality when *implementing individual projects*. Partners once again use their domain knowledge to provide input for the observation questionnaires. *Designing media* is presented as a core competence of Spotteron and supporting partners to create project identities including several aspects such as project name, claim, logo and app design. They use this to create a consistent look on user-interfaces and promotional material. Spotteron suggest partners *promote* upcoming apps with the aim of *recruiting* participants. This phase ends after the app is released through app stores.

6.2.2 Using the app

In this phase partners work with their app to engage citizen scientists. These users submit observations (yellow spot symbol) and interact via social media functions (green network symbol) such as commenting, liking and following. Partners and citizen scientists interact through their user profiles. This happens within individual partner project apps. In this phase Spotteron move into the background as they shift their focus from the app towards platform level. This involves making sure features still work with new requirements of devices, external tools or app stores and developing new platform features (cogwheel symbol) (Figure 9).

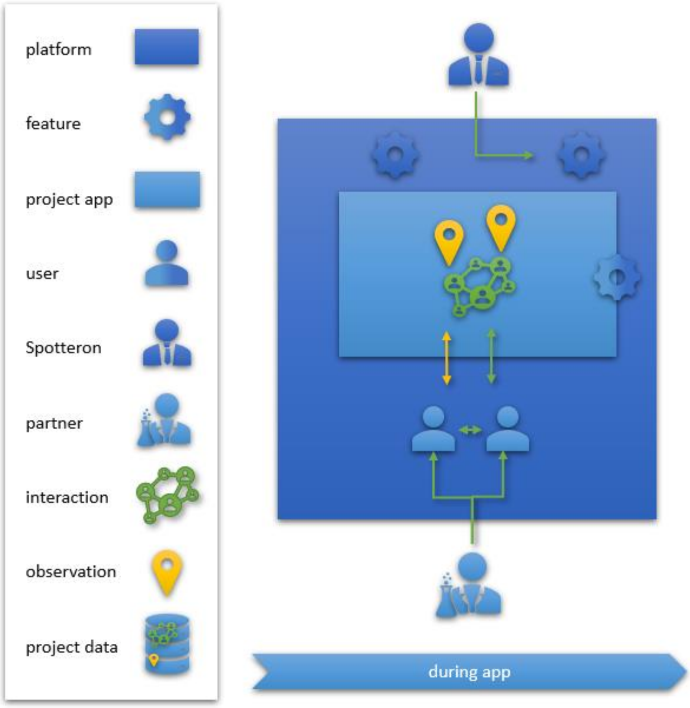


Figure 9 collaborator involvement "during app"

Spotteron aim to ensure legal compliance of the data collection process calling on users to provide only content they have full rights for and making this data public domain so project partners can work with it. They encourage participants to protect themselves through using pseudonyms and sharing accounts. In summary Spotteron safeguard platform operation on technical and legal levels, partners are administrators of their individual app who collaborate within their project community and citizens are social media users who learn by providing observations and interacting around them (Table 6).

	SPOTTERON	PARTNERS	CITIZENS*
INFRASTRUCTURE	platform	app	social media
ROLE	safeguard	administrator	user
MAIN CODES	maintaining, ensuring legal compliance	collaborating	collecting data

Table 6 framing collaborators during data collection

Spotteron encourages projects to stay on the platform, even if main funding runs out. For this they offer a special package which includes a web-app only solution which retains data and functionality. This phase ends when the project is no longer featured on the platform.

6.2.3 Continuing after app lifetime

This phase is not actively described on the webpage (grey chevron arrow) but rather traced back to related items in the webpage structure. After an individual app is discontinued partners continue analysing observation data and they publish findings. Spotteron maintains features which were custom developments for this project and found useful for others as part of the core platform functionality (cogwheel symbols). Users are no longer connected to the project but remain registered with the Spotteron platform (dark blue user icon) and their connections to other users in the social network remain (green arrow). Spotteron uses their project experience to create marketing material using app screenshots and publishes and speaks at conferences to promote their approach (Figure 10).

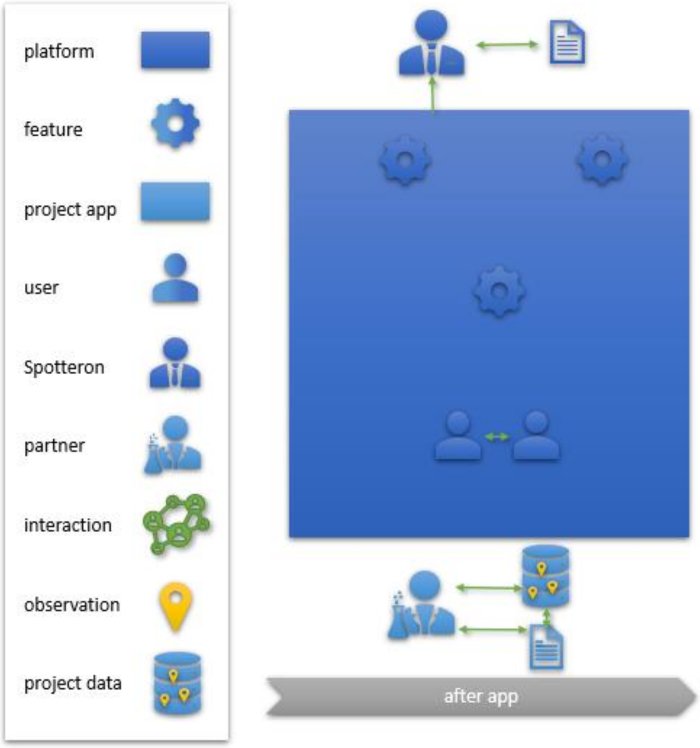


Figure 10 collaborator involvement "after app"

Spotteron and the citizens are connected to the infrastructure at the platform level in different ways. For Spotteron the platform is the focus of their work developing and maintaining features. Citizens are connected to the platform trough their registration even after individual projects run out. This enables them to switch to another Spotteron citizen science app. Partners are indirectly connected to the infrastructure on the data level since they work with the exported observations (Table 7).

	SPOTTERON	PARTNERS*	CITIZENS
INFRASTRUCTURE	platform	data	platform
ROLE	owner	scientist	user
KEY CONTRIBUTIONS	maintaining features, (promoting approach)	(working with data, creating impact)	-

Table 7 framing collaborators after app

The contributions *working with data*, *promoting approach* and *creating impact* are activities which are enabled through previous use of the infrastructure but not happening within it. I take this as cue to consider how broader perspectives and activities of contributors interact with the infrastructure in section 6.4. But before this I describe the contributions of citizen scientists in a social media infrastructure that is built around collecting data to tackle a research challenge.

6.3 Citizen science as social media interactions around observations

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Naturkalender ZAMG: An Active Digital Community - This Austrian citizen science project achieved a very active community, with more than 5000 app downloads, through continuous press and media coverage. Participants contribute observations of plant and animal species throughout the year and record their changing phases (e.g. first appearance of a species, fruit ripening, leaf colouring). The app, created by SPOTTERON, features an integrated community toolkit, which allows established users to welcome and support newcomers to the project and to help with the classification of observations via instant feedback loops in the comment sections of each contribution. To help with community management and data quality, regional project partners, such as national parks and meteorological stations, work as data moderators. For clear distinction between user types, these partners have unique profile pictures (avatars) with the visual design elements of the project. The project research team also interacts directly with the community via comments and feedback on new contributions. Further functionalities to support ongoing community building include highlighting valuable contributions and being able to appreciate a spot by pressing a heart-shaped button. The project team also utilises a 'push messages' feature to report news back to citizen scientists or to communicate seasonal information about key species to observe.

(Ruefenacht et al., 2021)

This chapter looks deeper into the use of Spotteron apps for citizen science. It explores how the core of the citizen science project, collecting observations, is integrated into a social media framework and what kind of interactions this enables. 6.3.1 highlights activities of citizen scientists at different levels of the infrastructure. 6.3.2 presents how Spotteron deals with the tension between privacy and social experience. 6.3.3 illustrates how individualistic observations are combined with collective interactions.

6.3.1 Engaging citizen scientists at different infrastructural levels

This section explores how citizen scientists are integrated in the infrastructure. It looks at human citizen scientist practices from the perspective of a digital participation infrastructure. This involves looking at what kind of understanding of people and interaction are being performed at different levels of the Spotteron digital citizen science infrastructure.

I will focus on features for citizen scientists as described on the Spotteron pages *Terms of Use* and *Features.* I introduce a vocabulary of *undefined users, platform users, app users and social media users* which connects participants to different infrastructure levels, registration requirements and features. Undefined users represent people who browse project data anonymously. Platform users have registered with Spotteron and are able to download open data. App users contribute spots to individual projects and social media users interact in the community. For each of these technical states I suggest a human counterpart: *interested person, potential citizen scientist, observer and peer*. This can be seen as a career model aiming at active and collective participation which Spotteron frames as observing and interacting within a social media community. The next sections present these labels and contributions in more detail.

6.3.1.1 Interested person as undefined user

The loosest connection between the infrastructure and citizens is browsing project data without login. I call this *undefined user* because there is no link to a user account (person symbol but no user symbol in Figure 11) but nevertheless an interaction with the infrastructure. Project data is public by default which allows *interested persons* to browse spots and see connected comments and user profiles without account or login.

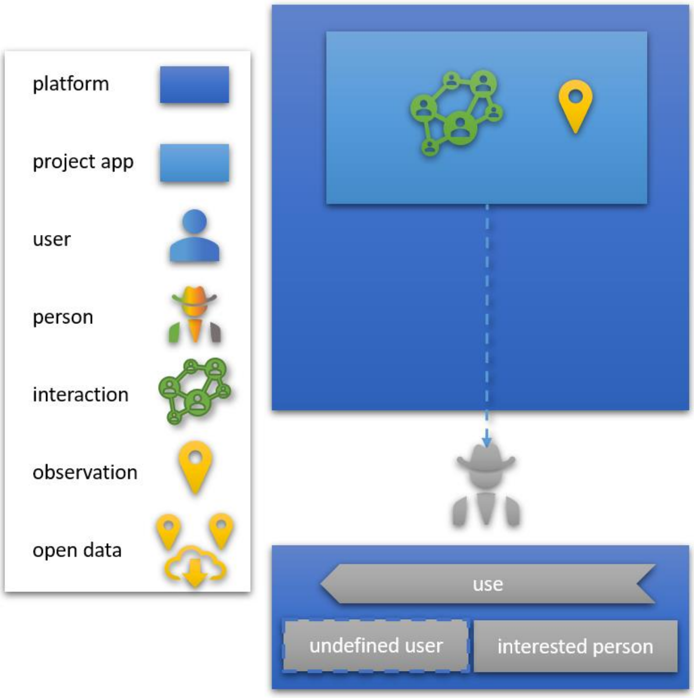

Figure 11 interested person as undefined user

In principle this gives access to all project data but the format does not allow systematic analysis e.g. of observations. Observations are displayed as single spots or aggregate stacks on maps. Individual spots can be opened through clicking on them on the map. Clicking on stacks leads to further zooming until individual spots become accessible. A list also gives access to all spots currently visible on the map. Spots integrate comments and links to user profiles which can also be browsed (Figure 12) .

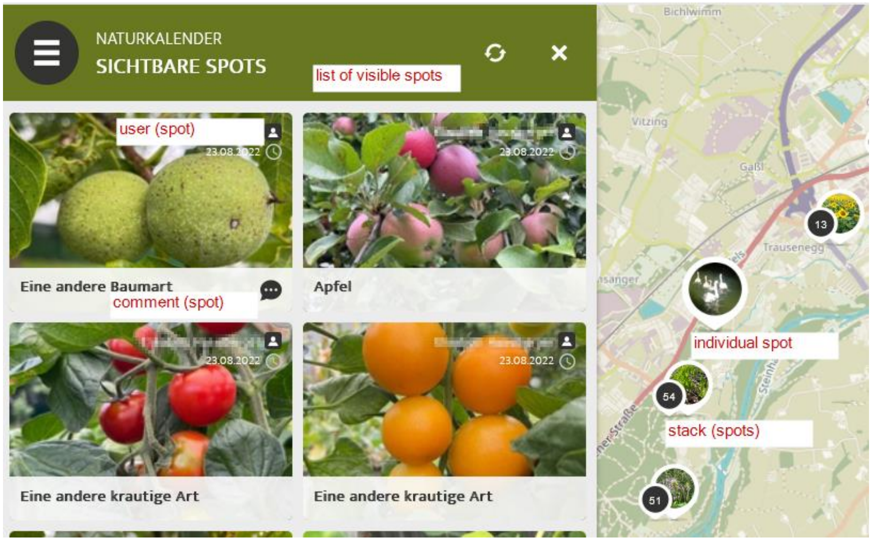

Figure 12 browsing spots

Spotteron contrasts browsing with actively participating in a community which suggests a framing as individualistic and passive use of social media (cp. chevron arrow and dotted line in Figure 11).

> *You can always use the applications of the projects on the Spotteron platform without registering or logging in for browsing, displaying and reviewing of the spots and contents - however if you want to participate actively, you have to create your own user account or log in to be able to be part of the community.*
> *[Terms of Use]*

From an infrastructural perspective the identity and interest of *undefined users* as well as their motivation to use the platform without login are not accessible (cp. neutral colour grey in Figure 11). This state is also available for people who already registered but are not logged in at the moment.

6.3.1.2 Potential citizen scientist as platform user

The next step in the user career is to register for a Spotteron account. This registration is done at the platform level. Therefore I suggest the notion of *platform user* (cp. Figure 13 dark blue user icon illustrates platform level). For users this allows to share the same credentials for different apps and enables cross-project activities e.g. following users which are active in multiple apps.

> *"[..] there are users who are emerging, who are stepping over one app. They start in one app and then they contribute in others. And this is really cool. This is one of the greatest achievements I would say. From a users perspective. To have that possibility. Because you don't want to be register all the time. And you don't want to put your information in all again. And also it doesn't make sense." [I2]*

Since the registration happens at the platform level there is no connection to individual projects at this point. This step can be seen as a pre-requisite to contributions to projects which is why I call it *potential citizen scientist* (cp. red person icon in Figure 13).

Figure 13 illustrates an accumulation of user rights. *Platform users* can still browse project information (right project) but additionally they can download open data from projects who decided to make it available through their respective project applications (left project).

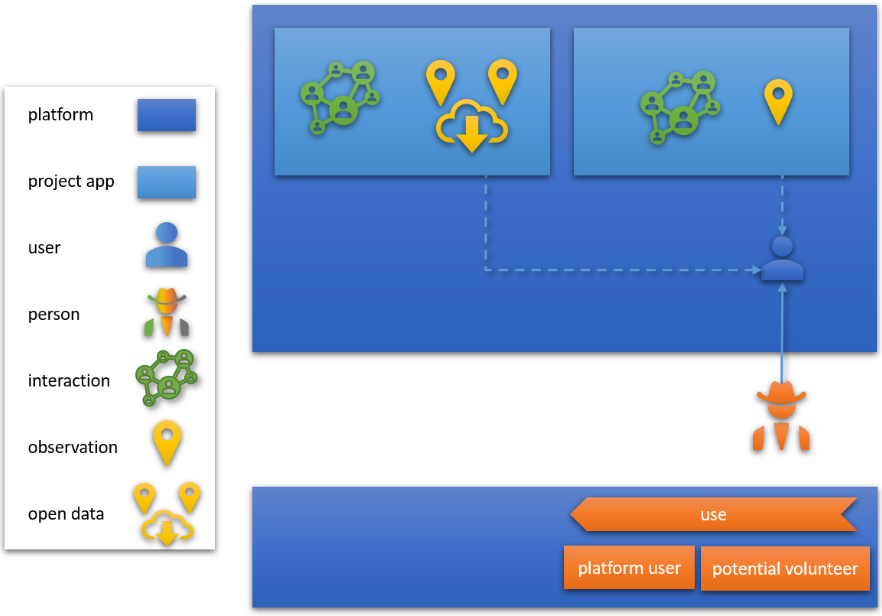

Figure 13 potential citizen scientist as platform user

After accepting the terms of use the download gives access to structured project data in tabular form. This contains all spots in anonymous form without social interactions (for more details based on my experience of working with Spotteron open data see 6.4.2).

Following the Spotteron logic of active contributions *platform users* are still understood as individualistic and passive (cp. dotted lines). They use (cp. chevron arrow) social media rather than engaging in the community or contributing new data to the platform. This is reflected in the red colour as part of a traffic-light-style colouring used for the citizen scientist career progress.

It is only with the first contribution of a user that a link to the respective project is established. This happens either through submitting an observation thus becoming an *observer* or participating through social media interactions thus becoming a *peer*.

6.3.1.3 Observer as app user

One way to contribute to a project is submitting observations. I call *app users* (light blue) who submit spots *observers*. They contribute to projects with (right project) or without open data (left project). Once submitted their contributions are available to *interested persons* and project partners. *Observers* are citizen scientists which contribute media content (cp. chevron arrow) in the form of spots to the social media infrastructure. Therefore from a social media perspective they can be seen as individualistic but more active than *potential citizen scientist*s which moves the traffic light to yellow (Figure 14).

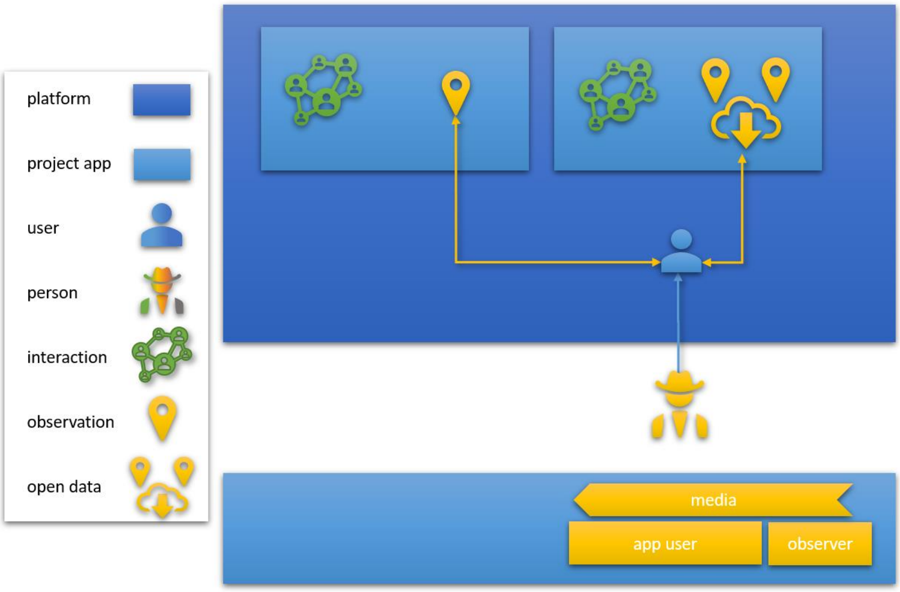

Figure 14 observers contribute spots as media objects to projects

Providing spots happens through custom user forms which vary between projects. They contain classifications, pictures and the option for the observer to include a spot comment. Some apps include custom features such as the uncertainty indicator at the middle of Figure 15.

Figure 15 observation user dialogue

App users can still browse project contributions and since they are logged in with their account they can also download open access data. They can submit further spots or move to the next level by engaging with the project community.

6.3.1.4 Peer as social media user

The final step of the Spotteron career is to engage with the community via social media interactions such as commenting, liking and following. I call *social media users* who interact in the community (green arrow between users) *peers*. These interactions contribute to the social dimension (cp. chevron arrow) of social media. Understanding digital participation as social media means that interactions are essential to form a community. As this step towards using social media function concludes the user career the traffic light switches to green (Figure 16).

Figure 16 peers use social media features to interact

Peers can like spots (top area). They can comment on spots and like comments from other users (lower area). In this case they discuss the spreading of an invasive species. Spots and comments are connected to the related user profiles which allows to start following other users and thereby building an individual network. Some apps contain custom features such as validation options for spots (top left) (Figure 17).

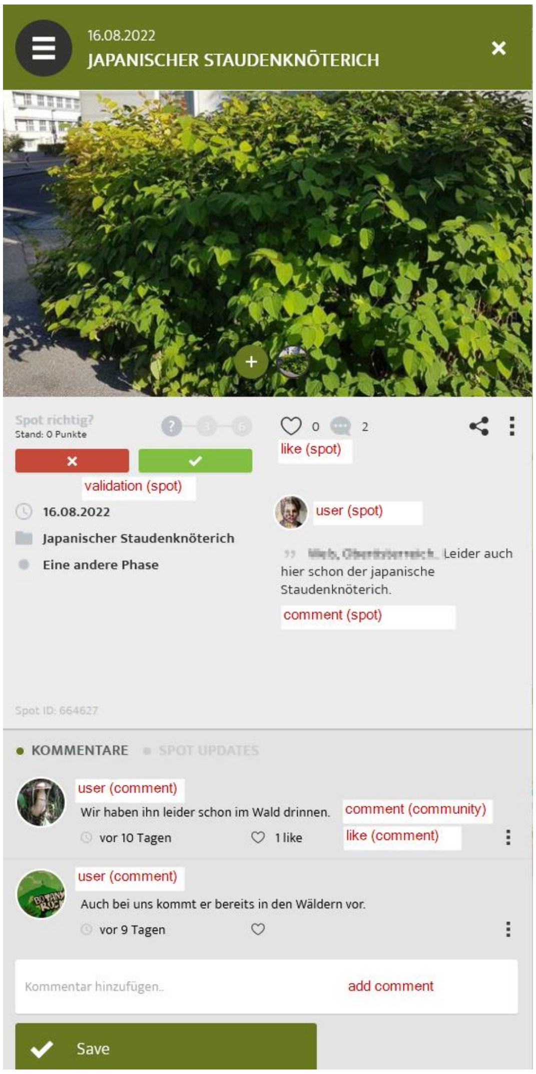

Figure 17 spot as entry point for social media interactions

Project partners and citizens have accounts on the platform. Spotteron suggests this supports a common-ground standing in social media interactions as project partners are regular members of the community and citizens can interact with them in the same manner as with other citizens.

6.3.2 Privacy and social experience

Spotteron provide some functions openly, others require a registration and active login. On a broader level this can be understood as a tension between privacy and social experience. A strict privacy perspective might aim to implement features to work without login. Social experience might suggest to create benefits through presenting and connecting users. Spotteron requires login in order to download open data, submit spots and participate in the community. Not all of these functions require a registration from a strictly technical point of view (Table 8).

ACTIVITY / REGISTRATION	NECESSARY	SPOTTERON
BROWSE PROJECT DATA	☒	☒
DOWNLOAD OPEN DATA	☒	☑

SUBMIT SPOT	☒	☑
PARTICIPATE IN COMMUNITY	☑	☑

Table 8 login requirements for features

Browsing project data does not require a user account and Spotteron implements it that way. Allowing access without registration or login can be seen as supporting privacy and lowering the entry barrier for newcomers. It can also be understood as supporting openness and transparency around project activities. This type of open access allows to quickly and anonymously browse what is going on in specific projects.

Downloading structured open data from projects technically does not require a user profile. However Spotteron asks for a platform user account. With this people are added to the platform user base, which provides value to platform owners although users are not necessarily connected to a project. In the validation interview Spotteron explain that registration for open data was requested by the partner who financed the development in order to document accepting terms but will be removed in the future to provide open access.

Submitting spots as such would not require an account since submissions could also be provided anonymously. However since Spotteron links spots to users in order to enable social media interactions around them Spotteron requests registration as default. Similarly participation in the community requires a registration in order to be able to link activities to the respective user profiles.

Spotteron highlight their commitment to *protecting participants* along the core principles strong encryption, no monetization of user data, and no tracking of users. They present protection as joint effort of Spotteron, partners and citizens.

Spotteron implemented their own follow social media network instead of using an existing one to ensure that no user data is collected. Spotteron describes protecting users through privacy-friendly design and suggestions to enhance privacy individually. Using Spotteron only requires a username and an e-mail address. For further privacy Spotteron suggest to use pseudonyms instead of real names. They promote shared institutional accounts for multiple participants to protect individual identities. In principle a single person could also be connected to several users accounts, although this counters the idea of having a single account for all apps. Therefore user profiles can be understood as partial self-representations of individual or collective participants.

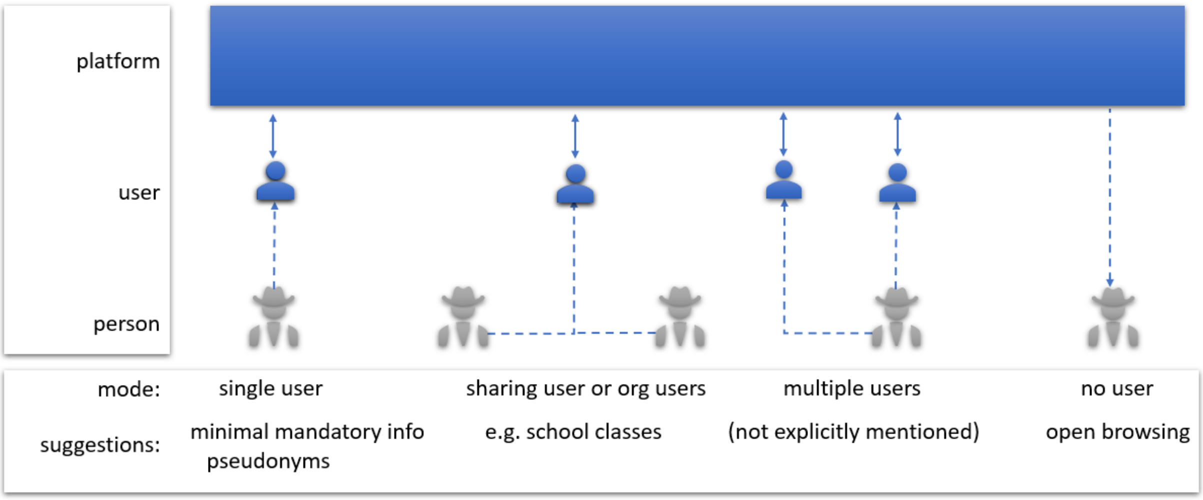

Figure 18 examples of relationships between users and persons

The tension between privacy and social connection surfaces again with the recommendation to use the option to provide personal information such as interests or educational background related to the project goal. Overall the focus on technically mediated social interactions increases the pressure towards extended user profiles. This can be understood as an inherent tension of social media. It points towards additional research to explore specificities and broader effects of the implementation of social media logics in citizen science. The next section provides first hints while exploring contributions of observers and peers.

6.3.3 Spot-centred social media interactions

Although collecting data is the main focus of projects and citizen scientists are heavily involved in this their contributions are not explicitly described on the webpage. The overall focus of the website to attract partners highlights app features and what they enable rather than active contributions by citizen scientists. This section aims to construct contributions from implicit hints in the text. I focus on the roles of observer and peer which Spotteron frame as active participation (Table 9).

USER	**UNDEFINED**	**PLATFORM**	**APP**	**SOCIAL MEDIA**
PERSON	interested person	potential	observer	peer
PARTICIPATION	passive		→ active	
CONTRIBUTION	individualistic			→ collective
FEATURE	browse	download	observe	interact

Table 9 connecting users, persons and features

The focus is on the shift from individualistic observations towards collective interactions. Observations are carried out by individual users using the app, interactions happen between users. Observations and interactions are first presented individually and then brought together as social media contributions around spots.

6.3.3.1 Contributions as observer

Spotteron suggest to engage users effectively and support quality of contributions through well-designed interfaces and motivating features. This does not address what kind of contributions users provide. I use the *Apps* section which describes partner projects to construct different types of user contributions which I present in a typology of aspects of observations made up of 4 Ps: *Passive (smartphone)*, *Place (map)*, *Process (clock)*, *Personal (thumbs up and down)* (Figure 19).

Figure 19 classification of aspects of observations

The light spot icon behind the citizen scientist figure in the background (Figure 19) indicates that the aspects of the observation and the required skills of citizen scientists are translated into spot information. Citizen scientists need to have access and knowhow to operate a smartphone (passive), put their observations on a map (place) and classify their observation either using knowledge about the outside world (e.g. process) or their embodied experience (personal).

I will now illustrate these four categories through presentations of data collection text snippets of some of the *App* projects on the Spotteron website. These text vary considerably concerning their focus e.g. on the project itself or on citizen scientists and whether their contributions are described in active or passive form or not at all.

Passive

I suggest the category of passive contribution where users provide their technological equipment e.g. as sensor or processor. Spotteron implicitly expects citizen scientists to have suitable mobile or desktop devices and know how to work with them.

Place

Place-related contributions include identifying places which hold something of interest to the project. One example is the Street Art project: citizen scientists need to know or find places with street art if they want to contribute to this app.

Street Art is a community built street art atlas. Through the app people who are interested in Street Art can put street art they discover in their own city or while travelling on a map and help other like[-]minded people find what they are looking for in their hometown or while on a trip. At the same time they contribute to a street art database.
[Apps]

Contributions are described as an active process of putting pictures of street art on a map and the usefulness of the data is described within the context of a peer community of street art enthusiasts. Since Spotteron uses maps as their primary representation technique all contributions are place-related in a sense. However some projects might require presence at or knowledge about particular places.

Process

Timing is crucial for some observations. It might be required that citizen scientists are at a specific place at a particular point in time in order to record a process step or behaviour relevant for the project. One example is recording the blossoming of particular plants to support climate research.

Nature seems to be on a rollercoaster ride these days. Sometimes there's spring in the middle of winter, then there are cold spells over and over again when it's almost summer. This is why nature- and climate researchers need more and more information about when plants begin to blossom, have fruits or start throwing off leaves or when animals are active. Entries in the ‚Nature's Calendar' App support the Austrian ZAMG's data collection.
[Apps]

This particular description foregrounds the needs of the researchers. Active work of citizen scientists is not directly mentioned but indirectly referenced through app entries. For this example the phenological phases (begin to blossom, have fruits, start throwing off leaves) are documented as classifications within a spot.

Some of the projects also involve seasonal patterns, e.g. phenological observations in winter are limited. However projects might aim to keep their users engaged e.g. by asking them to document icicles which does not have a scientific value but allow for continued data collection.

Personal

For some observations *personal* experience or judgement is necessary e.g. when documenting impressions about the environment.

In collaboration with the institu[t]e for transport at the University of Life Sciences, Vienna, this citizen science App was especially made for kids and teenagers. The Community Science project aspires to better understand how they perceive and rate possible dangers and their surroundings in general.
[Apps]

Contributions by citizen scientists are not described as an activity in the text. However citizen scientists are implicitly presented as capable of perceiving and rating their environment. These perceptions could be included as classifications or free text within a spot.

The categories in this classification are not career steps. Their order does not include a value judgement. These steps might happen simultaneously e.g. Spotteron contributions require basic skills *using technology* (Passive), putting observations on a map (Place) and *categorizing* (e.g. Process, Personal). Process and Personal are examples of special types of classification that are required in some but not all projects.

This typology highlights certain aspects that citizen scientists contribute through their observations. It also shows that project descriptions on the Spotteron website do not necessarily focus on the observations of citizens or highlight their active role in the project. The next section deals with social media interactions as second broad type of Spotteron contributions.

6.3.3.2 Contributions as peer

SOCIAL CITIZEN SCIENCE: As citizen scientists ourselves, this is a huge step forward to create a citizen science platform, which is not only about collecting data with the help of citizen scientists, but also to immerse users in the science project and to create a real social experience in citizen science. As stated in the definitions by various steering organizations, citizen science should always give something back to the citizen scientists.
[Community Features]

Spotteron build a social network that encourages interaction around observations which are linked to citizen scientists. There are different ways to interact within this community.

The quickest interaction is liking a spot or a comment within a spot. With this the contributor of the spot and followers in the network of the person who contributed the like are informed about this activity. Liking is limited to selecting a heart symbol. Spotteron describes liking as showing appreciation. In the validation interview they also mention small-scale viral like trends as an imported social media logic where content with many likes tends to accumulate even more likes.

Another option for interaction is commenting spots. The first way is by the observer right during submission. This might be used to highlight details of the observation or pose a question to the community and is presented in a prominent place and included in potential open data exports. The second way is for people to leave a comment within a spot. In this way conversations can unfold right within spots. These conversations are public and limited to the context of a single spot. There seems to be no way to directly reach out to another user. This strengthens social interactions which are focussed around spots, supporting the project goals to contribute and validate spots.

Spotteron describes comments as a way to increase the quality of contributions. The whole community can see new spots and are thus able to provide feedback e.g. concerning classification information. Some projects have special validation elements in the spot so users can provide feedback about the quality in structured ways. In other cases separate games are developed which encourage participants to validate spots.

Following allows to establish a connection to other users. Unlike in friendship networks this link does not need to be confirmed. Following activates notifications about activities of a particular user. The connection is established on a global level and not limited to a single project. This means that following another person presents activities in all project apps that both users are active in.

Following can be initiated from the profile of another user. This profile presents the collection of spots, badges that the person has earned through contributing spots and voluntary information users provided. Users can provide a picture, name, birthdate, motto and background information. In the data entry dialogue Spotteron describes the background information as important for analytic purposes of the project. On the webpage and in the validation interview they mention that this also helps to relate to people and build on common interests. Background information includes options for webpage, affiliation, education, interests, tools, and postal code.

The user profile is linked in all social media elements such as spots and comments and there is a user search which offers to find people via name, e-mail or city information. This indicates that only limited parts of the optional information are included in the search. The aim of this optional information seems to be providing more information about people who were already found through their project activities. Thus a connection to new people based on similar interest would have to be triggered through interesting contributions rather than through a profile search.

As interactions happen very much around spots it is vital to present spots to users to start with. This happens through the map (browsing), a filter view with all new spots or through the newsfeed in the user profiles. The newsfeed presents activities of followed users as well as technical updates of Spotteron and project updates. These features aim to keep users updated and engaged. The next section combines this with additional engagement mechanisms.

6.3.3.3 Engaging citizen science through infrastructure features

> *The most important part for sure the submitting one. Because without the submitting one you can't comment on anything. So, contributions or observations and data. This is the key. You know like. Also, in a hierarchy of quality. So good observations are very important. But also questions, like. When a users, like showed before. When a users does not know the exact species. And the community interacts and answers. It's also important. So, this plays together to create something. [I2]*

Personal engagement of individual citizen scientists can be challenging in citizen science projects with large volumes of contributors and observations. Spotteron offer technological support for motivation and engagement. In this section I will further discuss how those features are establishing connections between the infrastructure and different user groups.

Spotteron reserve special communication channels from project owner to users. Project owners may publish upcoming project events in the app or send direct messages e.g. informing about project news which address users as part of the project. Direct messages work as one-way broadcast from the project account without unsubscribing option for recipients. Spotteron also aim to keep the attention of citizen scientists using smartphone notifications.

Spotteron started out as an app focussed around contributing spots. Motivational features that revolve around individual contributions include badges which the system provides when reaching certain goals or a personal spot collection which allows to focus on their own contributions. In this case it is the app itself that presents information related to individual contributions which should provide a motivational boost. A leadership boards ranks the level of individual contributions within the community.

With the second major release Spotteron added social media features. Citizen scientists can show appreciation through liking or contribute with their expertise when commenting on other spots. Project owners also have the option to delegate classification power for all spots to special users. This gives community members additional ways to contribute to the project. Project members may still contribute to discussions and they maintain final classification authority. Social media interactions might lead to shifts in responsibility between project organisers and citizen scientists that could be explored in further research.

Spotteron brings together spots and interactions in a social media infrastructure thus I consider this type of citizen science as spot-centred social media interactions. Observations are the pivotal element and the central output of the citizen science projects. Combining them with interactions within a community is presented as a way to improve user experience and project output.

6.4 Broader perspectives of collaborators

> *"If I rank it from a development or from a technological standpoint then for sure design, app is very important and platform. If I rank it from my own experience as citizen scientist as participation then I have the community, experience, nature. You know like, it really depends on what kind of aspects you want to get out of it."*
>
> *[I2]*

Previous chapters consider different levels of the infrastructure as reference. 6.2 takes the app as frame, 6.3 social media features and data. This chapter introduces broader references of the main collaborators. 6.4.1 presents the infrastructural level of the platform perspective as longer-term counterpart to data, features, social media and app for Spotteron which also includes the perspective of multiple apps and projects running in parallel. 6.4.2 offers the start of my personal journey as citizen scientist within one Spotteron app as a more detailed practical ground for further discussions. 6.4.3 embeds Spotteron apps within broader participatory partner projects.

6.4.1 Citizen science as platform solution

For Spotteron the platform provides a long-term perspective within their infrastructural architecture. Spotteron work actively on the platform level to create and maintain features. The platform allows to share these features with all projects that run on platform (cp. cogwheel symbol on the left). In that sense features provide a potential longer-term perspective than apps. However when they are no longer seen as useful they can also be dropped.

> *"For example we now have a night mode […] Yeah, so that is one feature that is not used by other projects yet. But when another project has that need, too, you can, it's in general here. After a while it drops farewell. Because technology*

changes. The thing is, you can't really think of these apps and functionalities like fixed things. It's not like, ah, I don't know, is there a good, a good metaphor for that? It's like a plant. It flowers, it withers away. But next year it flowers again. In a way, it is a harsh metaphor. But yes, so, that can happen."[I2]

Features also include interacting via social media and sharing observations as spots. This repository of features allows Spotteron to focus on designing custom workflows (e.g. questionnaires) and user interfaces (e.g. graphics). New features might be inspired by requirements of partner projects (cp. cogwheel connected to app (2)). These features require additional development effort and are usually financed by partners. Alternatively they might be provided by Spotteron to support platform requirements (e.g. scalable server architecture or combining spots as stacks to improve map loading performance).

If we understand the platform as a repository of features Spotteron engage with the platform in two different infrastructural modes. They actively build the infrastructure in the foreground during development and maintenance and they passively draw on it in the background during designing custom apps.

A broader view on Spotteron offers for partners illustrates that solutions come in different configurations. They always include online apps which Spotteron frame as basic solution (computer with spot symbol). For some of the projects Spotteron provide webpages (computer with world symbol). Some projects include special solutions such as games for validating spots. However, the standard offer Spotteron promote are smartphone apps (smartphone with map symbol). The platform approach supports central maintenance of Spotteron solutions which run in parallel or in sequence (cp. Figure 20 (1), (2), (3)).

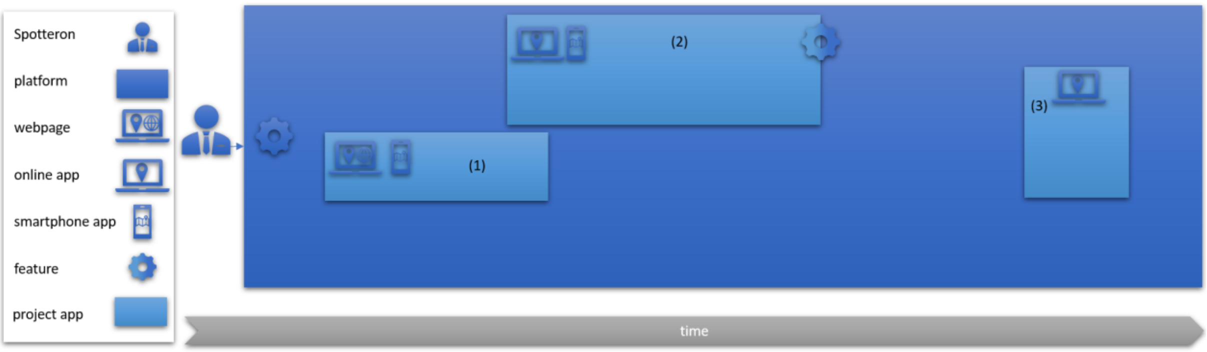

Figure 20 Spotteron platform as multi-project long-term perspective

Spotteron are also connecting tools. They integrate external tools such as OpenStreetMaps into their infrastructure. Development of Spotteron functionality is centralized at Spotteron with no option for external contributions. They enable external access to data from project apps through Application

Programming Interfaces. This is used in applications such as games they develop to increase data quality. Spotteron is also dependent on app stores who publish their work. Overall their approach is rather centralised and closed with integrating external application, controlling access to data through closed APIs thus limiting options for users and partners to experiment or extend the platform on their own.

Spotteron connects projects through a common forum which they use to clarify platform related issues centrally. This also allows projects to interact with each other. Some projects have their private forums which they use for internal team exchange.

An even broader Spotteron perspective includes their identification as citizen scientists combined with their claim to foster citizen science beyond a pure business perspective. We already discussed the social media framing of Spotteron for citizen scientist activities. The next chapter introduces the broader perspective of personal experience of citizen scientists within Spotteron projects.

6.4.2 Citizen science as personal experience

Spotteron wishes to attract a broad variety of users. However they state that they mainly attract people who are already enthusiastic about science. Spotteron also mention that some projects are easier approachable than other. They suggest this is linked to how easy it is to identify with the focus of observation or project theme. Taking pictures of plants to document phenological phases might be more attractive for a broader audience than measuring water levels of rivers or classifying spiders [I2].

There are users who are attached to a single project and others who contribute to multiple projects. With the platform registration users can participate in multiple projects or switch projects (2) during or after a project runs out. While user interactions within spots are lost when a project closes, connections to other users stay active. This allows to keep in touch with the already established community in other projects if they also participate there. Users might contribute a small amount of spots (1), contribute consistently (2) or with time variations (3) (Figure 21).

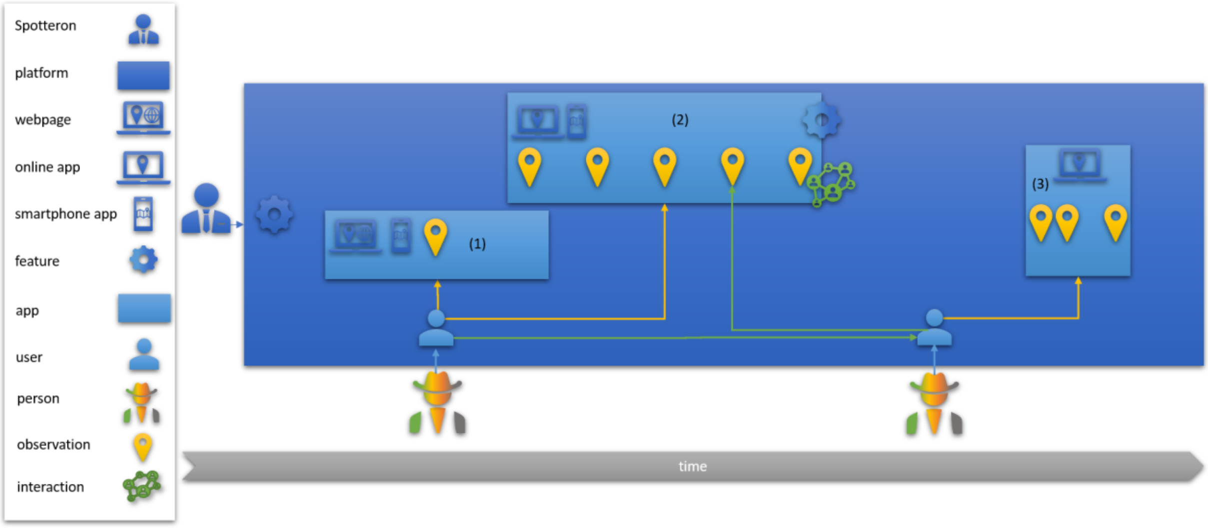

Figure 21 different rhythms of citizen scientist engagement

Spotteron does not systematically study their users. Their focus is on activity in the apps. They mention the longtail effect of a few very active users contributing most observations and many users with a small number of contributions [I2]. Their strong identification as citizen scientists and the distant view on other users suggests that they use their own experience as primary reference in the design phase.

The platform perspective includes potential for further research concerning the identification of users with the Spotteron platform, with individual apps (also in relation to each other) and their motivation to engage in several projects or change projects. I suggest to study opportunities for Spotteron to support longer-term conceptualization of users i.e. from individual citizen scientist contributing spots in an individual project towards engaged project member and participatory expert platform users. Currently broader engagement activities are left to be organised by partners. They may integrate a co-creation process for their project or involve users through events they promote in the app.

Then for sure, there are real life events. It's a very important part in many projects. And also a big important part in citizen science. It is not just keeping it digital. So, for example, there are workshops. There are community events like in Vienna we had the citizen science Day in the Natural History Museum, where all citizen science people come together and people just can visit. During the long night of museums it was. Or there is the Austrian Hub for citizen science "Österreich forscht" or the Swiss Hub "Schweiz forscht". So, there are many different levels. So there is also this, what I wanted to urge, is this real-life component. Yeah, and then it really depends on how the project operates. Some projects, you know, they even have a form and send out merchandise. Or have *activity on social media where people can go back. But still, this is then external from the platform. But important. [I2]*

These hints at a partner-centric view of non-virtual community activities. Citizens can participate in project events published in the app but organizing and promoting own activities such as joint mapping, analysis or activist events is not supported.

In order to present a more specific illustration of personal experience I present some of my own impressions around a 2 hour garbage collection experience with the Spotteron litterbug app which I carried out on April 13, 2019 in a small street at the outskirts of Vienna and which marks the beginning of my own citizen science career with Spotteron.

My personal motivation was to clean the street with a few family members and contribute to the litterbug app to learn more about the project and Spotteron. Overall my journey involved submitting observations which I reviewed again in the evening. This got me interested to browse spots in my neighbourhood and finally download open data from the project. The sequence of my activities does not follow a linear social media career path, and I did not actively interact via social media. However I used the social media part to read comments on the spots and by chance stumbled upon spots of my interview partner at Spotteron.

At the beginning we went out in the street and I started the app which opened right away. However, before starting to spot I had to create a user account in order to be able to create new spots. Although it was quickly done I was a bit annoyed and would have preferred a default option which allows to collect spots right away and create an account or log in afterwards for the upload or submit the spots anonymously instead. Since the registration is at the platform level it is only necessary for the first Spotteron app although login is requested after each start of an app.

Since I knew the location quite well I realised that the GPS signal was incorrect so I decided to position the spots manually. This indicates that place-based knowledge (cp. 6.3.3.1) is helpful to ensure high quality of data contributions.

Our first finding was a cigarette butt. I moved the position to the appropriate position on the street, selected the fitting type of garbage and amount and wanted to submit the spot. However I was forced to also submit a photo. As taking a picture of every single cigarette seemed inefficient I had to look for an alternative solution. I decided to count and collect the cigarettes and other items that occur in high numbers and only put in one spot at the end of our spotting trip with the total number. Since taking pictures slowed down the garbage collection I reframed it as a chance to document our trip and I made more personal shots by including the hands with the gloves or the shoes on it (Figure 22).

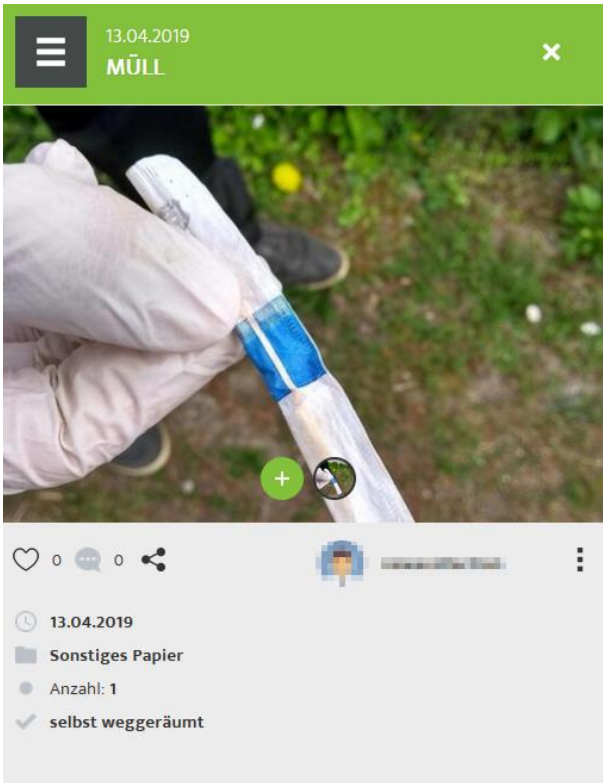

Figure 22 including the spotter in the picture

In some places there were several items of different type e.g. a cigarette butt, cigarette package and a bottle cap. I took a picture of these items and wanted to submit the findings with the correct categories. However a single spot can only contain one type of garbage. My next approach was to submit multiple spots in the same location with the correct classifications. However the app enforces a distance between spots which does not allow to report multiple findings in the same place. My solution was to sort the things according to the categories provided in the app (e.g. tissues, paper mugs, cigarette butts), take pictures for each category and distribute the spots manually because my focus was on correct classifications. I realised later that some users either take one picture of a spot and only categorize the most prominent item or use a custom classification and write several things into the description.

These classification examples show that mapping in practice requires balancing different goals such as speed and convenience of the mapping process with accuracy of location or categorization. The same is true on a more global level with achieving a balance between personal goals (cleaning the street efficiently) and projects goals (documenting accurate observations) and also potentially finding additional benefits (documenting personal effort).

There is also the option to mark whether you disposed the item or not which was not relevant for me since we collected and disposed our findings. However knowing the story of Spotteron I wondered whether there is an automatic notification to the respective authorities to pick reported litter up. The app itself did not provide guidance about how to deal with ambiguities concerning classifications or the effects or the checkbox. For the classification part I would have wished for more user guidance on what kind of contributions work best for the project.

Doing the spotting exercise made me look closer and realise how much garbage there is, even in places that I would consider rather clean. At the same time I realised there is the risk to focus just on the categories provided and skip other things that might also be interesting to observe. On one occasion we found a cork. There was no corresponding category so I classified it as other item and provided the details as text. I wondered whether textual feedback is used to refine the categories such as when many users report the same type of garbage manually.

There were continuous badges that popped up when creating the first entry, after three, five, ten and twenty. I had to smile about the quantitative feedback for such low numbers but I might be proud if I got a badge that highlights something that I perceive as valuable or special.

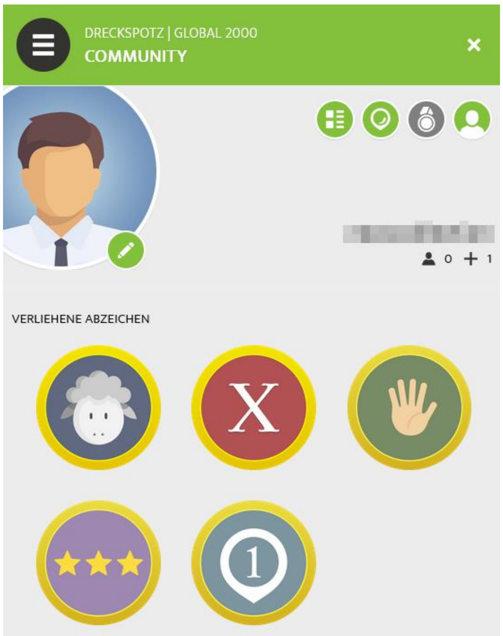

Figure 23 examples for badges for submitting several spots

In the evening we showed the spots to other family members on the computer and we checked that the categorization and location was done correctly. We made a few corrections including applying a better fitting category which we did not see in the first place. Sharing the achievements with other people demonstrates that there are also additional ways for engagement outside the data collection process and going beyond observers and peers.

We then checked the maps for spots from other users in our area and realised that there are not many contributions. Browsing further we realised that in the Wienerwald area there are many spots close to the main roads and walkways. This invites further research on how areas with and without contributions are presented. Empty spaces could mean that there is no litter or that there are no people observing. Dirty spaces could mean that there is a lot of garbage but it could also be relatively overrepresented if many people report in these areas.

One spot included a fallen tree. We got into a discussion of whether this can be considered as litter. Taking this further it becomes interesting to study what users of the app believe is the result of submitting an observation. It might be worthwhile reporting a fallen tree if the app has the potential to initiate freeing the path again. This would require informing the relevant authorities which might be different for garbage and trees.

Using a smartphone app to document the trash collection process slows down the effective rate of cleaning. However it allows to present individual users as responsible cleaners and documents the occurrence of trash in the observed area. Involving citizen scientists in data collection suggest a potential for a large number of contributions but not necessarily broader coverage. I suggest providing clear guidance on the goals of the project and understanding individual motivations to make sense of the collected data.

With my own contributions to the Dreckspotz/Litterbug app I got interested on the overall dataset. Since I already had contributed to the project I had a user account and could download the data directly after accepting the respective licence.

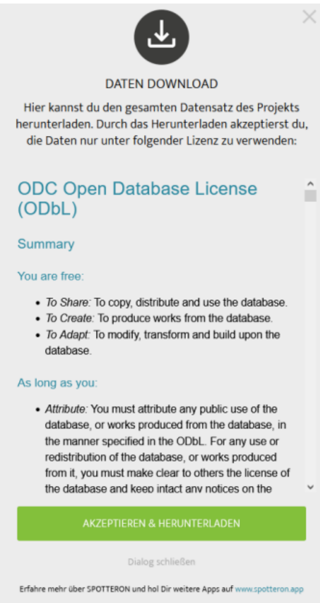

Figure 24 accepting the open data licence

The dataset is provided as csv File without information about the meaning of columns or the quality of entries. There seems to be no online tool available to analyse data directly and no handbook, guide or tutorial on how to approach the dataset.

I checked the content in a simple text viewer to find out that the separators are semicolons. Then I pasted the content into Excel and converted the individual lines into columns (cp. Figure 25).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	ID	ROOT_ID	LATITUDE	LONGITUD	CATEGORY	LITTER_CA	LITTER_CA	LITTER_CA	LITTER_BR	LITTER_CC	DISPOSAL	DISPOSAL	DISPOSAL	DISPOSAL	IMAGE	LITTER_CL	DESCRIPTI	SPOTTED_AT
2	17679	17679	48.20766	15.62413	litter	cigarette	butt			13			FALSE	FALSE	https://fil	FALSE	Hauptbah	15/05/2017 09:18
3	17695	17695	48.20814	15.64229	litter	cigarette	butt			30			FALSE	FALSE	https://fil	FALSE	Bushaltes	15/05/2017 16:25
4	17700	17700	48.20033	16.34688	litter	metal	beverage can, 0,33 li		Power Up	1			FALSE	FALSE	https://fil	TRUE	Auf Fenst	15/05/2017 17:49
5	17701	17701	48.20094	16.35063	disposal						dustbin		FALSE	FALSE	https://fil	FALSE	Wiener M	15/05/2017 17:54
6	17786	17786	48.20099	16.34906	litter	metal	beverage can, 0,33 li		Maximal (	1			FALSE	FALSE	https://fil	TRUE	Leere Dos	22/05/2017 14:55
7	17787	17787	48.1998	16.34952	litter	metal	beverage can, 0,5 liti		Ottakringe	1			FALSE	FALSE	https://fil	TRUE	Leere Bier	22/05/2017 14:59

Figure 25 example of formatted open data

Entries are anonymized which makes it hard to find your own contributions. Some of the users seem to have used the spot comment field as a first name tag. This might be form of creative resistance to anonymization or a basic workaround to find your own contributions.

Next I created a pivot table which summarizes the spots by primary and secondary category (columns F and G) and sums up the litter count (J). My first interest was to understand what kind of garbage has been tracked overall. Plastic was the top ranking category and foils the top ranking sub-category (light blue). This ranked even higher than the top level catch-all category Other (orange) (Figure 26).

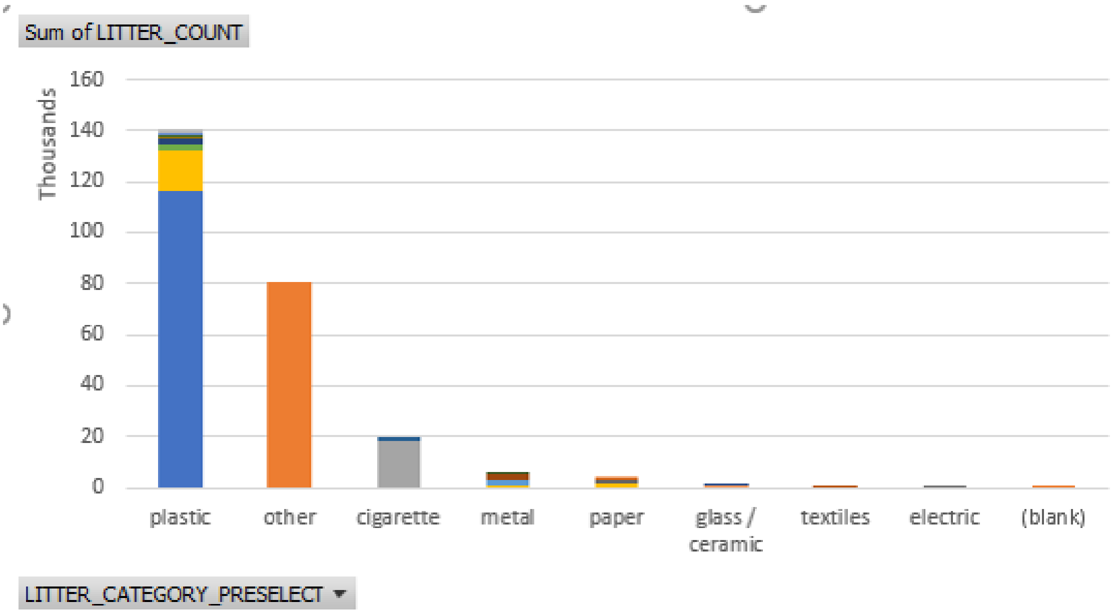

Figure 26 number of reported items per litter category

If we want to reach a real-world conclusion and we do not mind overgeneralizing we might boldly claim that the world is full of plastic and foils make up the largest part. If we are cautious we might state that litterbug users report the highest numbers for plastic garbage. This illustrates that it is hard to reach a practical conclusion concerning the environment working just with the numbers from the litterbug project.

We can see that there are particular types of litter that can be tracked which shapes what is reported and what can be analysed. The high use of the category Other might suggest that individual categories are not suitable for classification of a high number of reported items. There are also entries which have a blank litter category. Figure 25 suggest this includes non-litter categories such as dustbins.

The high number and dominance of reported foil got me interested and I looked into the individual observations which contribute to the high number of reported items. I realised that there are submissions with extremely high numbers, such as the one related in Figure 27 which reports more than 100 000 foil items. This means that this single entry already constitutes the vast majority of reported foil items. Looking at the picture does not help to confirm the unusual high number of reported items.

Figure 27 picture of a spot with high number of reported foils

My quick validation check indicates that the numbers in the reported items cannot be taken as a real measure for accurate quantification. The way trash is quantified might also vary by different categories thus comparisons between different categories might need careful considerations. This opens further research into how quantifications are used in citizen science projects and in the reports that are created with the data afterwards.

It might be helpful to have a quality indicator in the dataset which make it possible to work with validated data only. Alternatively a description of the validity and use of different fields would be helpful for people who want to work with the open dataset.

Looking at the number of observations per category shows a different picture. While Plastic is still the dominant category the types of plastic are more equally distributed. And metal, cigarettes and paper appear before the category Other (cp. Figure 28).

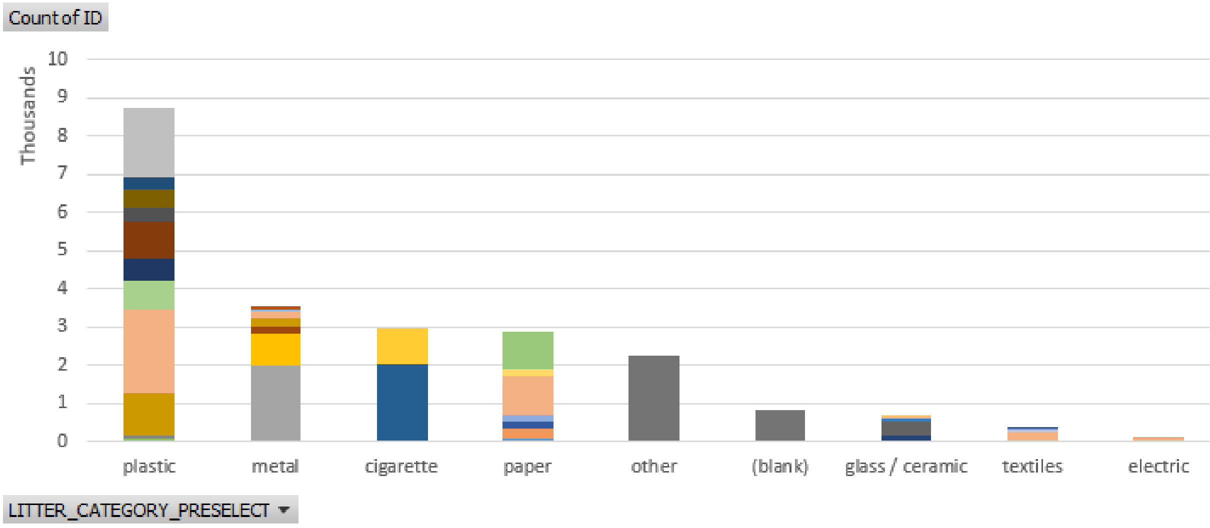

Figure 28 number of observations by category

However the intuitive logic of one spot equals one observation does not hold, as my own experience with the cigarette butts and mixed categories above show. This means that working with data requires different steps of validations before, during and after it is being produced and analysed.

The platform supports open data sharing, but leaves it up to the partners to decide whether to share and which model to use. It does not include tools or documentation which supports non-experts to interact with the data and it does not include quality check information in the export files. This position strengthens effective ownership of data by project partners who possess specific expertise and makes it harder for outsiders to work with project data even in cases where anonymous data is provided as download.

I argue that a central solution on the platform level for working with project data has large potential to further empower citizens. It allows to provide tools which guide analysis and interpretation, include information about the quality and meaning and mark entries that the downloading users contributed. It might also encourage projects to involve users in joint sensemaking events.

This hints towards digital participation and working with data being a part of a broader participatory approach. In the next section this framing will be further explored.

6.4.3 Citizen science as participatory approach

Spotteron describes partners as central for digital citizen science. Partners work together with Spotteron (designing their custom app) and they involve citizens (to collect data). Spotteron mention data management and science communication features as support for partners. Data management includes validating data, producing stable datasets and (real-time) linking to external tools. The last item suggests that a broader view on digital citizen science might include looking at workflow and tools scientists use in their daily work and how these interface with the Spotteron infrastructure. Science communication is supported through providing information about the project in a dedicated section of the app, on the webpage, in newsletters and in push messages. These are all features of the platform. Spotteron stress that they restrict themselves to the technical solution but do not interfere with the scientific aspects which they leave to the partners.

> *We don't interfere with any of the orientation of the project, the topic of the project. When they come with something like a technical stuff then we say it is doable or not. But just the technical part […] [S]ometimes we advise to open it up, that's all. So it gets a little bit more broader participation, perhaps in the future. [I2]*

This does not only involve the project topic but also methodological issues, including the overall participation approach. Spotteron does not directly involve citizens in the design of the science approach, but partners may choose to do so.

> *[T]his is the question if you mean it's a co-design approach. Also we have projects which I'm not experienced with because they do it. But they have co-design meetings. You know like. One project […] it's about one area in the Alps which moves through climate change. So there is rivers behaving strangely, wells drown up. And it's co-created. They go, the science team goes there and creates the questionnaire with them. […][T]he analysis could also be […] a Bürgerinitiative […] [It] depends on the project. Depends where it comes from. From which background. [I2]*

This indicates that in order to understand individual citizen science projects on the Spotteron platform it becomes important to consider both, the perspective of the platform builder which includes the features the platform offers and the perspective of the scientists who use the platform to support part of their practices. Although empirical material on these practices is limited the described partner contributions of financial and domain knowledge indicate that there are broader orientations at play when starting with a partner perspective. I outline a few environmental factors which affect the thematic, organisational and temporal orientations of partners and which offer room for further research.

Partners might have longer-term overall thematic foci which affect what kind of project they run. They might also run broader participatory projects in which the proportion of the Spotteron app might vary considerably. Spotteron apps might be anywhere from an appendix to a large participatory project to the full scale. Some participatory projects might have digital participation through Spotteron apps as their central activity, others might implement a broader set of participatory activities involving the same or different citizen scientist groups (cp. Figure 29)

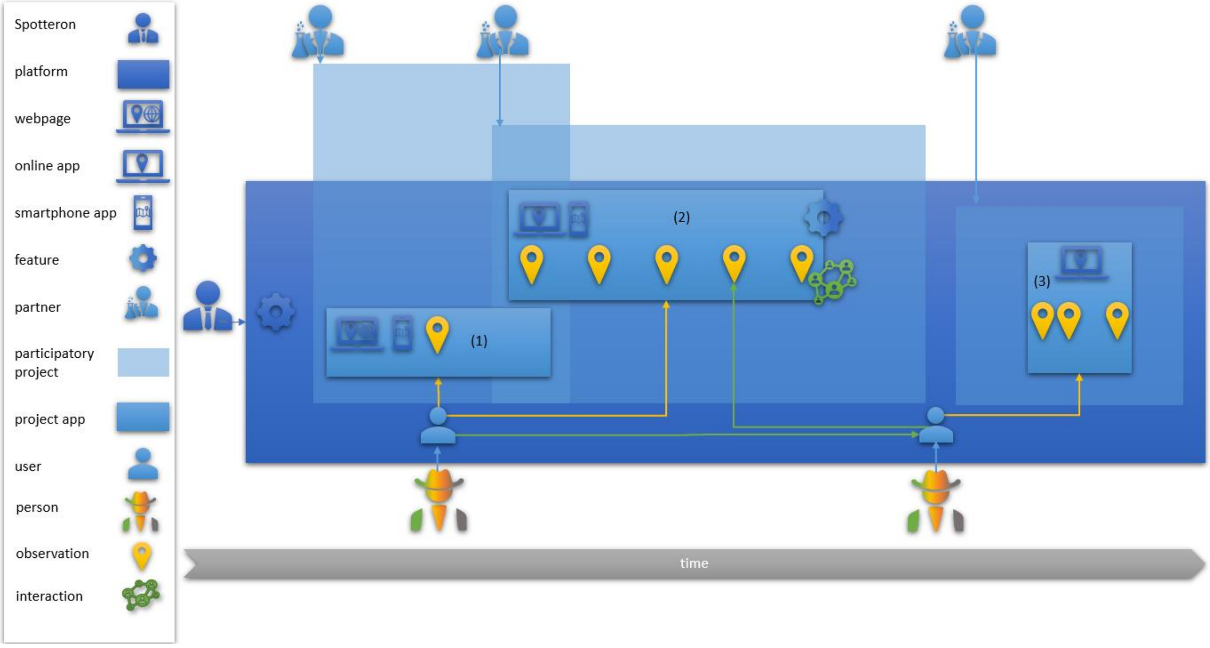

Figure 29 participatory project as integrative perspective

Broader partner perspectives regarding the Spotteron infrastructure include the possibility to work with data beyond the lifetime of their apps, build a network of engaged citizens and attract existing users from the Spotteron userbase. This hints at potential for further research concerning how partners deal with competition for users between projects using the same infrastructure.

The central position of partners offers a promising perspective to integrate all actor contributions using the research process as reference frame and considering the specifics of how the collaborators infrastructure digital citizen science within this. Since empirical material on partner research practices is rather limited I take that thought further to the discussion where I use generic phases of the scientific process in a process-centric visualisation of actor contributions (Figure 31).

7 Discussion: contributions to digital citizen science infrastructures

The aim of my work is to understand what kind of citizen science Spotteron promote through their infrastructure. My focus is on the collaborators and their contributions within this digital citizen science app platform. The empirical work positioned collaborators and their contributions within the dynamic evolution of a digital citizen science infrastructure. It started with the business proposal of Spotteron which is developing a custom digital citizen science app based on a common platform. It then analysed the social media infrastructure that is used for data collection and community building. And finally I explored how broader perspectives of collaborators connect with the infrastructure.

This discussion consists of two parts. The first section discusses key findings of my empirical work in relation to existing literature. In the second section I extend existing citizen science typologies with my own visual method which allows to present digital citizen science as multi-actor participatory activity.

7.1 Refining the state-of-the art: Spotteron as digital citizen science infrastructure

In this section I present literature which connects to my empirical findings. This includes areas as varied as labelling citizen science collaborators, motivations of scientists and citizens, contributions as personal, individual and collective, the heterogeneity or projects as well as openness and temporality of infrastructures. I use the levels of the Spotteron infrastructure as guiding elements of the discussion and extend the Spotteron focus on platform and app with the level of data for partners and features for users.

First I discuss different collaborator labels for Spotteron. Eitzel et al. (2017) suggest that labels used to describe people participating in citizen science projects vary in different settings and individual labels come along with potential caveats. While their focus is limited to the two classic actors citizens and scientists my thesis takes the case-specific labels employed by Spotteron as starting point: Spotteron, partners, citizen scientists and users. Partners and citizen scientists are the labels that correspond to the classic citizen science framing. Spotteron is an additional collaborator which is named rather than labelled. This indicates a new type of actor besides citizens and scientists. User is a label that connects people to the infrastructure. It suggest that there might be multiple labels attached to actors simultaneously e.g. citizen scientists can also be users of an app. I took this as invitation to look at potential implication of the current labels, suggests abstract role-based labels related to the infrastructure which are relevant for digital citizen science beyond the case and alternatives which allow to consider additional contributions that are currently not included.

The focus of the Spotteron webpage is finding partners to design custom citizen science apps based on their platform features. They use the labels Spotteron, partners and citizen scientists which emphasise the close collaboration between Spotteron and partners during app design. When the app is ready partners invite citizen scientists. Collecting evidence is presented through platform features and the label user is introduced which highlights the link of citizen scientists to features of project apps. After the citizen science app project is concluded partners continue working with project data and publish their findings as reports or papers. This indicates that a static view on a particular phase e.g. designing the app is not sufficient to capture all contributions. Understanding infrastructuring requires a longer-term, dynamic and broad perspective.

As a first way to understand how the collaborators infrastructure citizen science I present labels that link collaborators with an infrastructure level and a role (Table 10). These roles acts as first approximation to summarize more detailed contributions which will be discussed later. Spotteron acts as platform provider who maintains and develops features. They are also platform safeguard enabling legally compliant data collection and considering partner and citizen interests. In addition their role as app customizer means designing individual apps to meet partner requirements. Partners are owners and administrators of their project app. This indicates that they are involved in the design of the apps and have control over observation data and access to more features than citizens. Partners work with citizens who are framed as users of app features to generate data that is of interest to the project. After the app project ends partners continue working with observation data in their role as researchers outside the Spotteron infrastructure.

	SPOTTERON		**PARTNERS**		**CITIZENS**
INFRA-STRUCTURE	platform	app	app	data	feature
ROLE	provider, safeguard	customizer	owner, administrator	researcher	user

Table 10 long-term infrastructural role overview with Spotteron

Lin et al. (2016) explore human factors in building knowledge infrastructures. Concerning labels that collaborators identify with they noticed different motivations of people who contribute weather observations. While people who are interested in getting practical experience with collecting weather data or sharing weather data might feel comfortable with labels such as amateur science or citizen science, makers who are mainly interested to build their own equipment might resists such a classification. Applying this finding to the empirical case I contrast existing framings of collaborators with variations that include potential alternative motivations. Understanding different motivations allows to develop additional channels for contributions which increases the potential for participation.

Spotteron frame active users as those who contribute observations or interact using social media features. Browsing and downloading project data is described as passive use. The features browsing, open data and social media require connections to different levels of the infrastructure. Browsing is an open functionality which does not require registration. Downloading open data requires a registration which happens at the platform level. Using social media functions as observer (submitting spots) or peer (interacting through social media features) establishes a connection between the user and the app. These are the framings which focus rather closely on infrastructural dimensions such as features or associations to levels of the infrastructure.

Looking at persons I suggest the analytic labels *interested person*, *potential citizen scientist* and *citizen scientist* which describes assumed roles behind a social media citizen scientist career that aims to enrol citizen scientists to contribute observations and interact around them within a social media community. These analytic labels are not used by Spotteron but derived from the empirical material such as the registration requirements presented in the *Terms of Use* and the descriptions of the evolution of Spotteron from submitting observation towards building social media communities (chapter 3). Implementing citizen science as social media opens up new possibilities for citizen and potentially affects existing practices such as observations. Without social media submitting an observation could be a private issue between an observer and the project team. With social media an observation becomes a public item, open for discussion for other peers. The focus on social media also neglects other ambitions of users of the platform. To illustrate this I present examples for alternative user roles and ambitions (Table 11).

FOCUS/FEATURE	BROWSE	OPEN DATA	SOCIAL MEDIA
CONTRIBUTION	passive user		active user
INFRASTRUCTURE	undefined user	platform user	app user *observer *peer
PERSON	interested person	potential citizen scientist	citizen scientist
ROLE	*app enthusiast *participatory expert *potential client	*data analyst	*organization, group *project staff
AMBITION	learn about surrounding	carry out independent analysis	organize joint mapping events

Table 11 examples of alternative user framings

Browsing project data is done by people who identify as citizen scientists which are the target group for a social media citizen scientist career. Citizen scientists are interested in the science component of the project. However for other users there might be different motivations at play. People who browse could be app enthusiasts who try out a specific project app. They might be more interested in the functionalities the app provides. There might also be people who are interested what is happening in their immediate surroundings or use the app to learn about the project theme without contributing. All these examples include people who might be interested to connect with projects but for very different reasons. There are also other groups of people who might be interested to get an impression of the apps: participatory experts, project owners or potential clients might browse the platform to get an understanding whether it would be suitable to support their own goals.

People who download project data might be analysts who compare and mix different sorts of data and create illustrations for insights they derive from their analysis. These in a sense can be very actively engaged and produce material that is relevant for the project but their engagement happens to be outside the current platform focus.

Social media functions in the app enable and shape contributions of observers and peers. However apps are also used by project staff who are an important part of the community and participatory infrastructure. In addition the assumption of individual citizen scientists as members of the community might also lead to a understanding of a 1:1 relationship between user profiles and individual citizen scientists. This is not necessarily the case as accounts could be shared or a person could have multiple accounts. It also risks assuming that user profiles are identical to persons. However user profiles are digital self-presentations of persons rather than complete representations. Citizen scientists might also carry out activities outside the platform which create value beyond project data such as organizing independent joint mapping events or educational journeys related to a project topic.

Regarding observations Kasperowski and Hillmann (2018) present the distinction between individual and collective contributions. In the case of Spotteron observations are contributed by individual users therefore I referred to spots as individualistic contribution. However embedding them into a social media context enables discussions around them thus enabling the community to contribute. This demonstrates that embedding features within a social media environment might change how these features work. Spots are no longer an individual contribution but an invitation for interaction within a community. Gaining badges for observations is no longer just a motivational factor for individuals but might also serve as indicator of social credit within the project. Similarly the position on the leadership board does not only invoke an internal challenge to contribute more spots than others but is an additional way to promote own spots and attract followers in the social network. In summary contributions are no longer just aimed at the project but also towards gaining social credit within a peer community.

Lin et al. (2016) mention that aggregating data erases the personal character. This happens in a particular way in the Spotteron infrastructure. As long as observational data is contained within the infrastructure it is embedded in the social media logic. This makes observations personal on the individual level by linking it to a user profile. It also makes observations personal on a collective level by collecting input through community discussions. However in structured data that is accessible to partners or in open data downloads the connection to the user and social interactions are removed. The observation remain as floating object without provenance.

Concerning peers Kasperowski and Hillmann (2018) discuss conversations around optical artefacts between scientists and volunteers in the Galaxy Zoo project where volunteer classify astronomic pictures. These artefacts do not have a meaning for the classification task of the project but sometimes volunteers are interested to learn more about them. While in most cases project staff and volunteers engage in more detailed discussions about the artefacts, in about a quarter of the cases project staff lead back to the aim of the project, suggesting to ignore the artefact, assign a fitting classification or move on to the next picture. I call this disciplining through conversation. I extend this with the notion of *disciplining through features* that is present at Spotteron. Social media features are presented as community building features which support keeping citizen scientists engaged by connecting them around spots. There is no way for direct interaction between users. This disciplines users to stay focussed on observations. It also invites spot-related responses between citizen scientists thereby reducing the need for feedback and motivational efforts for partners.

For users heterogeneity of contributions between different apps on the platform require adaptation to new projects. Franzoni and Sauermann (2014) suggest to analyse this by looking at the nature of the task and the required skillset and I connect their conceptual terms to the case of Spotteron.

The platform approach standardizes the nature of the tasks which is observations. The overall approach of Spotteron can be conceptualized as distributed data collection being an independent and well-structured subtask, as it does not require input from other users.

However as features are customized for different projects the app level shows a variation concerning the requirements for participation. Some of the projects require common human skills e.g. classifying litter in nature, while others require more specialised skills or involve particular groups e.g. farmers to study the effects of plastic on soil.

Spotteron suggests that identification with the project topic and the target of observations is also a relevant dimension affecting participation in particular projects e.g. blossoming cycles of flowers might be more attractive than types of spiders and easier to identify with than rivers levels.

In the Spotteron project descriptions more specific types of contributions are mentioned which I classify as passive (provide technology), place (require knowledge about places), process (related to timing of observations) and personal (include judgement or impression). Categorizing is part of individual observation but sometimes discussions between users might lead to changed classifications. Therefore the social media infrastructure offers potential for collective sensemaking.

Spotteron do not enforce a pre-existing expert level for individual projects and aim for broad participation by making their projects available through public app stores. They promote individual and collective learning and rely on self-selection of participants. Expert knowledge is present in most communities through experienced members and project staff. I suggest to open the discussion of requirements for effective collaboration in citizen science beyond citizens to also include other collaborators.

Another aspect in literature is openness which I discuss with relation to different platform levels, project phases and collaborators. Franzoni and Sauermann (2014) suggest that two relevant dimensions of crowd science projects are open participation and open sharing of intermediate inputs. Goëta & Davies (2016) discuss efforts involved in preparing data for open use. This thesis contributes to this by illustrating how Spotteron supports open participation and sharing of intermediate inputs on an infrastructural level.

The development of features is carried out exclusively by Spotteron on the platform level. There is no way for external parties to develop their own features. Platform features are shared with all projects.

Customizing features is carried out by Spotteron with partners contributing requirements concerning their domain knowledge. Citizen scientists are not included in the collaboration with Spotteron. Some partners set up separate co-creation processes to include citizens e.g. in defining surveys. Project apps can be downloaded through public app stores.

Project data is available for browsing even without login. This includes community comments around the observations which might include additional input and context. Systematic access to observation data is available for scientists. For citizens access is restricted through a few measures. Providing open data is not a standard features of the platform but rather an individual decision of the project. Downloading open data requires registration at the platform level. There is no documentation on how to open the data export, interpret the dataset or understand the quality of individual contributions. This puts access to observation data at the discretion of projects and for users requires technical expertise and introduces uncertainty when working with open data.

Temporalities are another relevant aspect in the literature on infrastructures. This thesis contributes a discussion on temporal orientations around features and data and going beyond the infrastructure to also include external influences such as the environment or collaborators. Karasti et al. (2010) suggest that different temporal dimensions are present while working on infrastructures. Specifically they mention tensions between developers who use a fixed project time and information managers who think in open end infrastructure time. For the case of Spotteron project time can be related to the level of apps and infrastructure time to the level of the platform.

I extend temporalities to Spotteron features which are collected at the platform level and customized for individual apps. This introduces the challenge to estimate the potential of new features for future use in other projects in order to decide which ones should be maintained. Maintenance thus is an activity that connects the long-term orientation of the platform with the short-term orientation of the app.

Data is collected on the app level but used separately by partners after apps are gone. Citizen scientists contribute data according to their individual capacities. Observations themselves might be affected by external temporal aspects e.g. seasons in phenology or breeding cycles of animals. This connects temporalities within the infrastructure with outside orientations.

User registration at the platform level enables participation in several projects while keeping their social network. In addition to attachments to individuals projects this enables users to contribute to several projects on the platform simultaneously or sequentially. This provides a longer-term perspective for the user base of Spotteron.

Partners follow their own long-term issues and carry out projects which support this. This might include participatory projects in which Spotteron solutions can be a larger or smaller part. The level of the overall participatory project adds another layer of temporality which I suggest to use as central reference when discussing digital participation infrastructures.

The aim of my thesis is to present how Spotteron suggests infrastructuring citizen science. Therefore as a last part of the literature discussion I position Spotteron in two frameworks which can be used to classify citizen science.

Haklay (2013) introduces levels of participation and engagement of citizens in volunteered geographical information. He includes a dynamic perspective through considering the involvement in different phases of the science process from crowdsourcing to extreme citizen science. In this typology Spotteron can be seen between distributed intelligence (level 2) and participatory science (level 3) as it involves citizens as basic interpreters during observation but excludes them from problem definition.

Schrögel and Kollek (2019) develop a participatory science cube which is a multidimensional model classifying involvement of volunteers from institutional scientists to citizens related to the dimensions epistemic focus, normative focus and reach. Epistemic focus includes the involvement in the knowledge making process, normative focus depicts the involvement in governance and reach the level of openness of participation. With regard to the epistemic focus of citizens Spotteron is between crowdsourcing (submitting spots) and public input for analysis (classification and discussion of spots), the normative focus is left to institutional partners (e.g. defining project goals) and the reach is between an interested to broad public as Spotteron aims to keep projects relatively open.

These models include inspirations to grasp the dynamics of digital citizens science such as the necessity to understand differences within citizen science at the task level which I capture on a broader level by discussing contributions and the involvement of collaborators within the broader knowledge making process which I address by including phases and capturing complexity by using a multidimensional model considering different levels of the infrastructure and different groups of collaborators.

The models found in literature do not allow to present infrastructuring contributions of multiple collaborators. They focus on volunteers but not on the contributions and collaborations between multiple actors. This would already be helpful for understanding citizen science as collaboration between citizens and scientists. Moreover the case of Spotteron and the variations of labels and roles discussed above indicate that there might be additional collaborators involved in digital citizen science. Therefore I use the rest of the discussion to suggest different ways to approach this multi-actor challenge using Spotteron as illustrative example.

7.2 Beyond the state of the art: digital citizen science as multi-actor participatory action

In this section I introduce two visualisation which allow to depict and analyse contributions of multiple actors. The first one is an actor-centred *collaboration profile* which allows to assign contributions to collaborators as individual or collective efforts (Figure 30). The second one is a process-centred *involvement profile* which shows the involvement of individual actors in different phases of the research process (Figure 31).

I choose to first build a collaboration profile and use this as the basis for a transformation into an involvement profile. As a first step towards a broader participatory approach I link activity codes and collaborators which I identified through an analysis of the Spotteron webpage. This includes a broader perspective including contributions which are not purely digital and happen outside the infrastructure. I call this graphical depiction a collaboration profile (Figure 30).

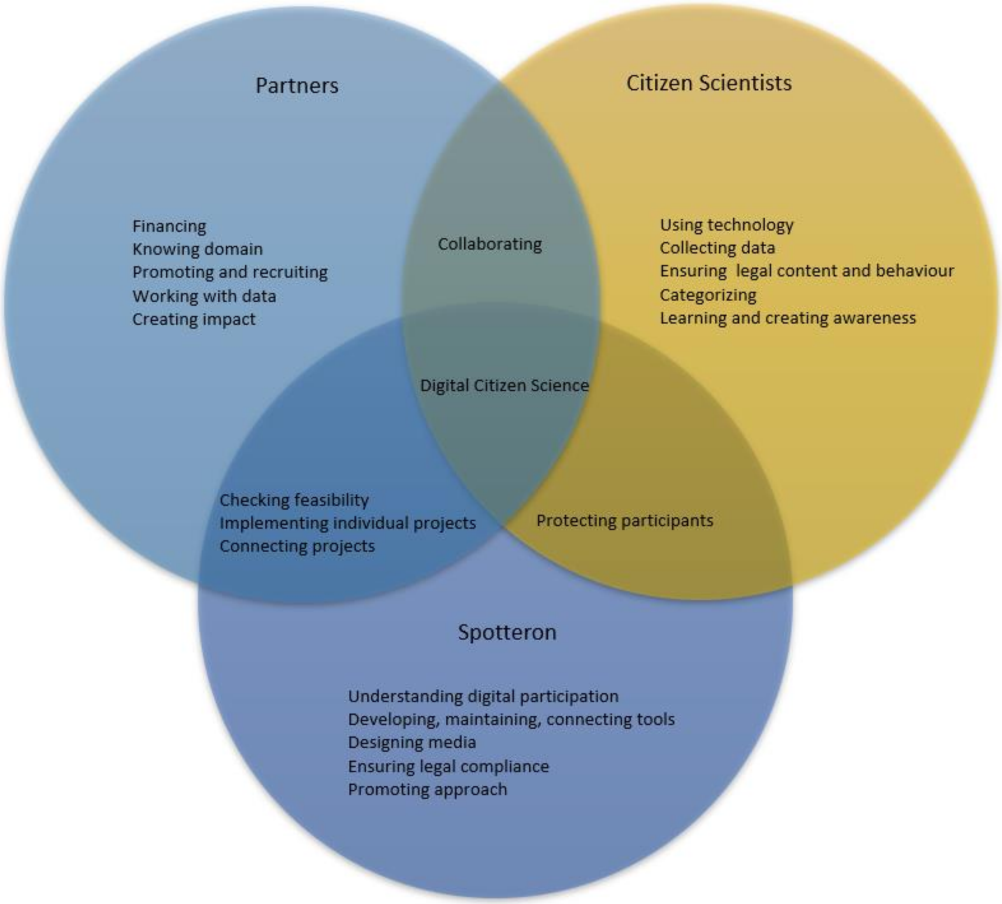

Figure 30 collaboration profile for Spotteron

Each collaborator is represented by a bubble. Contributions which a collaborator carries out on their own are in the area without overlap with other bubbles. Activities which require contributions from several collaborators are represented through overlap areas.

Individual activities of partners include financing, knowing the domain around their issue, promoting and recruiting participants for their project, working with data and creating impact. Citizen scientists use their technology to collect data and ensure that their contributions are legally valid. They learn about their environment while assigning categories in their observations and they may create awareness within their social environment. Spotteron further develop, maintain and connect their infrastructure in line with legal requirements. Designing custom project identities for their partners is important for Spotteron to enable a personal connection to individual projects. Spotteron also promotes their digital participation solution.

Joint activities include Spotteron and partners bringing in their respective expertise to check whether it is feasible to meet their requirements with the Spotteron platform. They then customize an individual app collaboratively. Partners use forums to connect with Spotteron and other projects. Partners and citizen scientists collaborate within social media community activities. Spotteron make recommendations which citizen scientists can implement to protect themselves.

This visualization encourages to understand digital participation as multisided and on equal footing between different contributors. Although they have a different focus all contributions are relevant to establishing a particular form of digital participation which emerges at the convergence point.

I call the intersection of all circles digital citizen science. In this case this should not suggest an overlap area but digital participation requires a combination of individual and collective contributions by different collaborators which are not necessarily purely digital.

The separation of collaborators might vary in different settings. DIY movements which produce technology that is used to drive their own issues might assume all three expert roles. Design projects might develop their own tools but still involve external contributors for their interventions and therefore focus on issue and technology. Collaborator labels can also be adjusted for other cases, depending on what the particular roles comprises.

Instead of using Spotteron, partners and citizen scientists abstract descriptive roles might be valuable, some of which I presented in the previous section. Using abstract role labels e.g. technology provider, participation facilitator or observer is valuable as reference points for contributions. This can be helpful to identify role confusions. An interview with Spotteron serves as an illustrative example: Spotteron described their strong involvement to collecting evidence. Referring back to abstract roles it quickly became clear that they were speaking from their identification with the role citizen scientists rather than platform providers.

In other cases when the focus is on clearly assigning responsibilities it might make sense to additionally introduce specific organisational names. Assuming that different individuals take up different roles it might also be useful to analyse how contributions are distributed amongst individuals instead of aggregated actors. One way to do that would be to introduce individuals as additional bubbles and position them on the existing visualisation e.g. within their respective organisation bubble.

The focus on mapping activities and contributors leads to a static perspective which does not consider the dynamic evolution of the infrastructure. To remedy this I use participatory projects of partners as central reference point. This is a perspective that is more stable across different cases than the platform-app approach of Spotteron which has been used in previous chapters. Partners are presented as the stable drivers of the project which are involved in all project phases and interface with all other actors. I define phases which are broad enough to cover activities of a range of partners within academia and civil society that Spotteron aims to attract.

Partners initiate projects in order to solve identified issues. They design a suitable approach which includes collecting evidence for analysis. After the project they communicate the solutions for their initial issues to their peers or stakeholders. I call this the IDEAS scheme because the phases aim to engage with issues (I), design (D), evidence (E), analysis (A) and solutions (S).

These phases allow to position the activities of Spotteron collaborators within a generic process. One way to focus on the phases is to put up a two dimensional table with collaborators and phases and list their contributions in the appropriate cell. I also included an indicator for the degree of involvement of different collaborators. For this I marked high effort contributions with + and low effort contributions with **-** (Table 12).

PHASE/COLLABORATOR	SPOTTERON	PARTNER	CITZEN SCIENTIST
ISSUE	+understanding digital participation -checking feasibility	+knowing domain +financing -checking feasibility	
DESIGN	+developing, maintaining, connecting tools +designing media +ensuring legal compliance -implementing individual projects -connecting projects -protecting participants	+knowing domain +promoting and recruiting -implementing individual projects -connecting projects	
EVIDENCE		+collaborating	+collecting data +collaborating -using technology -ensuring legal content and behaviour -protecting participants
ANALYSIS		+working with data	-categorizing -learning and creating awareness
SOLUTION	-promoting approach	+creating impact	

Table 12 collaborator contributions in project phases for Spotteron

This should be seen as an informed qualitative assessment rather than a process with quantitative precision. I did not measure hours spent by different collaborators and these might also vary between different projects on the Spotteron platform. Instead I used the empirical material to suggest levels of magnitude concerning involvement for a supposed standard Spotteron approach.

Defining the issue is driven by partners who bring in their domain knowledge and financial resources. Spotteron adds their know-how on digital participation. These contributions allow to check the feasibility of the platform to meet project requirements.

In the design phase Spotteron have high efforts as this includes addressing technical, design and legal issues on platform and app level. Partners contribute their domain expertise and prepare building a project community.

Citizen scientists contribute substantially when building evidence through collecting data. They collaborate within their project community which also includes partners.

In the analysis phase it is mainly partners who work with the collected data. However I suggest that citizen scientist also contribute analytic work by categorizing and learning within the community.

Communicating solutions is mainly done by partners, although Spotteron also have an interest to show the impact of their digital citizen science solution.

Checking feasibility and implementing individual projects can be understood as envelope activities which indicate that these are joint activities by different collaborators that contain more specific individual contributions and therefore the level of contribution is estimated low.

The level of effort in the individual rows reflect the involvement of individual collaborators within a phase and the entries in the columns reflect the centre of gravity of their contributions. Since Table 12 is rather exhaustive I use a summary table which only includes zero to four + signs depending on the level of effort of experts in particular phases and therefore removes specific activities and presents contribution levels of individual collaborators to phases (Table 13).

	SPOTTERON	**PARTNER**	**CITIZEN SCIENTIST**
ISSUE	++	++++	
DESIGN	++++	+++	
EVIDENCE		++	++++
ANALYSIS		++++	+
SOLUTION	+	++++	

Table 13 involvement of collaborators in project phases for Spotteron

This transformation follows the descriptions in the paragraphs above. It encourages a nuanced comparative ranking concerning the contributions e.g. a slight lead for Spotteron in the design phase and minor contributions of citizen scientists in the analysis phase. This cross-checking comparison and fine-tuning approach is supported through the structure of the table with two dimensions in rows and columns. This table can be transformed into a spider graph which I call involvement profile (Figure 31). For the visual presentation the + signs have been transformed to values on the axis. The value range goes from 0 to 100 with each + signs representing 25. These values are not used as axis labels to avoid the impression of quantitative accuracy. The further outside the higher the involvement of the actor in the respective phase.

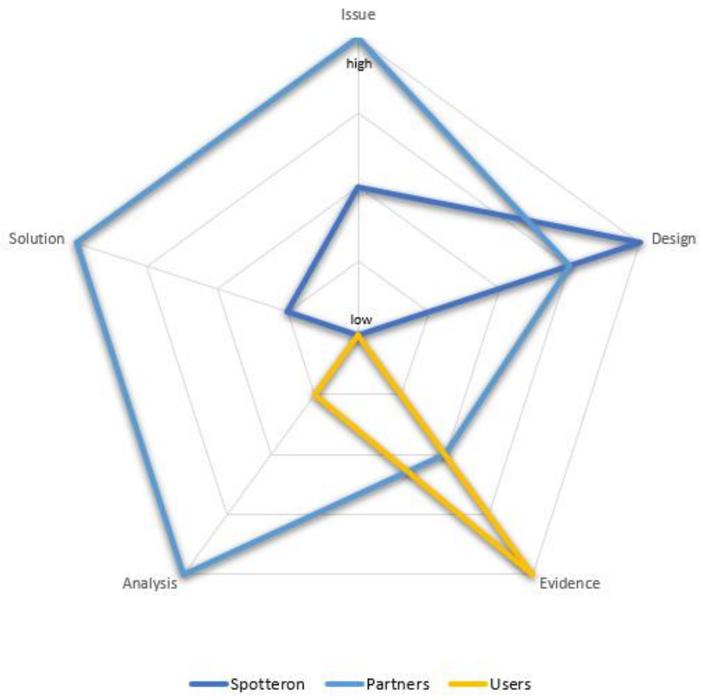

Figure 31 involvement profile for Spotteron

The table and graph illustrates that partners are the collaborators who hold the projects together by being involved in all phases. Spotteron is mainly involved in the design phase customizing apps to address partner requirements and citizen scientists are mainly collecting evidence.

This depiction does not consider the different levels of the infrastructure but uses generic phases which could be applied for the analysis of other participatory approaches. My approach was to start with a narrow digital development logic and expand the perspective through including a limited number of broader phases which can potentially also include other participatory elements. Different ways to structure the phases are possible e.g. splitting design into technical design and research design or including other phases such as promotion or dissemination. The list of contributions strongly reflects my analysis of the Spotteron webpage. The phases and contributions I present are flexible starting points and inspiration for further scholarly and practical discussion and refinement rather than fixed end points. Using a consistent phase model would allow comparative work between different digital participation approaches.

Using the degree of involvement does not suggest a hierarchical value judgement. For a participatory project more involvement is not necessarily better. Successful participation aims to maximize quality of results through opening processes appropriately, involving relevant collaborators, and using adequate methods and tools. The aim of this visual method is to get a quick impression on the involvement of different collaborators in different phases with a focus on activities relevant around the Spotteron infrastructure.

Digital participation solutions can be realised through different actor constellations. Sometimes digital participation project organizers also develop the tools they use for their projects. This requires them to possess technical expertise in addition to domain and collaboration expertise. This constellation means that the actors doing the design and development are equally close to the community which gets involved in the digital participation project. This is a chance for involving potential users directly in design and development.

In other cases (such as the one studied in this thesis) solution providers offer applications for or develop them with partners who want to involve citizen scientists. This leads to a greater gap between actors who provide the solution and those who use it. For platforms the distance to users is potentially greater with a larger and diverse user base compared to single-use apps.

When solution providers and partners work together closely it is their preferences, perspectives and interests which are reflected in the digital participation tools, not so much those of the citizen scientists. Even if they assume to have a good understanding of users it is their imagination of users which is considered. Therefore I suggest to consciously decide how collaborators are involved in infrastructuring digital science. For this I suggest to understand the digital citizen science component as one part of a broader participatory approach.

8 Conclusion: aligning collaborator perspectives in digital citizen science infrastructures

This chapter concludes my investigation on what forms of citizen science the platform providers Spotteron promote. In the first section I integrate main findings, discuss limits of imagined forms of collaboration and include practical ideas on how additional contributions could be supported. This should not be understood as a normative pledge towards more participation but as illustrating contrast to show how that the configuration of collaboration present in this work is just one of many possibilities.The second section presents ideas for further research and finishes with ideas on how the visual tools developed as part of my work can also be used by practitioners. In that sense these conclusion aim to be relevant for all groups involved in digital citizen science: technologists, citizens and scientists.

8.1 Main findings

In citizen science lays so much potential, if it's done right. In our opinion, the symbiosis of scientific or environmental goals with those amazing high-tech computers and sensors, everybody of us carries around in the pockets everyday can help not only scientific research, but also the way people recognize and care about their surroundings. By their ongoing involvement, citizen scientists become part of something much bigger - a growing and curious community.

[Spotteron Webpage: About > Mission[28]]

The mission statement of the Spotteron presents citizen science as involving a combination of *science* and *technology* to support people to connect in meaningful ways with their *environment* and with each other in *communities*. This provides an overall setting of citizen science as science and technology driven educational community experience. In my thesis I analysed in more detail which forms of collaboration Spotteron suggest to realise their mission.

Spotteron, partners and citizen scientists are identified as main collaborators and they are described as contributing to different aspects of this mission statement. Partners provide their domain-specific knowledge when aligning projects with *scientific or environmental goals*. Spotteron build on their technological and design skills as well as their own experience as citizen scientists to develop *mobile participation apps*. Citizen scientists are involved in topic-related *social media communities*.

[28] https://www.spotteron.net/about/mission, last accessed: 13.12.2022

In my analysis I looked at three interconnected levels of the technical architecture: *platform, app and features*. Individual collaborators contribute to different levels in line with their personal ambitions. Spotteron maintain their *platform* a central repository of features which they customize during *app development*. Partners administer these *apps* to enable *digital participation*. Citizen scientists use app *features* in line with their *personal motivations*.

In addition in my analysis I identified three framings of digital citizen that highlight different level of the infrastructure: digital citizen science as *long-term platform building*, *app-based project* and (*practice supported by features for) spot centred social media interactions.*

The perspective on *long-term platform-building* includes multiple projects running in parallel. Spotteron maintain the platform which allows to share features with all projects. Drawing on a common set of features can be understood as a form of standardization of technical support for citizen science practices. Partners may commission new features which Spotteron develops. This perspective encourages exchange of partners across different projects to shape digital citizen practices. There is potential for inviting additional contributions by opening the development process for partners or tech enthusiasts.

For citizen scientists the platform allows to follow their community across projects and contribute in different projects using similar interfaces. This turns citizen scientists on the platform into a potential resource for all projects. There is potential for long-term contributions of citizens on the platform level such as inviting experienced Spotteron users in the design of new features or strategic platform decisions.

Understanding digital citizen science as a*pp-based project* positions partners as the centre of citizen science. Partners work with Spotteron to develop custom apps for participation. Partners use these apps to involve citizen scientists. An extended temporal perspective includes activities that are based on data collected through these apps such as publications or reports. A broader partner perspective positions digital citizen science with apps within the participatory component of an overarching research project.

Citizen scientists need to resolve ambiguous situations during observations e.g. how to classify multiple items from different categories. They could be further supported through information on how the contributions of citizen scientists are used in the project and FAQs or (short video) trainings which show how to provide relevant data include ambiguous situations.

The app design process is currently a closed collaboration between Spotteron and partners. Involving citizens in the design of the project and app could be supported by co-design approaches. Implementing structured ways for bottom-up activities would allow citizen scientist to contribute during the course of projects.

Features are most prominent when presenting *digital citizen science as social media interactions around observations*. The focus is on app features which support citizen scientists. These include two main generalisations defined at the Spotteron platform level. The first is defining observations as geo-located classification activities (spots) which fits for many partners with an environmental and natural science background which potentially reduces diversity of supported topics. The second one is implementing social media features as overarching regime for citizen scientist practices. This supports particular practices rather than others and shapes how existing and new practices are carried out and perceived.

The focus on social media changes the act of submitting observations from exchange between citizen scientist and project towards sharing within a community. It supports liking as appreciation and commenting as validation of observations. This enables users to contribute own observations and validate contributions from other users. Spotteron restricts interactions to observations and it does not support forms of direct interaction between users. This keeps citizen science focused on the project goal of collecting validated data but restricts connecting on a person to person level. Opening communication beyond spots, either introducing additional activities or enabling direct messages between users would broaden the spectrum for contributions for citizen scientists.

Social media communities are built through following other users. The user profile acts as central reference point that presents credibility through a collection of spots and badges for achievements. Anonymous contributions are not possible because social media interactions require a profile which hints at a tension between values of privacy and connectivity. If people decide to provide additional information in their profile e.g. concerning their interest then enabling to search for people with particular attributes could also foster additional collaboration.

The focus on contributing spots within a social media framework suggests a user career for which I introduced abstract vocabulary. It starts with *interested persons* who browse project data anonymously. Those are encouraged to register with the platform to become *potential citizen scientists*. The next expected steps are using the app to provide data as *observer* and becoming *peers* using social media features to interact with the community.

This model frames using the app as active and alternative practices that involve browsing data and engaging with open data as passive. This narrow framing of individual users on a path towards observers within social media community neglects potential alternative motivations and benefits such as browsing to learn about the local environment, carrying out independent analysis of open data and organising bottom-up events. Exploring and supporting such alternative engagements and providing channels to make these visible would be a ways to provide additional inspirations for broader contributions.

Currently projects do not provide open data as default and the platform does not provide support beyond downloading a data file. One way to strengthen this alternative practice is promoting open data as platform default and providing documentation, tools and communication channels which support citizen scientist in producing, discussing and publishing results of their data analysis.

Publishing events is only possible for partners. Encouraging citizen scientists to publish events directly within their communities or suggest activities relevant for the project is another potential way to foster bottom-up contributions in a structured way.

Overall a strong focus on features renders invisible the active role of citizen scientists who employ their technical devices and draw on their personal experience and knowledge of places and processes when contributing. Ways to highlight these would be to actively mention these contributions throughout the webpage, editing existing sections such as the project descriptions, or setting up a separate section or version of the webpage that specifically address citizen scientists.

8.2 Further research

This thesis looked at how Spotteron describes citizen science on their webpage as collaboration between different actors within apps that run on their digital platform. Therefore it involves an interpretative stance in the analysis of how citizen science is presented by designers. First validation steps such as autoethnography and interviews were incorporated in this work but there is still space to directly investigate the perspectives of different collaborators e.g. carrying out interviews or ethnography with citizen scientists or partners.

The case of a commercial and local digital citizen science platform is a first step towards introducing diversity compared to the US platforms dominantly analysed in literature on digital citizen science (Section 2.2). There are more opportunities to explore the variety of digital citizen science practices focussing on the involved collaborators.

Studying the variation of business models of platforms and their potential effects on citizen science could be one approach that sticks with the designer view. There are other digital participation platform with different payment models and openness such as Sapelli[29] (open source and free) or Epicollect[30] (free and changed from open source to closed source) or Coreo[31] (commercial and closed source) to name a few.

Another stream of investigation would be to look at different backgrounds of citizen science project organisers. These include exploring different practices promoted by academic and non-academic research organisations as well as non-research organisations such as environmental protection NGOs.

[29] https://www.sapelli.org/, last accessed: 13.12.2022
[30] https://five.epicollect.net/, last accessed: 13.12.2022
[31] https://coreo.io/, last accessed: 13.12.2022

The variety is also not limited to platform approaches but also to individual apps that run at single platforms. This invites studies on how users decide which and how many projects they contribute to, how platform organisers promote cross-app use and how project organisers relate to this competition when aiming to attract citizens and keep them engaged.

This thesis provided first insights how particular infrastructural levels such as maps, social media and data affect existing citizen science practices. There are plenty of additional opportunities related to this.

For social media this involves investigating which values social media features import into citizen science (e.g. attention grabbing, positive reinforcement, self-presentation) and how these affect citizen science practices or non-native social media functions as well as exploring how delegating functions that are otherwise fulfilled by project organisers (e.g. feedback for submissions, encouragement, social credit) to digital communities work out in social media community settings that involve both citizens and partners.

Understanding how maps populated by citizen scientists are used by project organisers is another opportunity that reaches beyond this thesis. Spotteron relies on maps and classifications as crucial infrastructural elements. This might skew the focus of project partners towards research questions with a spatial component which can be mapped. Maps are necessarily incomplete representations of the world and the choice what is represented includes a political dimension. At the same time maps are sometimes perceived as accurate and complete. Citizen science contributions usually do not aim at systematic coverage. Therefore it becomes an interesting further research question how the data collected in the projects and the maps which are created with it are presented in different contexts (e.g. research or advocacy) when aiming to create impact.

Since technical infrastructures and human practices are related to each other there are also opportunities to enable additional forms of participation. When providing open data supportive measures are necessary to make these data usable to a more general population. This includes documentation, tools which support analysis and potentially ways for sharing and discussing independent analysis. There is also the potential to enable participation beyond the digital such as enabling users to connect to each other on a personal level and potentially also promote independent activities which are related to the project theme such as joint mapping or analysis sessions.

On the rhetoric level we have seen that different stories about citizen science infrastructure highlight different technical capabilities at varying levels such as platforms, apps, social media, features or data and involve different framings of collaborators and their contributions. It appears critical to actively consider broader perspectives and contributions of all involved actors. This could encourage more flexible longer-term engagement opportunities and an egalitarian presentation of different collaborators.

This thesis supports such a multi-actor approach towards digital citizen science. The abstract labels and visual tools introduced in this work encourage negotiations and conscious decisions on whom to involve at which stage of the citizen science process. Researchers may apply those tools analytically to further cases and suggest refinements based on cross-case comparisons. Beyond this these tools aim to be relevant for practitioners.

The collaboration profile may serve as a way to depict contributions of different collaborators in diverse digital participation settings. It invites to look at each actor or group and identify contributions. For this the number of actors, their labels, the list of contributions and their position can be adjusted. It also allows to introduce new analytical aspects e.g. adjust overlaps (e.g. representing degree of collaboration), size (e.g. representing contributions) or colour codes of different actors as well as include individuals as bubbles within aggregate actors.

The involvement profile allows a faster grip on understanding which collaborator appears to be involved in which phase of the project. This can be useful when comparing variations in collaboration between different projects or approaches. It may help project organisers to select digital solutions that support an appropriate degree of involvement of different contributors. For this project organisers could draw a complete involvement profile which suggests their ideal distribution of involvement for different contributors. This includes decisions such as how deeply they want to get involved into design issues or how strongly they intend to involve citizens and how strongly those contribute respectively in each project phase. These decisions would best be made without thinking about (potential technical) solutions in mind. Platform experts could do the same exercise independently but focus on their understanding of the project as well as the capabilities of their platform. It would be helpful to discuss scales beforehand so that the illustrations are comparable. With this preparation these two illustrations could be brought together and discussed. This gap analysis can be helpful to discuss in detail different expectations and understandings as well as the degree of digital support available for different degrees of participatory engagement. In this context it is important to note that not all participation has to be digital but digital means can be part of the participatory mix. The flexibility of the visual tool allows to depict actors, roles and phases which are relevant for particular citizen science configuration on platform and project level. For projects they can also include specific, individual contributors instead of aggregate ones. This translation into a qualitative overview could follow different logics which are dependent on the analytic purpose. Instead of depicting the degree of involvement (represented through effort of contributions) it would also work to depict power structures (who leads which tasks and phases) or the degree of interactions (collaboration with other actors). If done with several actors it is important to agree on the purpose, logic and scale of the depictions. This in itself can help to move towards a more common understanding, particularly when involving actors with diverse backgrounds. With these tools this master thesis makes a contribution to supporting collaborators in digital citizen science to align their political and practical views around participation and contribution.

This thesis does not aim to give the final word on what digital citizen science is. It rather presents and discusses forms of digital citizen science identified through empirical work. This is an invitation to you as reader to join the discussion and shape the understanding of digital citizen science or get active and fill the practice of digital citizen science with life.

Appendix

German abstract

Diese Arbeit schlägt vor digitale Bürger*innenwissenschaft (Citizen Science) als Zusammenwirken mehrere Akteure zu begreifen. Technologieanbieter entwickeln digitale Funktionen die beeinflussen wie Citizen Scientists Daten beisteuern und wie die Wissenschaft diese nutzt. Die Betrachtung dieses Zusammenspiels erweitert den in der aktuellen Literatur vorherrschenden Fokus auf einzelne Akteure.

Der gewählte Fall Spotteron, eine österreichische kommerzielle Plattform für die Entwicklung digitaler Citizen Science-Apps, bietet einen Kontrapunkt zu oft untersuchten US-Plattformen. Wie Spotteron Citizen Science präsentiert wird anhand von Webseitentext, Interviews, Autoethnographie und digitalen Experimenten analysiert. Dabei werden drei Darstellungen identifiziert:

Die erste Perspektive beinhaltet das Geschäftsmodell von Spotteron, das digitale Bürger*innenwissenschaft als App-Design auf der Grundlage gemeinsamer Plattformfunktionen darstellt. Diese betont die Zusammenarbeit zwischen Spotteron, die Design und technologische Kompetenz bereitstellen, und Partnern, die Fachwissen und Finanzierung einbringen. Fokus ist das Ermöglichung des korrekten Erfassens von Beobachtungen durch gut gestaltete Benutzeroberflächen und Workflows.

Das zweite Verständnis betrifft das Teilen von Beobachtungen innerhalb einer Social-Media-Community. Dabei liegt der Schwerpunkt auf den Citizen Scientists als Nutzern von App-Funktionen. Daraus lässt sich ein zugrunde liegendes Karrieremodell für Citizen Scientists ableiten. Dieses verbindet Nutzer*innen mit verschiedenen Ebenen der Infrastruktur wie Plattform, App, sozialen Medien und Daten. Diese Karriere beginnt als interessierte Person, welche anonym Projektdaten durchsucht. Diese werden ermutigt, sich auf der Plattform zu registrieren, um potenzielle Citizen Scientists zu werden. Citizen Scientists können als Beobachter Daten über die App bereitstellen oder als Peers die integrierten sozialen Medien nutzen, um mit der virtuellen Community zu interagieren. Die Einführung sozialer Medien in Bürger*innenwissenschaft verändert bestehende Citizen Science Praktiken. So sind Beobachtungen nicht länger potenziell anonyme, individualistische Beobachtungen, die ausschließlich mit dem Projektteam geteilt werden. Stattdessen werden sie zu personalisierten, offenen Einladungen zur Interaktion mittels sozialen Medien für die Projektcommunity. Das beinhaltet, dass ein Teil des Feedbacks, für den ursprünglich das Projektteams zuständig war, an die Community delegiert wird.

Die dritte Sichtweise ist die Zusammenführung breiterer Perspektiven verschiedener Beteiligter. Dazu gehört das Verständnis der digitalen Bürger*innenwissenschaft als Plattformlösung für Technologieanbieter, als persönliche Erfahrung für Citizen Scientists und als partizipativer Ansatz für Wissenschaftstreibende.

Um weitere Untersuchungen zu unterstützen, werden in dieser Arbeit abstrakte analytische Bezeichnungen und visuelle Werkzeuge vorgestellt. Diese ermöglichen die Beforschung digitaler Citizen Science Plattformen und einzelner Projekte. Dazu gehören ein Kollaborationsprofil, das die Mitwirkenden und ihre individuellen und kollaborativen Beiträge darstellt. Außerdem ein Beteiligungsprofil, das es ermöglicht, das Mitwirken mehrerer Akteure in allen Phasen eines digitalen Bürger*innenwissenschaftsprojekts darzustellen. Dieser Werkzeugkasten kann als Ausgangspunkt für Wissenschaftler*innen dienen, um verschiedene Formen der digitalen Beteiligung zu untersuchen und zu vergleichen. Außerdem ist er relevant für Citizen Science Praktiker*innen, die sich Klarheit darüber verschaffen möchten, in welchem Maße sie Beitragende in ihre Projekte einbeziehen wollen und wo digitale Technologien sie dabei unterstützen können.

English abstract

This thesis suggest to understand digital citizen science as collaboration of different actors: *digital* features are designed by technology providers which relate to the ways *citizen*s contribute data and how *science* uses it to solve an issue. This integrated multi-collaborator perspective aims to widens the predominant focus on single contributors in current literature on digital citizen science.

Asking how the Austrian commercial digital citizen science app development platform Spotteron presents citizen science provides further variation compared to often studied US platforms. Analysing webpage texts and enriching them with interviews, autoethnography and digital experiments reveals three relevant framings of digital citizen science.

The first perspective includes Spotteron's business model which is digital citizen science as *app-design based on common platform features*. This highlights the collaboration between Spotteron who provide design and technological competence and their partners who bring in domain knowledge and financing. The focus is on enabling contributions through well-designed workflows and interfaces.

The second understanding *sharing observations within a social media community* takes up the focus on citizens as users of features. It describes an underlying career model for citizens that connects them to different levels of the infrastructure such as platform, app, social media and data. It includes *interested persons* who browse project data anonymously who are encouraged to register with the platform to become *potential citizen scientists* which can then provide data using the app as *observer* and further becoming *peers* as they use social media features to interact with the community. The introduction of social media into citizen science has potential to changes the meaning of existing practices such as turning observations from potentially anonymous, individualistic contributions shared exclusively with the project team into personalised, open invitations for social media community interactions which also involves delegating part of the feedback of the project team to the community.

The third view is *aligning broader perspectives of different collaborators*. This includes understanding digital citizen science as *platform solution for technology providers*, *personal experience for citizens* and *participatory approach for scientists*. To support further investigation and integration this thesis introduces abstract analytic labels and a visual toolkit that allows to study digital citizen science platforms and individual projects. This includes a *collaboration profile* which depicts collaborators and their individual and collaborative contributions and an *involvement profile* which allows to connect contributions to generic phases of a digital citizen science project. This toolkit can be used as a starting point for scholars to study and compare different forms of digital participation and for citizen science practitioners to develop clarity to which degree they want to involve collaborators in their projects and where digital technologies could support.

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