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ORIGINAL PAPER

"For whom? By whom?": critical perspectives of participation in ecological citizen science

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Abstract
This paper is a search for common ground between two natural scientists, two childhood studies and education scholars and two human–animal studies or critical animal studies scholars all working within a shared citizen science project. The search takes the form of a thematic mapping of existing literature on ecological citizen science, with two questions: "Participation on whose terms?", and "Participation for whose benefit?". First, we draw from the field of *childhood studies* to show how the concept of participation can be theorized further. Second, we recontextualize ecological citizen science research from a *multispecies* perspective, following the non-anthropocentric turn in human and social sciences which has so far drawn limited attention both in educational research and in citizen science projects. We proceed by critically treading the blurry line between predetermined or science-led participation and emergent or participant-led research, forming a fruitful space for examining and reconceptualizing the prevailing human/nature distinction in science and pedagogy. What we end up proposing is not so much a solution to the issues we have located, but rather an invitation to consider participation as a possibility for engaging with the ongoing tensions regarding the apparatuses of power that guide the research practices, researchers' thinking and ethics. For the democratic ethos of citizen science projects, these observations can result in an ongoing process of asking how would it be possible to make space for various knowledges to be regarded as such: How could different kinds of knowledge co-exist, potentially generating more just worlds?

Keywords Ecological citizen science · Participation · Childhood studies · Human animal studies · Critical animal studies

In recent years, the educational and democratic dimensions of citizen science have received growing attention. Science policy bodies have embraced the societal potential of citizen

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science, for example, the European Commission considering it as "[a] boost in democratic legitimacy, accountability and transparent governance" (Figueiredo Nascimento, Cuccillato, Schade and Guimarães Pereira 2016, p. 3). Strasser, Baudry, Mahr, Sanchez and Tancoigne (2019) argue that widening the lens on citizen science research toward parallel participatory approaches provides an important point of comparison for citizen science. Such a point of reference can help in further developing the participatory practices of citizen science projects.

The question of what is meant by participation is thus crucial. In education at large and science education in particular, the participation of children and young people is well researched (e.g., Olitsky and Weathers 2005); however, participation in knowledge construction as part of ecological research, also beyond species lines, still demands attention and this is our particular focus. In this paper, the question of participation is located specifically to young people's and animals' participation in ecological citizen science projects and further justified in two ways. First, as interdisciplinary citizen science projects host human sciences along with natural sciences, a shared understanding of what participation means in each approach and can mean in interdisciplinary practice needs to be developed. Second, when young citizens and other than human inhabitants are identified as stakeholders in research of their living environments, the means with which they can be heard in research situations need to be developed.

Currently citizen science studies involving young people typically restrict their participation in the phase of producing or collecting data only; young people rarely feature in other phases of research projects. Ecological citizen science functions as a framework for projects that are often relatively fixed as involved young citizens cannot modify study designs methodologically or otherwise based on their interests. On the contrary, the young participants are often selected based on their ability to perform the pre-selected methods. Furthermore, these developments, foregrounding the importance of inclusive participation, remain also explicitly anthropocentric. Studies are aimed to be conducted "*for the people*, *by the people*" with other than human animals portrayed exclusively as objects of data collection rather than invested subjects in their living environments, or in some cases even their own lives.

These critical observations related to the practicing of participation in ecological citizen science projects are at the core of this paper. The objective is to discuss the opportunities and challenges of a new, more inclusive, community of practice in the light of existing research literature. The writing began as a search for common ground between two natural scientists, two childhood studies scholars and two human–animal studies/critical animal studies scholars all working within a shared research project: Citizens with Rats [Citizens with Rats—From Citizen Science to Non-Anthropocentric Education, funded by the Academy of Finland (2020–2024)]. The project had emerged as a combined effort of two previous studies: one mapping the rat population of the greater Helsinki urban area with students [Helsinki Urban Rat Project (2018-) funded by Maj and Tor Nessling Foundation, Kone Foundation and Emil Aaltonen Foundation] and the other exploring children's relations to significant animals in their daily lives [AniMate (2017–2021) funded by the Emil Aaltonen Foundation and Eudaimonia Institute of the University of Oulu]. The former had shown that a citizen science project focusing on rat populations with young people is engaging and produces learning experiences but does not affect youth on the level of thinking about rats as members of their communities that much (Aivelo and Huovelin 2020). Insights from the latter project suggested that experienced frictions, rather than harmony in relations to other animals, as well as the possibility of imagining the other as an individual in relation to your life are what matter and engage young people at a deeper

educational, even existential level (Hohti and Tammi 2019). These insights were combined to form the new project CitiRats with a particular focus on difficult co-habitation, centering on the complexities of human–animal co-living in urban contexts and aiming at increasing young people's experiences of their communities as multispecies. The research design required—and keeps requiring—extensive thinking and re-thinking of what participation is, what it "does", as well as who counts as a citizen or a community member, a resident of a shared neighborhood: For instance, are rats included (and what would their "science" look like)? These questions, along with existing observations and critique of participation or stakeholder positions in citizen science, began to justify, if not demand the discussion of this paper.

This paper takes the form of a thematic mapping of existing literature that we have constructed by cross-reviewing each other's main fields of research—ecological citizen science, childhood studies, human animal studies/critical animal studies. In practice, this meant that we worked in three pairs, each pair reviewing studies in someone else's field, all searching with keywords "citizen science", "young people/children", and "animals". We met up as a group of six two times during these mappings and shared our findings on what participation meant in principle and in practice in the papers we had read, and how our understandings differed between the fields we represent. This led to two more ethically focused questions for final discussions that then took the form of this paper: "Participation on whose terms?", and "Participation for whose benefit?". We identified these discussions as missing or at best only implicitly expressed in the papers on ecological citizen science we reviewed. All in all this mapping took place as a thematic and dialogical process meant to develop our understanding and shared ethical take of participation in interdisciplinary work with children and animals. The selection of literature was thus not systematic but served a pragmatic interest: each pair searched and read as many publications, with a timespan of c. 30 years, and geographically diverse, as they felt necessary for being able to discuss and share insights towards sketching a shared community of practice. The list of reviewed texts can be found as an "Appendix".

Focusing on research in each other' fields brought forward not only insights related to other fields of research but on each of our own as well and moreover helped us to realize shared issues between the fields—this is then what we chose to focus on. The notion of participation as an easy given was something that disturbed all of us across the fields and so, instead of accounting our interdisciplinary differences, this paper depicts a chosen and shared goal: to develop the conceptual and practical understanding of inclusive participation in ecological citizen science through our interdisciplinary collaboration.

To set the scene of this paper, we will first outline the field of citizen science and probe its takes on participation. Then, as a result of our cross-reading of texts from each other's fields, we set two critical lenses to ecological citizen science to highlight aspects that we consider crucial to be incorporated into its goal of democratic participation. First, we draw from the field of *childhood studies* to show how the concept of participation, particularly in citizen science projects within formal education, can be theorized further. We draw on three decades of discussions and recent insights within childhood studies to highlight opportunities and challenges and to critically scrutinize underlying assumptions in participatory research designs. Second, we recontextualize ecological citizen science research from a *multispecies* perspective, following the non-anthropocentric turn in human and social sciences which has so far drawn limited attention both in educational research (excluding environmental education which we will return to) and in citizen science projects.

We conclude by proposing a new community of practice with a view of participation based on ethics of inclusion, ethics of fairness, and ethics of producing potential

new worlds (Bodén 2021) in ecological citizen science research. This community, with its opportunities and challenges, aims at acknowledging not only the diversity of means and interests of citizen participation but also the other than human members included and invested in citizen science endeavors. We will discuss the implications of this multispecies and inclusive framing of participation to designing citizen science projects, and to articulating the adjacent educational goals.

Setting the scene: natural scientific human–animal studies

Humans have studied other animals for many reasons and at least as long as we have been dependent on them. Hunter-gatherers needed to understand how their prey or predators attacking them behave. Since the agricultural revolution, pastoralists and animal breeders have been studying their animals for efficient food production. With the institutionalization of Western modern science, non-human animals have had a new explicit role: they have been used as model animals, i.e., humans have done scientific experiments on animals to understand how the human body or mind functions. These three roles—observing environment, breeding animals and experimenting with animals—have continued until this day, but have not fared without critique.

The following expansion of scientific endeavor during the nineteenth century has led to professionalization of science. While early scientists were usually amateurs or wealthy gentlemen of independent means, the rise of academic education and research created a professional class of researchers. Animal experimentation has been reserved for this class, whereas observations about nature are less strictly controlled. Hospitality to amateur collaborators has varied historically. Despret (2016) notes how the institutionalization of ethology took place hand in hand with the efforts to exclude amateur ethologists, naturalists who lived and worked with animals and had derived their insights in everyday life interactions. The name of the game was science as objective knowledge derived from experimental settings. However, some fields of science, such as zoology, botany and meteorology, conserved their amateur collaborators who provided observations of the weather or organisms to allow for collection of the long-term large datasets. In many ways, these amateur collaborators, such as bird ringers or hobby lepidopterists collecting butterfly collections, paved the way for active participation of non-professional researchers.

In the second half of the 1900s, expanding scientific progress required an increasing suite of resources: data, money, public acceptance and skilled workers. Public participation in research was seen as a way of progressing all these goals. The development of the concept of citizen science in the 1990s was accompanied with aims of better engaging citizens in science discourse and building a more trustful relationship between science and the public (Strasser, Baudry, Mahr, Sanchez, and Tancoigne 2019). The need for this connection arose partly from the ongoing need for workers in STEM fields, and the increased scientific literacy and public interest in science were also important contributors. Furthermore, expanding academic research required democratic approval from the citizens as most of the research institutions were dependent on the public finances. Here, the citizen science projects were viewed to serve a dual goal of acquiring large data sets through the public participation in the research and promoting public understanding of science (Trumbull, Bonney, Bascom and Cabral 2000).

However, it was also articulated more than before that science policy should be more responsive to people's concerns and understanding and by doing so strengthening the

democracy of science (Irwin 1995). All too often, the wider public had been seen "as a passive rather than an active force—as witnesses to a series of arguments rather than effective participants" (Irwin 1995, p. 81) In this regard, enabling the participation for the citizens in scientific research, citizen science projects can be seen to promote manifestation of science not only *for the people* but also *by the people*. Instead of presuming a (scientific) expertise as a starting point for environmental activity and scientific communication, Irwin (1995) suggests that the initiative and analytical eye could belong to "the diversity of public groups who are currently witnesses to environmental debate" (p. 80).

Thus, a citizen science approach aiming for democratization not only counteracts the gatekeeping function of the professionalization of science, but also aims to empower larger groups of citizens not previously able to take part in science at all, such as citizens of limited resources, minority groups or children and youth. For this to realize fully, and to develop into genuine forms of co-creation, a critical outlook on the practices and principles—often implicit—of citizen science projects is in place. To date, this has been taken up mostly as exploration of the forms of participation of citizens in the projects. Researchers have distinguished between different levels of participation, starting from contractual or contributory forms of data acquisition to co-creative and collegial work between professional scientists and participating citizens (e.g., Shirk, Ballard, Wilderman, Phillips, Wiggins, Jordan, McCallie, Minarchek, Lewenstein, Krasny and Bonney 2012). It has been brought out that professional scientists might be drawn to citizen science projects because of the increased funding opportunities and the opportunity for promoting their research, which may be echoed in poor motivation for actively engaging with the public (Golumbic, Orr, Baram-Tsabari and Fishbain 2017). Whereas not all citizen science projects are even intended to democratize science but are designed from the standpoint of scientific questions or educational objectives, projects aiming at increasing public engagement in science need to address some critical points. Bonney, Phillips, Ballard and Enck (2016) suggest that project developers need to pay much better focus on questions such as how lay knowledge is framed alongside scientific expertise and whose knowledge counts within the realm of institutionalized science.

Developing science communication toward dialogue between the professionals and the public has turned out to be challenging. Whereas a story of dialogical communication is repeatedly told and often linked to citizen science projects, the "deficit model"—from experts with knowledge to publics without it—stubbornly surrounds the science communication (Trench 2008) and, as we will discuss further on, extends also to animal others. To provide a focused discussion on the aim of democratization of citizen science and increased public engagement, we shed light to the notion of participation in ecological citizen science. In particular, we discuss citizen science projects including young people and other animals to focus the discussion even further as well as to serve our own pragmatic interest.

A focus on participation

In recent years, more and more citizen science projects have been implemented with children and young people in the context of schools. The educational aims of school-based citizen science projects resemble the aims of projects aimed for general audiences such as adults where the goal of promoting public understanding of science is the leading rationale. In this regard, both affective factors like interest and self-efficacy to participate in science as well as understanding of the processes of science and skills to participate in them are deemed important (Phillips, Porticella, Constas and Bonney 2018). Educationally focused studies have argued

that participation in citizen science projects can increase students' knowledge on the content (Alexander and Russo 2010), interest and motivation (Aivelo and Huovelin 2020), support the development of scientific literacy and promote pro-environmental attitudes (Kim and Lee 2019).

Whereas many citizen science projects acknowledge the educational potential and may involve more or less formal investigation of educational outcomes, the opportunity to gather large amounts of ecological data is generally considered as the main purpose (see Soanes, Cranney, Dade, Edwards, Palavalli-Nettimi and Doherty 2020). This being the case, the researchers emphasize the quality and integrity of the gathered data and discuss issues such as training of the students, simplifying the protocols or cross-validation methods and validity assessment as the challenges in the projects (e.g., Freiwald, Meyer, Caselle, Blanchette, Hovel, Neilson and Bursek 2018). Students' engagement and interest are also described, but many times viewed through the success of the data collections (e.g., Herodotou, Aristeidou, Miller, Ballard and Robinson 2020). As Soanes, Cranney, Dade, Edwards, Palavalli-Nettimi and Doherty (2020) note, the school-based citizen science projects easily fail because "the science was not tailored to engage students to collect quality data, or the educational and engagement aspects were over-emphasized at the expense of data integrity" (p. 11).

Another prevailing aspect of citizen science projects, including school based, is consideration of other than human animals, or "wildlife" mainly as object(s) to be studied and understood. Most of the reported citizen science projects on environmental topics we came across in our literature mapping focused on wildlife exclusively as a topic of the ecological inquiry and the objects to be observed and gathered data from. In the few exceptions, the participants' affective relations to the studied animals and potential change in these relations to the benefit of the animals were also studied: Aivelo and Huovelin (2020) noted that the students' views on urban rats developed into emotionally more positive ones during an inquiry of tracing rat movement. Ganzevoort and van den Born (2019) report that citizen science participants consider plant and animal encounters to be particularly significant when encountering species that are rare, new to them or accompanied with surprising experiences.

Altrudi (2020) describes a citizen science project related to a mobile application with an aim of connecting people to nature. Along with increased conceptual knowledge on nature, the only emotion the participants describe was excitement of rare or surprising discoveries. Altrudi discusses the characteristics of the nature connection that is pursued through the project and shows how the assumptions, values and knowledge practices that underpin the natural sciences with a human/nature division tend to be reproduced and reinforced. Such authoritative and one-dimensional definitions of nature tend to suppress; Altrudi argues, "a more intimate way of knowing, sensing, or interacting that acknowledges the nonhuman others as the subjects with whom we share and coconstitute our habited spaces" (p. 16).

A clear call thus exists to further develop practices of participation in ecological citizen science. In this paper, the routes and means for this development are sourced from ongoing discussions in the fields of research which the authors represent: childhood studies and human–animal studies as well as critical animal studies.

Critical perspectives offered by childhood studies: "On whose terms?"

Childhood studies have developed into its own research field since the 1990s when a number of scholars began to emphasize childhood as a social construct and category. Children's lives began to be viewed as worth studying in their own right, as well as part of

communities, societies, and cultures (James and Prout 1990) instead of being located in the "waiting rooms" to be socialized through education. Researchers were encouraged to find pathways to produce knowledge on "children's own perspectives on their everyday lives and experiences" (Christensen and James 2017). Inspired by feminist focus on power relations and voice, the scholarly project to construct knowledge on childhood and children's experiences became a political project emphasizing participation, agency and voices of children as a marginalized social group.

Departing from the aim of listening to somehow authentic voices of children, childhood scholars such as Lee (2001), Prout (2005) and Kraftl (2020) have pointed out that both adults and children live in the midst of complex cultural, social, technological and natural assemblages, making it difficult to view childhood merely in terms of becoming an adult, or being a (generalizable) child "in its own right". Thus, while the emphasis on individual voices and participatory rights is in place when space is made for new groups in the democratic sphere, it might also risk turning into a form of individualism that regards interests as internal to individuals and detaches them from the broader natural cultural phenomena.

Recently, Bodén (2021) analyzed different positionings of children as participants in research with the help of prepositions *on, to, with, for* and *by.* She argued that instead of a continuum of participation, in which "research on children" would mark the most objectifying and unethical setting, and "research by children" would represent the maximum level of participation, all research settings draw from more complex sets of ethical underpinnings. Bodén (2021) found three assumptions of ethics behind different modes of participation: an *ethics of fairness*, *an ethics of inclusion* and *an ethics of producing potential new worlds*. For her, irrespective of the mode of research—whether positivist randomized control trial or art-based "child-friendly" study setting, what should be emphasized is how the research project in question relates to these assumptions and how it further contributes to them.

When we set out to review citizen science studies from the perspective of childhood studies, our hypothesis was that even though active participation and citizenship of young people are widely agreed on as the premise of the present-day scholarship on childhood (e.g., Pascal and Bertram 2009), they would be less present in citizen science. Against these pre-assumptions, many citizen science studies engaging youth and children did claim that there is unique value in involving young people in citizen science. While the primary justification for inclusion of young people was often educational and the actual research contexts were schools or school-related activities that children attended in formal ways, another dominant reason for involving young people was that they are able to produce situated knowledge about their own environments, such as their own neighborhoods or natural environments around them. However, the vast majority of ecological citizen science studies restricted young people's participation to the mechanical and predetermined phase of producing or collecting data, and children were rarely involved in other phases of the research. Citizen science itself was pictured as a framework for projects that were relatively fixed, and the study designs were not methodologically or otherwise modified according to the experiences or goals present when involving young people in the projects.

The mapping of existing literature took us to realize a paradigm gap between the research practices, including methods, commonly employed in childhood studies on the one hand, and citizen science on the other. In the majority of social scientific childhood and youth studies, young people's agency and voice are seen as central and as having consequences to methodology: how knowledge itself is perceived and how research methods are shaped. For instance, interviews and questionnaires have been seen as too rigid and not suitable for approaching children's ways of being and knowing (e.g., Punch 2002).

Instead, studies more sensitive to "child perspectives" have emphasized the importance of playing, drawing, storytelling and photography as children's ways of knowing and being in the world (e.g., Hohti and Karlsson 2014). This is in contrast with the natural scientific paradigm that underpins the majority of ecological citizen science projects: methods are tried and tested beforehand, not molded on-demand and in response to the specificities of the situation. This tension is perhaps most visible in connection with the educational purposes that underpin most school-based citizen science projects. Childhood studies scholars regard education as a concrete part of children's world here and now, locating the educational relevance of children's agency and viewpoints as having intrinsic value (Horton and Kraftl 2006). That is, children's experiences and expressions of their lives are highlighted as worthy, also of scholarly interest, *regardless* of the assessed long-term benefits for their individual development or future participation in society (Horton 2010). In contrast, citizen science projects coupled with educational objectives tend to subscribe to the more developmental psychological theories of childhood as a distinct, knowable and predictable phase of life. Emphasis in these approaches is on the individual human child and on their development into or toward something predefined by others than themselves (Rautio 2014).

From the perspective of childhood studies, the engaging of "children" or "a child" as participant in a citizen science venture is thus by no means a simple question: it requires acknowledging differences in what is meant by childhood or of being a child. Some of the differing discourses portray the child as an agentic actor, others focus on a developing human being, yet others couple the child with the functional attribute "learner" (Burman 2011). Less often, but more so in childhood studies, the child is understood as a participant in societal activities. A more contested view is to regard the child as a political agent (Häkli and Kallio 2018), and even less entertained is the idea of a child as a producer of scientific knowledge (Skelton 2008). With regard to ecological citizen science, one of the core questions to pose relates to just this: whether children are considered as learning the ropes of an existing system (natural science), or agents capable of contributing to or even transforming the system.

"Learning to act like scientists"

As we highlight in this section, in the studies we mapped, children's knowledge (i.e., children's ways of knowing) made no difference to the system: the disciplinary knowledge and ways of producing new knowledge were not challenged by children's participation. The results of children's engagement resided instead mainly within the framework of "education", and the most highlighted objective was to support the development of children into scientific inquirers or enthusiasts. The most honest reports of the rationale and means of including children in citizen science projects state strategic reasons: projects are more easily funded if children and educational settings are included (Golumbic, Orr, Baram-Tsabari and Fishbain 2017).

Ecological citizen science is frequently seen as a learning opportunity within schools—both for learning about ecology and learning to become a scientist or to understand scientific process. In "Never Too Young to be a Citizen Scientist", Hatton, Grimbilas, Kane and Kenyon (2019), for example, write about a yearlong project called the Tulip Garden, in which kindergarteners successfully learn about plants and seasons. The authors claim that citizen science projects can be integrated at any grade level. Over the time, children become engaged in making predictions, becoming scientists, learning about plants, living things, weather, and seasonal changes. Participation in projects like the Tulip Garden

"gives students an understanding of the scientific process" (Saunders et al. 2018), "provides learning experiences for students" (Weckel, Mack, Nagy, Christie and Wincorn 2010), or offers "an effective opportunity for inspiring children and others to have fun *learning to act like scientists*" (Zárybnická, Sklenicka and Tryjanowski 2017; emphasis added).

This emphasis on learning does not fare without internal critique, however. In a recent study on children engaging in citizen science, Castagneyrol, Valdés-Correcher, Bourdin, Barbaro, Bouriaud, Branco, Centenaro, Csóka, Duduman, Dulaurent, Eötvös, Faticov, Ferrante, Fürjes-Mikó, Galmán, Gossner, Harvey, Howe, Kaennel-Dobbertin, Koricheva, Löveï, Lupaștean, Milanović, Mrazova, Opgennoorth, Pitkänen, Popović, Roslin, Scherer-Lorenzen, Sam, Tahadlová, Thomas and Tack (2020) suspect that the educational and societal value of citizen science projects including children tend to be overestimated (see also Trumbull, Bonney, Bascom and Cabral 2000). A provocative critique formulated from a childhood studies perspective would be that the stated rationale of inclusion of children in these projects is just another word for socialization and colonizing "savage" (childhood) knowledge with a superior scientific (adult) one. These "learning opportunity" projects reflect a biologically and developmentally determined understanding of the child participant. They step in to be educated into something they are not yet. While certainly provocative, this critique pushes us to re-think inclusion and participation as *non-innocent* concepts: they insist discussing the philosophical assumptions on research ethics in more detail (Bodén 2021).

Some of the mapped studies depart from the so-called learning opportunity projects and claim that volunteering citizens, also children, are needed not as objects of education but in order to make the actual scientific endeavors succeed. These claims, however, tend to equate the usefulness of children with their capabilities of collecting good enough data rather than justifying children's participation with *who they are* (e.g., because of their age, particular knowledges, or position in society). For example, Schuttler, Sears, Orendain, Khot, Rubenstein, Rubenstein, Dunn, Baird, Kandros, O'Brien and Kays (2019) highlight that "children as young as 9 years old can collect valuable mammal monitoring data using camera traps while connecting with nature and learning through their own scientific discoveries". Didone, Kotrschal, Millesi and Hemetsberger (2012) promote the scientific value of children as reliable observers in animal behavior research: "The results showed no significant differences between the performance of pupils and professional biologists, confirming the children's enormous potential to be reliable observers in animal behavior research" (p. 867). Froschauer (2018) acknowledges children's right to participate in knowledge production and locate research projects as a simulation of this right: "Citizen science opportunities provide real-life experiences that link what students are doing in school to what is happening in the world. They can feel a part of the effort to increase our knowledge about topics that impact their lives. This can be rigorous science reflecting what scientists do while also building solid disciplinary core ideas in the sciences" (p. 5).

Projects embracing the particular advantages and opportunities that child participation can bring are few outside of the issues of data quality, but they do exist. For example, Didone, Puehringer-Sturmayr, Neuböck-Hubinger, Gegendorfer, Kotrschal and Hirschenhauser (2019) take an interesting approach to the connection between information and attitudes at a communal level. In their study, young people were trained to communicate their knowledge on an endangered bird species in order to engage the local community in the long-term ornithological monitoring of the free-flying and individually marked colony of northern bald ibis. After being invited to talk about their experience with as many people as possible, young people acted as surveyors to assess the knowledge of the public. The scientists found a potential to induce sustainable changes with respect to attitude toward

science, at least among local communities. This study interestingly pays attention to childhood and/or adolescence as a societal structure that can bridge other generations, families and communities with scientific and sustainable knowledge and values. This contrasts with the direction of the conventional idea of socialization, in which the child who is only growing up to become a member of a community is usually positioned as the object or the receiver of values and norms. This also urges us to wonder and imagine, what kinds of stories are the ones being told when putting science to work as a community building activity.

In a similar vein, drawing on the family and community networks of schoolchildren, Weckel, Mack, Nagy, Christie and Wincorn (2010) studied human–coyote interaction. Surveys were distributed via school children (kindergarten to grade 12) as part of a voluntary class assignment, to maximize the number of homeowners participating, alongside with providing learning experiences for students. In the study, 1500 students interviewed their parents on whether a coyote had been seen or heard on their property from 2003 to 2006.

The tug-and-pull of the earlier mentioned paradigm gap is obvious: children's genuine participation is argued to require adjustments in research methods (childhood studies), whereas focus on predetermined methods and data quality is argued to set limits to participation (natural sciences). Unless this is realized and contested, childhood remains to be defined in ecological citizen science projects technically and narrowly through competence or the lack of it in terms of young people's ability to participate in activities determined by adult scientists and their cultural framings. The potential of young citizens to impact science more profoundly and surprisingly than just as qualified data collectors needs to be promoted if the development of democratic ethos of citizen science is taken seriously. Could it be possible to consider the method (etymological root of which is in Latin word *methodus* meaning a way of going, a path) as something that is "made by walking" in ecological citizen science?

The critical perspective offered by human–animal studies: "For whose benefit?"

Human and social sciences, but notably less educational sciences, have witnessed what has been called "the animal turn" in the past decade (Ogden, Hall and Tanita 2013). This turn refers to an increasing scholarly interest in animals' ways of perceiving and acting (Weil 2010), the relationships between humans and other animals, and the role and status of animals in (human) societies in new terms and under new premises (Peters, Sucki and Boscardin 2014). Emergence of the interdisciplinary field of human–animal studies (HAS) preceded the animal turn but also coevolved with it and was amplified by it. The disciplinary palette of human–animal studies comprises most often psychology, social sciences and environmental humanities, making the focus of research the complexity of human–animal relations, the socio-cultural and political contexts of these relations and "the spaces that animals occupy in human social and cultural worlds" (DeMello, 2012, p. 4) and potentially also vice versa (e.g., Despret 2016).

One strand within the wider field of HAS is the philosophical approach of posthumanism, broad in its research methodologies and focus. In general, posthumanism seeks to consider the experiences of all beings, both human and nonhuman (Snaza and Weaver 2015), aiming to challenge human exceptionalism and binaries (e.g., human/animal, nature/culture). It also considers anthropocentrism insufficient in addressing social justice issues and ecological crises (Ulmer 2017). Some posthumanist and HAS research has been criticized,

however, for what is considered as a largely uncritical (Arcari, Probyn-Rapsey and Singer 2020) and apolitical (Giraud 2019) approach to multispecies relations. In contrast, critical animal studies (CAS) foreground the importance of accountability and take into consideration the political context of research and its consequences (Pedersen and Stanescu 2014). CAS has an explicit political agenda, as it focuses on "the circumstances and treatment of animals" (Taylor and Twine 2014). The boundaries between HAS and CAS are not always clear-cut, and one area where (some) posthumanist and CAS research converge is on the necessity to challenge and transform anthropocentric conceptions about who is considered part of our (planetary) community and whose interests or ways of perceiving and acting are taken into consideration.

Critical animal studies scholar Pedersen (2010) aptly acknowledges how traditional anthropocentric conceptions of democracy do not sufficiently consider the well-being and interests of everybody. In fact, animals are systematically excluded from public debate on the way they should be treated, viewed, positioned and represented (Snaza 2015) and their social positioning and hierarchical categorizations according to their relation or utility to humans governs their lives. This tension is also remarked in the field of environmental education research, where it has been argued that research involving animals tends to focus on the benefits for humans without attending to the lives of the other animals (Russell and Spannring 2019). Russell and Spannring (2019) argue that this shortcoming might be due to the prevailing humanistic roots of education and the lack of substantive ethological knowledge by the educators.

The methodological advances advocating for and accommodating participation or inclusion of not only humans but other animals in research concerning their lives are often referred to as "multispecies", most familiar being perhaps multispecies ethnography (Kirksey and Helmreich 2010). Multispecies scholarship tends to be heavily situated and context-specific favoring the inquiry of particular relations rather than interactions at the level of species, to form "a more nuanced understanding of interspecies liaisons and sociality" (Wilkie, 2015, p. 331). A multispecies perspective in research does not mean a mere inclusion or adding of "the animal", but focusing on the inseparability and connectedness of humans with other animals: "Cross-species relationships thrive in so many locations, *creating new animals and new humans*, shaped not only by their novel genomes but also by their unpredictable bonds in new circumstances" (Segerdahl 2012, p. 157, italics added). Then, again, from CAS perspective, some multispecies approaches that highlight the "mutual entanglement" of children and other animals have been criticized for glossing over "asymmetric power relations" (Gunnarsson Dinker and Pedersen 2016) and highlighting so-called becomings and entanglements "without directly addressing power relations is problematic" (Giraud 2019, p. 171). As discussed in conclusion, we regard participation as a non-innocent phenomenon or practice: it is crucial to interrogate these practices by asking on whose terms does participation take place, and to recognize situations in which participation perhaps does not serve the interest of the other animals.

When examining how the animal turn has influenced citizen science projects, we had trouble finding examples. A persistent feature in ecological citizen science projects is the use of wildlife studied as objects of observations. Furthermore, the kinds of objects the observed animals are is derived from a human viewpoint: species to conserve, individuals to count, behaviors to observe; annoying pests, valuable game, exotic wildlife, frightening predators. Studies of human–wildlife interactions and conflicts abound and focus typically on conservation attitudes (e.g., Patterson, Kalle and Downs 2017), knowledge (e.g., Steinke, Breton, Berzitis and Herbert 2017) or emotions (e.g., Lincoln, Larson, Cooper, and Hauber 2016) of local people toward feared, disliked or otherwise unwanted wildlife,

often in connection with mapping of sightings of the individuals of such species (e.g., Schaus et al. 2020).

Animal individuals other than wildlife are also highlighted as convenient sources of information: with their citizen owners, pet dogs represent an intermediate between laboratory animals and humans in research of human aging (Kaeberlein 2016), insects are readily available throughout school yards and easily killable for purposes of education and knowledge accumulation (Steinke, Breton, Berzitis and Herbert 2017), and their monitoring develops a diversity of human skills and technological advances (e.g., Schaus et al. 2020). Conservation oriented projects often state that one of the objectives is to increase local understanding and awareness of the given species under study. Some projects even go as far as to claim their objective to be the strengthening of the human–animal relationships. Athalie Alexander and Sharon Russo (2010) claim that by encouraging "teachers and students to understand how better to interact with wildlife in their backyards" has an impact on how they are able to make decisions later on in life that take nature in consideration.

A benevolent reading of this kind of anthropocentrism in ecological citizen science projects, from the viewpoints of HAS and CAS, offers the insight that these projects are often about educating local people in order to ensure more harmonious co-existence with the other than human animals in their communities and surroundings: to take other than human animals into account. In the case of young people as participating citizens, the educational objective is explicit (e.g., Soanes, Cranney, Dade, Edwards, Palavalli-Nettimi and Doherty 2020); with adult participants the projects sometimes state their objective less explicitly: for example, making stakeholders *more receptive* to management and conservation policy (Weckel, Mack, Nagy, Christie and Wincorn 2010), or *increasing the likelihood* of supporting conflict resolution programs (Patterson, Kalle and Downs 2017). Researchers such as Macuch (2019) explicitly call for children to be included in environmental citizen science projects because they are future adults. In their view, young citizens, when growing up, through participation in eco-citizen science projects, learn commitment to environmental stewardship. This, however, echoes some of the traditional sustainability and environmental education frameworks which have been argued to amplify a "humanist stewardship model" (Taylor 2016), reflecting simplified instrumental underpinnings of efforts to educate for environmental citizenship where "desired behavioral outcome of an environmental education activity is known, more or less agreed upon and can be influenced by carefully designed interventions" (Wals 2011, p. 180).

Re-contextualizing ecological citizen science from a non-anthropocentric or multispecies perspective extends animals from mere objects of research to subjects situated and active in their relationalities. A multispecies focus therefore attempts to take seriously the issue of participation through expanding anthropocentric methodologies (Tammi, Leinonen, Hohti and Rautio 2020). Central to a multispecies framing is opening up spaces where the "voice, agency and value in the more-than-human members of the communities to which we belong" (Lupinacci 2019) can be considered and represented in just ways that work to "disturb and disrupt oppressive arrangements" (Gunnarsson Dinker and Pedersen 2016, p. 58). This means also reconsidering how oppression and justice might be defined in more than just human terms: What would justice be for a rat, for instance?

In our mapping of the literature, HAS provides a critical perspective to ecological citizen science by suggesting that non-human animals have agency in societies that warrants participation in research concerning their lives. CAS in turn provides further critical insights about non-human animals' interests as intrinsic, even if opposed to human interests and sometimes even independent from the level of species conservation: animal individuals' rights are held at par with rights of human individuals. The challenge here for

ecological citizen science is how to take in consideration these different ways of being, knowing and acting in order to reconsider what participation in the ecology/community means for its members and what this means for the ecological/communal well-being, in other words a movement from individual interests to ecological view that would ground on the contradicting individual interests: multispecies democratization.

Revisiting the study where children acted as "knowledge multipliers" through exchanging observations on Northern bald ibis in their communities (Didone, Puehringer-Sturmayr, Neuböck-Hubinger, Gegendorfer, Kotrschal and Hirschenhauser 2019), taking the animal turn would involve asking, what does it mean for a bird to live in this specific community, allowing them to multiply knowledge as well. This framing is akin to ethologist Despret's (2016) efforts to ask the right questions: for instance, what might a maze mean for the rat.

With the reservation that this mapping of literature is not systematic or exhaustive, we can conclude that no studies were encountered in which non-human animals had explicit agency or participatory roles in the designs of the studies. We had anticipated reporting of animal behavior impacting the design or course of studies, the identification of animal individuals over collective species representatives or perhaps even the use of ethological methods approaching the potentialities of animal input into research communications (Despret 2016). Wary of what participatory roles animals could have in citizen science projects where their agency, right to a (good) life of their own and space and what that could look like, we nonetheless posit that shifting the framing of citizen science projects "from learning *about* animals, to learning *with*, *for* and *from* animals" (Gunnarsson Dinker and Pedersen 2016, p. 420) can help us move from anthropocentric concerns.

A new community? Opportunities and challenges for participation

In this paper, we have reported our readings in the intersections of ecological citizen science, childhood studies and HAS/CAS focusing on the concept of participation, in the ethical questions of *for whom and by whom* in specific. In this regard, we have highlighted two emerging critiques with which to develop a more inclusive community of ecological citizen science. The first critique coming specifically from childhood studies but also educational research at large points out the importance of inclusion of young citizens as knowledge producers on their own terms: of rethinking the means of participation to better respond to children's ways of being and knowing. The second critique, informed by the animal turn and the related fields of inquiry, regards the scope of participants and the depth of participation by drawing attention to who is considered a stakeholder and a knowledge producer in ecological citizen science: What might the other animals be interested in during the research process and what relations seem important to them; what is at stake for the non-human habitants?

The approaches in which children are rendered as active co-researchers, taking part in considering research designs, selecting methods and refining research questions (e.g., Skelton 2008), even leading research (Kellett 2010) are still few and far between (Rautio 2014). However, as De Freitas, Rousell, Trafi-Prats and Hohti (*in press*) point out, there is an essentializing risk in encapsulating young peoples' knowledge as an origin or *starting point* from which research might emerge. Rather, ethics in participatory settings might be more about ongoing reflexivity and balancing. Olitsky and Weathers (2005) emphasize that the academic language might be experienced by the participating young people as establishing and reaffirming social boundaries rather than providing an open community. For

minimizing this, and to otherwise pay closer attention to research ethics in participatory settings, they suggest modes of ongoing reflexivity in terms of language, students' voices and choices and educational/developmental goals, and fostering interpersonal relationships. We add that interpersonal relationships in ecological citizen science projects also involve interspecies relationships. To pay attention to the relationships of the participants during the research necessitates that attention is also paid to what the participants find important and interesting (beyond the notion of voice as necessarily audible) during the research. Still, participatory approaches do not have to mean that the included groups are treated as independent knowledge producers whose processes of inquiry would be somehow authentic if not disturbed by the researchers.

As much as the inclusion of young citizens on their own terms and as parts of complex networks yields potential for developing participation in ecological citizen science, so does following the critique posed as part of the animal turn. Beginning to regard other than human animals as relational subjects rather than merely objects to be observed, it becomes possible to ask new sets of questions important for crafting citizen science projects. How do the participating animals interpret, perceive and act upon and within their worlds, including the research settings? What kind of intersubjective ties are formed through the inquiry? How does it matter to the human and other than human animals (and further, other modes of being) to be included and how, within which timescales? Is non-participation an alternative? How to incorporate participants' versions of the world as legitimate accounts? Who is allowed to define, with what means, and to which extent what is interesting in the given (research) setting?

In all, our observations confirm what has previously been brought up in childhood studies and critical human–animal studies: research settings are never neutral, and participatory research settings cannot be seen as ethical per se. Each research setting presents a unique combination of power relations and other relations, in which participants occupy, and shift through various positions. As Bodén (2021) argues in her reflection on ethics of participation, these positions can be scrutinized in regard to a scale illustrating whether research is being done "on, to, for, with or by" these participants, all these prepositions guiding toward thinking directionalities, positionings, hierarchies in terms of the specific philosophical assumptions that underpins the research. Bodén mentions three such assumptions: Ethics as inclusion focuses on the participants "there and then" of the study, ethics as fairness emphasizes the future outcomes for the participants while ethics as producing potential new worlds draws attention to the situated and relational contexts of inquiry, with a consideration on matters of care in research (Bodén 2021).

For the democratic ethos of citizen science projects, these observations can result in an ongoing process of asking, how would it be possible to make space for various knowledges to be regarded as such: How could different kinds of knowledge co-exist, potentially generating more just worlds? Crafting common grounds, spaces where different "sciences" could meet, would be an effort toward (multispecies) democracy yet to come.

Whenever the aim is to support citizens' involvement in and learning about science, future citizen science projects will need to increasingly explore the opportunities to connect the participants' knowledges and initiatives with the scientific goals of the research. This might be advanced, for example, by designing the research process in a way that highlights participants' choices during data collection or taking the emerging understanding and ideas as opportunities to (re-)direct and extend the research (Olitsky and Weathers 2005). Increasing the choice of the participants might increase the unpredictability of the research design intended by the researchers. But as instances of open-endedness and emerging novelty are integral to the process of science itself (Latour 1987), the acceptance

of these aspects in the citizen science projects would bring the participants and researchers together to do research in a situated way rather than through predestined steps. An approach of this kind will also contribute to the commonly highlighted educational aims of citizen science projects regarding knowing the scientific practices and *doing* science. From the point of view of the scientists, this approach would require training for this kind of collaboration and perhaps make citizen science projects more costly and more difficult to control. While the scientists' views as also stakeholders in citizen science should not be surpassed, they can nevertheless be taken to represent a position of power in knowledge production by mainstream citizen science.

We have found inspirational a discussion in Cultural Studies of Science Education by Mack, Augare, Different Cloud-Jones, David, Quiver Gaddie, Honey, Kawagley, Little Plume-Weatherwax, Lone Fight, Meier, Pete, Rattling Leaf, Returns From Scout, Sachatello-Sawyer, Shibata, Valdez and Wippert (2012) and Lowan (2012) regarding how Western science and Indigenous sciences might form and meet on a common ground. As Mack, Augare, Different Cloud-Jones, David, Quiver Gaddie, Honey, Kawagley, Little Plume-Weatherwax, Lone Fight, Meier, Pete, Rattling Leaf, Returns From Scout, Sachatello-Sawyer, Shibata, Valdez and Wippert (2012, p. 153) suggest in their argument for a "transformative science": "once the individuals come to believe that Western science is not the only legitimate knowledge producer, then maybe a conversation can be opened about how different forms of research and knowledge production take issues of locality, cultural values, and social justice seriously". With our extension of the issues of participation to other than human animals, we add to this list the issues of multispecies or ecological justice, and consideration on what justice would mean, when going beyond human-only activities and meaning-making. To this end, we find helpful Mueller and Tippins' (2015) idea of situated tensions concerning theory and practice within science education pedagogy. They use the notion of ecojustice to evaluate the holistic connections between cultural and natural systems, environmentalism, sustainability and Earth-friendly marketing trends. Here, citizen science and youth activism are positioned as two of the pedagogical ways ecojustice philosophy (see also Lupinacci 2019) can be enacted.

On the one hand, Indigenous knowledges should be considered multiple in that they are relational and situated, while on the other hand, these knowledges involve similarities with Western science, including the disciplined observations of nature (Lowan 2012). We like to think that the same applies for both children's and other than human animals' multiple, relational and situated knowledges about how the world (or worlds) works—that is, if you may, *children's and animals' sciences*.

Appendix 1

This is the list of reviewed articles per each pair of scholars. NB Some of the readings overlap, and the same article might be mentioned in more than one pair's review. The loose theme of each pair (e.g., human–animal studies) refers to the scholarly focus of the researchers rather than limits the reviewed articles.

I Human–animal studies

We did searches in Web of Science, ERIC and Google scholar with "human–animal studies" or "critical animal studies" or "human–animal" and "citizen science," as well as with "animal" and "human" and/or "child*" and "citizen," and then selected the following articles for closer reading.

Cherry, E. (2018). Birding, citizen science, and wildlife conservation in sociological perspective, *Society & Animals*, *26*(2), 130–147.

Crain, C., Cooper, J.L. & Dickinson, R. (2014). Citizen science: a tool for integrating studies of human and natural systems, *Annual Review of Environment and Resources*, *39*(1), 641–665.

Daly, B. & Morton, L.L. (2006). An investigation of human–animal interactions and empathy as related to pet preference, ownership, attachment, and attitudes in children, *Anthrozoös*, *19*(2), 113–127.

Dinker K.G., Pedersen H. (2016). Critical animal pedagogies: re-learning our relations with animal others. In H. Lees, N. Noddings (Eds.), *The Palgrave International Handbook of Alternative Education*. London: Palgrave Macmillan.

Eaton, K., Hoagwood, M.A., Morrissey, M. & Peth-Pierce, R. (2017). Animal-assisted therapies for youth with or at risk for mental health problems: A systematic review, *Applied Developmental Science*, *21*(1), 1–13.

Feuerstein, A. & Nolte-Odhiambo, C. (2017). *Childhood and Pethood in Literature and Culture*. London: Routledge.

Fournier A.K. (2019). Studying animal-assisted intervention through citizen science. In *Animal-assisted intervention*. Palgrave Pivot Cham.

Frigerio D. et. al. (2018). Citizen science and wildlife biology: synergies and challenges, *Ethology, 124*, 365–377.

Kaeberlein M. (2016). The biology of aging: citizen scientists and their pets as a bridge between research on model organisms and human subjects. *Veterinary Pathology*, *53*(2), 291–298.

Kogan, L.R., Granger, B.P., Fitchett, J.A. (1999). The human–animal team approach for children with emotional disorders: two case studies. *Child & Youth Care Forum*, *28*, 105–121.

Larson, L.R., Conway, A.L., Hernandez, S.M. & Carroll, J.P. (2016). Human-wildlife conflict, conservation attitudes, and a potential role for citizen science in Sierra Leone, Africa. *Conservation & Society*, *14*(3), 205–217.

Larson, L.R., Cooper, C.B. & Hauber, M.E. (2016). Emotions as drivers of wildlife stewardship behavior: examining citizen science nest monitors' responses to invasive house sparrows, *Human Dimensions of Wildlife*, *21*(1), 18–33.

May, D.K., Seivert, P., Cano, A., Casey R.J. & Johnson, A. (2016). Animal-assisted therapy for youth. A systematic methodological critique. *Human–Animal Interaction Bulletin*, *4*(1),11–18.

Mueller, M. (2014). Is human-animal interaction (HAI) linked to positive youth development? Initial answers, *Applied Developmental Science*, *18*(1), 5–16.

Patterson, L., Kalle, R. & Downs, C. (2017). A citizen science survey: perceptions and attitudes of urban residents towards vervet monkeys. *Urban Ecosyst*, *20*, 617–628.

Pedersen, H. (2011). Release the moths: critical animal studies and the posthumanist impulse, *Culture, Theory and Critique*, *52*(1), 65–81.

Schaus J. et. al. (2020). Application of the random encounter model in citizen science projects to monitor animal densities, *Remote Sensing in Ecology and Conservation*, 1–15.

Soanes K. et. al. (2020). How to work with children and animals: a guide for school-based citizen science in wildlife research, *Austral Ecology*, *45*, 3–14.

Steinke, D. (2017). The school malaise trap program: coupling educational outreach with scientific discovery, *PLOS Biology*, *15*(4), e2001829.

Stewart, K. & Cole, M. (2014). *Our children and other animals. The cultural construction of human–animal relations in childhood*. London: Routledge.

Weckel, M.E., Mack, D., Nagy, C., Christie, R. and Wincorn, A. (2010). Using citizen science to map human—coyote interaction in suburban New York, USA. *The Journal of Wildlife Management*, *74*, 1163–1171.

II Childhood studies

We did searches in Web of Science, ERIC and Google scholar with "childhood" or "children" or "child" and "citizen science" and another search with "child" and "citizen" and "animal" with criteria: peer-reviewed, international. Then, we selected the following for closer reading and made notes on how they conceptualized the child, what kind of animals were involved, how citizen was understood and how the importance of the study was justified (e.g., educational outcomes).

Alexander, A., & Russo, S. (2010). Let's start in our own backyard: children's engagement with science through the natural environment. *Teaching Science: The Journal of the Australian Science Teachers Association*, *56*(2), 47–54.

Castagneyrol, B., Valdés-Correcher, E., Bourdin, A., Barbaro, L., Bouriaud, O., Branco, M., Centenaro, G., Csóka, G., Duduman, M.-L., Dulaurent, A.-M., Eötvös, C.B., Faticov, M., Ferrante, M., Fürjes-Mikó, Á., Galmán, A., Gossner, M.M., Harvey, D., Howe, A.G., Kaennel-Dobbertin, M., Koricheva, J., Löveï, G.L., Lupaștean, D., Milanović, S., Mrazova, A., Opgennoorth, L., Pitkänen, J.-M., Popović, M., Roslin, T.V., Scherer-Lorenzen, M., Sam, K., Tahadlová, M., Thomas, R. and Tack, A.J.M. (2020). Can school children support ecological research? Lessons from the Oak Bodyguard citizen science project. *Citizen Science: Theory and Practice*, *5*(1).

Didone, F., Kotrschal, K., Millesi, E., & Hemetsberger, J. (2012). Children and scientific observations: Pupils measuring Greylag goose behaviour. *IJCDSE*, *3*, 871–876.

Didone, F., Puehringer-Sturmayr, V., Neuböck-Hubinger, B., Gegendorfer, G., Kotrschal, K., & Hirschenhauser, K. (2019). Monitoring public awareness about the endangered northern bald ibis: a case study involving primary school children as citizen scientists. *PeerJ*, *7*, e7569.

Froschauer, L. (2018). Citizen science. *Science and children*, *55*(8), 5–5.

García-Holgado, A., García-Peñalvo, F. J., & Butler, P. (2020). Technological ecosystems in citizen science: a framework to involve children and young people. *Sustainability*, *12*(5), 1863.

Hatton, M., Grimbilas, S., Kane, C., & Kenyon, T. (2019). Never too young to be a citizen scientist!. *Science and Children*, *57*(3), 49–54.

Herodotou, C., Aristeidou, M., Miller, G., Ballard, H., & Robinson, L. (2020). What do we know about young volunteers? An exploratory study of participation in Zooniverse. *Citizen Science: Theory and Practice*, *5*(1), 2.

Hidalgo-Ruz, V., & Thiel, M. (2013). Distribution and abundance of small plastic debris on beaches in the SE Pacific (Chile): a study supported by a citizen science project. *Marine environmental research*, *87*, 12–18.

Lee, L. & Lu, J. (2020). Using a citizen science approach in early childhood education: a call for strengthening evidence. *Cogent education*, *7*(1).

Makuch, A. (2019). Eco-citizen science for social good: promoting child well-being, environmental justice, and inclusion. *Research on social work practice, 30*(2), 219–232. Web.

Mueller, M., & Tippins, D. J. (2015). *Ecojustice, citizen science and youth activism*. Dordrecht: Springer.

Pascal, C. & Bertram, T. (2009). Listening to young citizens: the struggle to make real a participatory paradigm in research with young children. *European early childhood education research journal*, *17*(2), 249–262.

Saunders, M. E., Roger, E., Geary, W. L., Meredith, F., Welbourne, D. J., Bako, A., … & Moles, A. T. (2018). Citizen science in schools: engaging students in research on urban habitat for pollinators. *Austral ecology*, *43*(6), 635–642.

Schuttler, S. G., Sears, R. S., Orendain, I., Khot, R., Rubenstein, D., Rubenstein, N.,... Kays, R. (2019). Citizen science in schools: students collect valuable mammal data for science, conservation, and community engagement. *Bioscience*, *69*(1), 69–79.

Soanes, C. (2020). How to work with children and animals: a guide for school-based citizen science in wildlife research. *Austral ecology, 45*(1), 3–14. Web.

Weckel, M., Mack, D., Nagy, C., Christie, R. & Wincorn, A. (2010). Using citizen science to map human–coyote interaction in suburban New York, USA. *Journal of wildlife management, 74*, 1163–1171.

Zárybnická, M., Sklenicka, P. & Tryjanowski, P. (2017). A Webcast of bird nesting as a state-of-the-art citizen science. *PLoS biology*, *15*(1), p. e2001132.

III Natural sciences/ecology

We did exploratory searches in Web of Science, Google Scholar and ERIC with "citizen science animals" and "citizen science school," selected potential articles based on their abstract, and chose the below-mentioned articles for closer reading.

Aivelo, T., & Huovelin, S. (2020). Combining formal education and citizen science: a case study on students' perceptions of learning and interest in an urban rat project. *Environmental Education Research, 26*(3), 324–340.

Alexander, A., & Russo, S. (2010). Let's start in our own backyard: Children's engagement with science through the natural environment. *Teaching Science: The Journal of the Australian Science Teachers Association, 56*(2), 47–54.

Altrudi, S. (2020). Connecting to nature through tech? The case of the iNaturalist app. *Convergence, 27*(1), 124–141.

Bielanski, M., Taczanowska, K., Brandenburg, C., Adamski, P., & Witkowski, Z. (2018). Using a social science approach to study interactions between ski tourers and wildlife in mountain protected areas. *Mountain Research and Development, 38*(4), 380–389.

Bombaug, R. (2000). From citizen scientists to engineers. *Journal of Professional Issues in Engineering Education and Practice, 126*(2), 64–68.

Bonney, R., Ballard, H., Jordan, R., McCallie, E., Phillips, T., Shirk, J., & Wilderman, C. C. (2009). Public participation in scientific research: Defining the field and assessing its potential for informal science education. A CAISE Inquiry Group Report. *Online Submission.*

Booth, J. N., Chesham, R. A., Brooks, N. E., Gorely, T., & Moran, C. N. (2020). A citizen science study of short physical activity breaks at school: improvements in cognition and wellbeing with self-paced activity. *BMC medicine, 18(1)*, 1–11.

Bravo, T., Taber, J., & Davis, H. (2020). A case study of highly-engaged educators' integration of real-time seismic data in secondary classrooms. *Frontiers in Earth Science 8*, 180.

Brossard, D., Lewenstein, B. & Bonney, R. (2005). Scientific knowledge and attitude change: The impact of a citizen science project. *International Journal of Science Education, 27*(9), 1099–1121.

Bunn, D., Sah, K., Kattel, P., Kimweri, I., Schwind, J.S., & Msoffe, P. (2016). Can school children reliably collect rural household data in developing countries? Evidence from Nepal. *Development in Practice, 26*(6), 808–815.

Cherry, E. (2018). Birding, citizen science, and wildlife conservation in sociological perspective. *Society & Animals, 26*(2), 130–147.

Cretois, B., Linnell, J.D.C., Grainger, M., Nilsen, E.B., & Rød, J.K. (2020). Hunters as citizen scientists: Contributions to biodiversity monitoring in Europe. *Global Ecology and Conservation, 23*, e01077.

Dawson E. (2018). Reimagining publics and (non) participation: Exploring exclussion from science communication through the experiences of low-income, minority ethnic groups. *Public Understanding of Science, 27*(7), 772–786.

El Bizri, H. R., Fa, J. E., Lemos, L. P., Campos-Silva, J. V., Vasconcelos Neto, C. F., Valsecchi, J., & Mayor, P. (2021). Involving local communities for effective citizen science: Determining game species' reproductive status to assess hunting effects in tropical forests. *Journal of Applied Ecology, 58*(2), 224–235.

Figueiredo Nascimento, S., Cuccillato, E., Schade, S., & Guimarães Pereira, A. (2016). *Citizen engagement in science and policy-making*. Luxembourg: Publications Office of the European Union.

França, J. S., Solar, R., Hughes, R. M., & Callisto, M. (2019). Student monitoring of the ecological quality of neotropical urban streams. *Ambio, 48*(8), 867–878.

Freiwald, J., Meyer, R., Caselle, J. E., Blanchette, C. A., Hovel, K., Neilson, D., … & Bursek, J. (2018). Citizen science monitoring of marine protected areas: case studies and recommendations for integration into monitoring programs. *Marine Ecology, 39*, e12470.

Frigerio, D., Pipek, P., Kimmig, S., Winter, S., Melzheimer, J., Diblíková, L., … & Richter, A. (2018). Citizen science and wildlife biology: Synergies and challenges. *Ethology, 124*(6), 365–377.

Frigerio D, Puehringer-Sturmayr V, Neuböck-Hubinger B, Gegendorfer G, Kotrschal K., & Hirschenhauser K. (2019). Monitoring public awareness about the endangered northern bald ibis: a case study involving primary school children as citizen scientists. *PeerJ, 7*, e7569

Ganzevoort, W., & van den Born, R. (2019). The thrill of discovery: Significant nature experiences among biodiversity citizen scientists. *Ecopsychology, 11*(1), 22–32.

Haklay, M. (2013). Citizen science and volunteered geographic information: Overview and typology of participation. In D. Sui, S. Elwood, M. Goodchild (Eds.), *Crowdsourcing geographic knowledge: volunteered geographic information (VGI) in theory and practice. Springer Science & Business Media.* pp. 105–122.

Gozdzik, A., Apsholm, P.E., Wam, H.K., Wawrzyniak, T., & Wielgopolan, A. (2019). Citizen science initiative for schools: Edu-arctic monitoring of meteorological and phenological parameters. *Proceedings of EDULEARN19 Conference 1st-3rd July 2019, Palma, Mallorca, Spain*.

Gracanin, A., Roger, E., Katsis, A.C., O'Loughlin, L.S., Emery, N.J., Ocock, J.F., & O'Hanlon, J.C. (2020). An artificial bird nest experiment in urban environments: Lessons from a school-based citizen science programme. *Austral Ecology, 45*, 523–528.

Grasser, S., Schunko, C. & Vogl, C.R. (2016). Children as ethnobotanists: methods and local impact of a participatory research project with children on wild plant gathering in the Grosses Walsertal Biosphere Reserve, Austria. *Journal of Ethnobiology and Ethnomedicine 12*(1), 1–17.

Greenlees, M., Brown, G.P., & Shine, R. (2020). Pest control by the public: Impact of hand-collecting on the abundance and demography of cane toads (Rhinella maina) at their southern invasion front in Australia. *Global Ecology and Conservation, 23*, e01120.

Harris, E.M., Dixon, C.G.H., Bird, E.B., & Ballard, H.L. (2020). For science and self: Youth interactions with data in community and citizen science. *Journal of the Learning Sciences, 29*(2), 224–263.

Hecht, J., & Cooper, C.B. (2014). Tribute to Tinbergen: Public engagement in ethology. *Ethology, 120*, 207–214.

Hermoso M.I., Martin, V.Y., Stotz. W., Gelcich, S., & Thiel M. (2019). How does the diversity of divers affect the design of citizen science projects? *Frontiers in Marine Science 6*, 239.

Hiller, S.E., & Kitsantas, A. (2014). The Effect of a horseshoe crab citizen science program on middle school student science performance and STEM career motivation. *School Science and Mathematics 114*, 302–311.

Hyder, A., & May, A.A. (2020). Translational data analytics in exposure science and environmental health: a citizen science approach with high school students. *Environmental Health 19*, 73.

Irwin, A. (1995). *Citizen science: A study of people, expertise and sustainable development*. New York: Routledge.

Kelemen-Finan, J., Scheuch, M., & Winter, S. (2018). Contributions from citizen science to science education: an examination of a biodiversity citizen science project with schools in Central Europe. *International Journal of Science Education, 40*, 17, 2078–2098.

Kermish-Allen, R., Peterman, K., & Bevc, C. (2019). The utility of citizen science projects in K-5 schools: measures of community engagement and student impacts. *Cultural Studies of Science Education 14*, 627–641.

Kim, G., & Lee, H. (2019). A case study of community-based socioscientific issue program: focusing on the abandoned animal issue. *Journal of Biological Education*, 1–15.

Kim, K.K., Ngo, V., Gilkison, G., Hillman, L., & Sowerwine J. (2020). Native American youth citizen scientists uncovering community health and food security priorities. *Health Promotion Practice, 21*(1), 80–90.

Kobori, H., Dickinson, J. L., Washitani, I., Sakurai, R., Amano, T., Komatsu, N., … & Miller-Rushing, A. J. (2016). Citizen science: a new approach to advance ecology, education, and conservation. *Ecological research, 31*(1), 1–19.

Koomen, M.H., Rodriguez, E., Hoffman, A., Peterson, C., & Oberhauser, K. (2018). Authentic science with citizen science and student-driven science fair projects. *Science Education, 102*, 593–644.

Kullenberg, C., Rohden, F., Björkvall, A., Brounéus, F., Avellan-Hultman, A., Järlehed, J., … & Westberg, G. (2018). What are analog bulletin boards used for today? Analysing media uses, intermediality and technology affordances in Swedish bulletin board messages using a citizen science approach. *PloS one, 13*(8), e0202077.

Le Féon, V., Henry, M., Guilbaud, L., Coiffait-Gombault, C., Dufrêne, E., Kolodziejczyk, E., … & Vaissière, B. E. (2016). An expert-assisted citizen science program involving agricultural high schools provides national patterns on bee species assemblages. *Journal of Insect Conservation, 20*(5), 905–918.

Lüftenegger, M., Bardach, L., Bergsmann, E., Schober, B., & Spiel, C. (2019). A citizen science approach to measuring students' achievement goals. *International Journal of Educational Research, 95*, 36–51.

Matthews, C. E., Huffling, L. D., & Benavides, A. (2014). The ins & outs of developing a field-based science project: Learning by lassoing lizards. *The American Biology Teacher, 76*(5), 320–326.

Martin, V.Y. (2017). Citizen science as a means for increasing public engagement in science: Presumption or possibility? *Science Communication, 39*(2), 142–168.

Martin, V.Y., & Greig, E.I. (2019). Young adults' motivations to feed wild birds and influences on their potential participation in citizen science: An exploratory study. *Biological Conservation, 235*, 295–307.

Merenlender, A.M., Crall, A.W., Drill, S., Prysby, M., & Ballard, H. (2016). Evaluating environmental education, citizen science, and stewardship through naturalist programs. *Conservation Biology, 30*, 1255–1265.

Merlino, S., Locritani, M., Stroobant, M, Mioni, E., & Tosi, D. (2015). SeaCleaner: Focusing citizen science and environment education on unraveling the marine litter problem. *Marine Technology Society Journal 49*(4), 99–118.

McKenney, E., Flythe, T., Millis, C., Stalls, J., Urban, J.E., Dunn, R.R., & Stevens, J.L. (2016). Symbiosis in the soil: Citizen microbiology in middle and high school classrooms. *Journal of Microbiology & Biology Education, 17*(1), 60–62.

McKinley, D. C., Miller-Rushing, A. J., Ballard, H. L., Bonney, R., Brown, H., Cook-Patton, S. C., … & Soukup, M. A. (2017). Citizen science can improve conservation science, natural resource management, and environmental protection. *Biological Conservation, 208*, 15–28.

Miczajka, V.L., Klein, A-M., & Pufal, G. (2015). Elementary school children contribute to environmental research as citizen scientists. *PLoS ONE 10*(11), e0143229.

Miller-Rushing, A., Primack, R., & Bonney, R. (2012). The history of public participation in ecological research. *Frontiers in Ecology and the Environment, 10*, 285–290.

Moore, K. (2008). *Disrupting science: Social movements, American scientists, and the politics of the military, 1945–1975*. Princeton: Princeton University Press.

Mulder R.A., Guay P.-J., Wilson M., & Coulson G. (2010). Citizen science: recruiting residents for studies of tagged urban wildlife. *Wildlife Research, 3*7, 440–446.

Phillips, T.B., Ballard, H.L., Lewenstein, B.V., & Bonney, R. (2019). Engagement in science through citizen science: Moving beyond data collection. *Science Education, 103*, 665–690.

Paige, K., Lawes, H., Matejcic, P., Taylor, K., Stewart, V., Lloyd, D., Zeegers, Y., Roetman, P., & Daniels, C. (2010). "It felt like real science!" How operation magpie enriched my classroom. *Teaching Science, 56*(4), 25–33.

Pandya, R.E. (2012). A framework for engaging diverse communities in citizen science in the US. *Frontiers in Ecology and the Environment, 10*, 314–317.

Phillips, T., Porticella, N., Constas, M., & Bonney, R. (2018). A framework for articulating and measuring individual learning outcomes from participation in citizen science. *Citizen Science: Theory and Practice, 3*(2).

Pierce, C. (2015). Learning about a fish from an ANT: actor network theory and science education in the postgenomic era. *Cultural Studies of Science Education, 10*(1), 83–107.

Pitt, A.N., & Schultz, C.A. (2018). Youth-based citizen science monitoring: Case studies from three national forests, *Journal of Forestry, 116*(2), 109–116.

Portas, A.M., Barnard, L., Scott, C., & Harrison R. G. (2016). The national eclipse weather experiment: use and evaluation of a citizen science tool for schools outreach. *Philosophical Transactions of the Royal Society in London*, *374*(2077), 20,150,223.

Ruiz-Mallén, I., Riboli-Sasco, L., Ribrault, C., Heras, M., Laguna D., & Perié, L. (2016). Citizen science: Toward transformative learning. *Science Communication 38*(4), 523–534.

Saunders, M. E., Roger, E., Geary, W. L., Meredith, F., Welbourne, D. J., Bako, A., … & Moles, A. T. (2018). Citizen science in schools: Engaging students in research on urban habitat for pollinators. *Austral ecology, 43*(6), 635–642.

Schuttler, S. G., Sears, R. S., Orendain, I., Khot, R., Rubenstein, D., Rubenstein, N., … & Kays, R. (2019). Citizen science in schools: students collect valuable mammal data for science, conservation, and community engagement. *Bioscience, 69*(1), 69–79.

Shirk, J. L., Ballard, H. L., Wilderman, C. C., Phillips, T., Wiggins, A., Jordan, R., … & Bonney, R. (2012). Public participation in scientific research: a framework for deliberate design. *Ecology and society, 17*(2).

Soanes, K., Cranney, K., Dade, M. C., Edwards, A. M., Palavalli-Nettimi, R., & Doherty, T. S. (2020). How to work with children and animals: A guide for school-based citizen science in wildlife research. *Austral Ecology, 45(*1), 3–14.

Storksdieck, M., Shirk, J. L., Cappadonna, J. L., Domroese, M., Göbel, C., Haklay, M., … & Vohland, K. (2016). Associations for citizen science: Regional knowledge, global collaboration. *Citizen Science: Theory and Practice, 1*(2), 10.

Strasser, B. J., Baudry, J., Mahr, D., Sanchez, G., & Tancoigne, E. (2019). 'Citizen science'? Rethinking science and public participation. *Science & Technology Studies, 32*(2), 52–76.

Thornton, T., & Leahy, J. (2012). Trust in citizen science research: A case study of the groundwater education through water evaluation & testing program. *Journal of the American Water Resources Association, 48*, 1032–1040.

Trumbull, D. J., Bonney, R., Bascom, D., & Cabral, A. (2000). Thinking scientifically during participation in a citizen-science project. *Science Education, 84*(2), 265–275.

Tsivitanidou, O. E., & Ioannou, A. (2020). Citizen Science, K-12 science education and use of technology: a synthesis of empirical research. *Journal of Science Communication 19*(4).

Walkinshaw, L.P., Hecht, C., Patel, A., & Podrabsky, M. (2019), Training high school student "citizen scientists" to document school water access: A feasibility study. *Journal of School Health, 89*, 653–661.

Weigelhofer, G., Pölz, E-M., & Hein, T. (2019). Citizen science: how high school students can provide scientifically sound data in biogeochemical experiments. *Freshwater Science, 38*(2), 236–243

Wiggins, A., & Crowston, K. (2011). From conservation to crowdsourcing: A typology of citizen science. *44th Hawaii international conference on system sciences*.

Zoellick, B., Nelson, S.J., & Schauffler, M. (2012). Participatory science and education: Bringing both views into focus. *Frontiers in Ecology and the Environment, 10*, 310–313.

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References

Aivelo, T., & Huovelin, S. (2020). Combining formal education and citizen science: A case study on students' perceptions of learning and interest in an urban rat project. *Environmental Education Research, 26*(3), 324–340. https://doi.org/10.1080/13504622.2020.1727860

Alexander, A., & Russo, S. (2010). Let's start in our own backyard: Children's engagement with science through the natural environment. *Teaching Science: The Journal of the Australian Science Teachers Association, 56*(2), 47–54. https://doi.org/10.1007/978-3-319-56375-6_15

Altrudi, S. (2020). Connecting to nature through tech? The case of the iNaturalist app. *Convergence*. https://doi.org/10.1177/1354856520933064

Arcari, P., Probyn-Rapsey, F., & Singer, H. (2020). Where species don't meet: invisibilized animals, urban nature and city limits. *Environment and Planning E: Nature and Space*. https://doi.org/10.1177/2514848620939870

Bodén, L. (2021). On, to, with, for, by: Ethics and children in research. *Children's Geographies*. https://doi.org/10.1080/14733285.2021.1891405

Bonney, R., Phillips, T. B., Ballard, H. L., & Enck, J. W. (2016). Can citizen science enhance public understanding of science? *Public Understanding of Science, 25*(1), 2–16. https://doi.org/10.1177/0963662515607406

Burman, E. (2011). Un/thinking children in development. In G. S. Cannella & L. D. Soto (Eds.), *Childhoods. A handbook*. Peter Lang.

Castagneyrol, B., Valdés-Correcher, E., Bourdin, A., Barbaro, L., Bouriaud, O., Branco, M., Centenaro, G., Csóka, G., Duduman, M.-L., Dulaurent, A.-M., Eötvös, C.B., Faticov, M., Ferrante, M., Fürjes-Mikó, Á., Galmán, A., Gossner, M.M., Harvey, D., Howe, A.G., Kaennel-Dobbertin, M., Koricheva, J., Löveï, G.L., Lupaştean, D., Milanović, S., Mrazova, A., Opgennoorth, L., Pitkänen, J.-M., Popović, M., Roslin, T.V., Scherer-Lorenzen, M., Sam, K., Tahadlová, M., Thomas, R. and Tack, A.J.M. (2020). Can school children support ecological research? Lessons from the *Oak Bodyguard* Citizen Science Project. *Citizen Science: Theory and Practice, 5*(1), online. https://doi.org/10.5334/cstp.267

Christensen, P., & James, A. (2017). *Research with children: Perspectives and practices* (3rd ed.). Routledge.

De Freitas, L., Rousell, D., Trafi-Prats, L. & Hohti, R. (in press). A poetics of opacity: towards a new ethics of participation in gallery-based art projects with young people.

Despret, V. (2016). *What would animals say if we asked the right questions?* (B. Buchanan, Trans.). University of Minnesota Press.

Didone, F., Kotrschal, K., Millesi, E., & Hemetsberger, J. (2012). Children and scientific observations: Pupils measuring Greylag goose behaviour. *International Journal for Cross Disciplinary Studies in Education, 3*, 871–876. https://doi.org/10.20533/ijcdse.2042.6364.2012.0124

Didone, F., Puehringer-Sturmayr, V., Neuböck-Hubinger, B., Gegendorfer, G., Kotrschal, K., & Hirschenhauser, K. (2019). Monitoring public awareness about the endangered northern bald ibis: A case study involving primary school children as citizen scientists. *PeerJ, 7*, e7569. https://doi.org/10.7717/peerj.7569

Figueiredo Nascimento, S., Cuccillato, E., Schade, S., & Guimarães Pereira, A. (2016). *Citizen engagement in science and policy-making*. Publications Office of the European Union.

Freiwald, J., Meyer, R., Caselle, J. E., Blanchette, C. A., Hovel, K., Neilson, D., & Bursek, J. (2018). Citizen science monitoring of marine protected areas: Case studies and recommendations for integration into monitoring programs. *Marine Ecology, 39*, e12470. https://doi.org/10.1016/j.gecco.2021.e01649

Froschauer, L. (2018). Citizen science. *Science and Children, 55*(8), 5–5.

Ganzevoort, W., & van den Born, R. (2019). The thrill of discovery: Significant nature experiences among biodiversity citizen scientists. *Ecopsychology, 11*(1), 22–32. https://doi.org/10.1089/eco.2018.0062

Golumbic, Y. N., Orr, D., Baram-Tsabari, A., & Fishbain, B. (2017). Between vision and reality: A study of scientists' views on citizen science. *Citizen Science: Theory and Practice, 2*(1), 1–13. https://doi.org/10.5334/cstp.53

Giraud, E. H. (2019). *What comes after entanglement? Activism, anthropocentrism and an ethics of exclusion*. Duke University Press.

Gunnarsson Dinker, K., & Pedersen, H. (2016). Critical Animal Pedagogies: Re-learning our relations with other animals. In H. E. Lees & N. Noddings (Eds.), *The Palgrave handbook of alternative education* (pp. 415–430). Palgrave MacMillan.

Hatton, M., Grimbilas, S., Kane, C., & Kenyon, T. (2019). Never too young to be a citizen scientist! *Science and Children, 57*(3), 49–54. https://doi.org/10.2505/4/sc19_057_03_49

Herodotou, C., Aristeidou, M., Miller, G., Ballard, H., & Robinson, L. (2020). What do we know about young volunteers? An exploratory study of participation in Zooniverse. *Citizen Science: Theory and Practice, 5*(1), 2. https://doi.org/10.5334/cstp.248

Hohti, R., & Tammi, T. (2019). The greenhouse effect: Multispecies childhood and non-innocent relations of care. *Childhood, 26*(2), 169–185. https://doi.org/10.1177/0907568219826263

Horton, J., & Kraftl, P. (2006). What else? Some more ways of thinking and doing 'children's geographies.' *Children's Geographies, 4*(1), 69–95. https://doi.org/10.1080/14733280600577459

Horton, J. (2010). 'The best thing ever': How children's popular culture matters. *Social and Cultural Geography, 11*, 377–398. https://doi.org/10.1080/14649361003774563

Hohti, R., & Karlsson, L. (2014). Lollipop stories: Listening to children's voices in the classroom and narrative ethnographical research. *Childhood, 21*, 548–562. https://doi.org/10.1177/0907568213496655

Häkli, J., & Kallio, K. (2018). Theorizing children's political agency. In T. Skelton & S. Aitken (Eds.), *Establishing geographies of children and young people. Geographies of children and young people.* (Vol. 1). Springer. https://doi.org/10.1007/978-981-4585-88-0_1-1

Irwin, A. (1995). *Citizen science: A study of people, expertise and sustainable development*. Psychology Press.

James, A., & Prout, A. (1990). *Constructing and reconstructing childhood: Contemporary issues in the sociological study of childhood*. The Falmer Press.

Kaeberlein, M. (2016). The Biology of aging: Citizen scientists and their pets as a bridge between research on model organisms and human subjects. *Veterinary Pathology, 53*, 291–298. https://doi.org/10.1177/0300985815591082

Kellett, M. (2010). Small shoes, big steps! Empowering children as active researchers. *American Journal of Community Psychology, 46*(1–2), 195–203. https://doi.org/10.1007/s10464-010-9324-y

Kim, G., & Lee, H. (2019). A case study of community-based socioscientific issue program: Focusing on the abandoned animal issue. *Journal of Biological Education*. https://doi.org/10.1080/00219266.2019.1699150

Kirksey, S. E., & Helmreich, S. (2010). The emergence of multispecies ethnography. *Cultural Anthropology, 25*, 545–576. https://doi.org/10.1111/.1548-1360.2010.01069.x

Kraftl, P. (2020). *After childhood: Rethinking environment, materiality and media in children's lives*. Routledge.

Latour, B. (1987). *Science in action: How to follow scientists and engineers through society*. Harvard University Press.

Lee, N. (2001). *Childhood and society: Growing up in an age of uncertainty*. Open University Press.

Lincoln, R., Larson, C., Cooper, B., & Hauber, M. (2016). Emotions as drivers of wildlife stewardship behavior: Examining citizen science nest monitors' responses to invasive House sparrows. *Human Dimensions of Wildlife, 21*(1), 18–33. https://doi.org/10.1080/10871209.2015.1086933

Lowan, G. (2012). Expanding the conversation: Further explorations into Indigenous environmental science education theory, research, and practice. *Cult Stud of Sci Educ, 7*, 71–81. https://doi.org/10.1007/s11422-012-9379-1

Lupinacci, J., et al. (2019). Teaching to end human supremacy: Learning to recognise equity in all species. In I. I. Nocella (Ed.), *Education for total liberation: Critical animal pedagogy and teaching against speciesism* (pp. 81–98). Peter Lang.

Mack, E., Augare, H., Different Cloud-Jones, L., David, D., Quiver Gaddie, H., Honey, R., Kawagley, A., Little Plume-Weatherwax, M., Lone Fight, L., Meier, G., Pete, T., Rattling Leaf, J., Returns From Scout, E., Sachatello-Sawyer, B., Shibata, H., Valdez, S. & Wippert, R. (2012). Effective practices for creating transformative informal science education programs grounded in native ways of knowing. *Cultural Studies of Science Education*, *7*. https://doi.org/10.1007/s11422-011-9374-y

Makuch, A. (2019). Eco-citizen science for social good: Promoting child well-being, environmental justice, and inclusion. *Research on Social Work Practice, 30*, 219–232. https://doi.org/10.1177/1049731519890404

Mueller, M., & Tippins, D. J. (2015). *Ecojustice, citizen science and youth activism*. Springer.

Ogden, L. A., Hall, B., & Tanita, K. (2013). Animals, plants, people, and things: A review of multispecies ethnography. *Environment and society, 4*(1), 5–24. https://doi.org/10.3167/ares.2013.040102

Olitsky, S. & Weathers, J. (2005). Working with students as researchers: Ethical issues of a participatory process. *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research, 6(1),* Art. 38. http://nbn-resolving.de/urn:nbn:de:0114-fqs0501383

Pascal, C., & Bertram, T. (2009). Listening to young citizens: The struggle to make real a participatory paradigm in research with young children. *European Early Childhood Education Research Journal, 17*, 249–262. https://doi.org/10.1080/13502930902951486

Patterson, L., Kalle, R., & Downs, C. A. (2017). Citizen science survey: Perceptions and attitudes of urban residents towards vervet monkeys. *Urban Ecosyst, 20*, 617–628. https://doi.org/10.1007/s11252-016-0619-0

Pedersen, H. (2010). Education policymaking for social change: A post-humanist intervention. *Policy Futures in Education, 8*, 683–696. https://doi.org/10.2304/pfie.2010.8.6.682

Pedersen, H., & Stanescu, V. (2014). Conclusion: Future directions for critical animal studies. In R. Twine & N. Taylor (Eds.), *The rise of critical animal studies: From margins to the centre* (pp. 262–275). Routledge.

Phillips, T., Porticella, N., Constas, M., & Bonney, R. (2018). A framework for articulating and measuring individual learning outcomes from participation in citizen science. *Citizen Science: Theory and Practice*. https://doi.org/10.5334/cstp.126

Prout, A. (2005). *The future of childhood: Towards the Interdisciplinary study of children*. Routledge Falmer.

Punch, S. (2002). Research with children: The same or different from research with adults? *Childhood, 9*, 321–341. https://doi.org/10.1177/0907568202009003005

Rautio, P. (2014). Mingling and imitating in producing spaces for knowing and being: Insights from a Finnish study of child–matter intra-action. *Childhood, 21*, 461–474. https://doi.org/10.1177/0907568213496653

Russell, C., & Spannring, R. (2019). So what for other animals? Environmental education research after the animal turn. *Environmental Education Research, 25*, 1137–1142. https://doi.org/10.1080/13504622.2019.1687639

Schuttler, S., Sears, R., Orendain, I., Khot, R., Rubenstein, D., Rubenstein, N., Dunn, R., Baird, E., Kandros, K., O'Brien, T., & Kays, R. (2019). Citizen science in schools: Students collect valuable mammal data for science. *Conservation, and Community Engagement, BioScience, 69*(1), 69–79. https://doi.org/10.1093/biosci/biy141

Shirk, J. L., Ballard, H. L., Wilderman, C. C., Phillips, T., Wiggins, A., Jordan, R., McCallie, E., Minarchek, M., Lewenstein, B. V., Krasny, M. E., & Bonney, R. (2012). Public participation in scientific research: A framework for deliberate design. *Ecology and Society*. https://doi.org/10.5751/ES-04705-170229

Skelton, T. (2008). Research with children and young people: Exploring the tensions between ethics, competence and participation. *Children's Geographies, 6*(1), 21–36. https://doi.org/10.1080/14733280701791876

Snaza, N., & Weaver, J. A. (2015). Introduction: Education and the posthumanist turn. In N. Snaza & J. A. Weaver (Eds.), *Posthumanism in educational research* (pp. 1–15). Routledge.

Soanes, K., Cranney, K., Dade, M. C., Edwards, A. M., Palavalli-Nettimi, R., & Doherty, T. S. (2020). How to work with children and animals: A guide for school-based citizen science in wildlife research. *Austral Ecology, 45*(1), 3–14. https://doi.org/10.1111/aec.12836

Steinke, D., Breton, V., Berzitis, E., & Herbert, P. D. N. (2017). The school malaise trap program: Coupling educational outreach with scientific discovery. *PLoS Biology, 15*(4), e2001829. https://doi.org/10.1371/journal.pbio.2001829

Strasser, B., Baudry, J., Mahr, D., Sanchez, G., & Tancoigne, E. (2019). "Citizen Science"? Rethinking science and public participation. *Science & Technology Studies, 32*, 52–76. https://doi.org/10.23987/sts.60425

Tammi, T., Leinonen, R.-M., Hohti, R., & Rautio, P., et al. (2020). Multispecies co-citizens—Encounters of children and animals in everyday life. In T. Räsänen (Ed.), *Companion travellers.* SKS.

Trench, B. (2008). Towards an analytical framework of science communication models. In D. Cheng, M. Claessens, T. Gascoigne, J. Metcalfe, B. Schiele, & S. Shi (Eds.), *Communicating science in social contexts: New models, new practices* (pp. 119–138). Springer.

Trumbull, D. J., Bonney, R., Bascom, D., & Cabral, A. (2000). Thinking scientifically during participation in a citizen-science project. *Science Education, 84*, 265–275. https://doi.org/10.1002/(SICI)1098-237X(200003)84:2%3c265::AID-SCE7%3e3.0.CO;2-5

Ulmer, J. (2017). Posthumanism as research methodology: Inquiry in the Anthropocene. *International Journal of Qualitative Studies in Education, 30*, 832–848. https://doi.org/10.1080/09518398.2017.1336806

Weckel, M., Mack, D., Nagy, C., Christie, R., & Wincorn, A. (2010). Using citizen science to map human–coyote interaction in suburban New York, USA. *Journal of wildlife management, 74*, 1163–1171. https://doi.org/10.2193/2008-512

Weil, K. (2010). A report on the animal turn. *Differences, 21*(2), 1–23. https://doi.org/10.1215/10407391-2010-001

Zárybnická, M., Sklenicka, P., & Tryjanowski, P. (2017). A webcast of bird nesting as a state-of-the-art citizen science. *PLoS Biology, 15*(1), e2001132. https://doi.org/10.1371/journal.pbio.2001132

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