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ORIGINAL ARTICLES

Postdigital Citizen Science: Mapping the Field

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Abstract

This paper provides a brief overview of citizen science, attending to its tensions and possibilities. We acknowledge the creative potential of citizen science for expanding and diversifying public participation in knowledge production and dissemination, and we also draw attention to its contradictions. We point to emerging postdigital tensions as new technologies and vast public databases are increasingly becoming cornerstones of citizen science. We discuss how postdigital citizen science operates in the context of knowledge capitalism while aiming at its transformation and highlight three key challenges for postdigital citizen science: the challenge of technology, the challenge of political economy, and the challenge of participation. Different postdigital challenges cannot be separated from each other, so we call for a deep reimagination and reconfiguration of citizen science in and for the postdigital condition. We start this reimagination by asking three questions: What is postdigital citizen science? Who (or what!) is the postdigital citizen scientist? How to conduct postdigital citizen science?

Keywords Postdigital · Research · Citizen science · Citizen humanities · Professionalization of science · Terminology · *Wissenschaft* · Technology · Participation · Political economy · Positionality · Knowledge capitalism · Knowledge socialism · *Homo economicus* · *Homo collaborans* · Critical praxis · Data · Artificial intelligence · Reimagination

Introduction

Citizen science is much older than academia. According to Silvertown (2009: 467), '[t]he rise of science as a paid profession is a relatively recent phenomenon, dating from the later part of the 19th century'. In *The Science of Citizen Science*, Vohland and colleagues (2021: 2) argue that '[r]ecognition of citizen science is growing in the fields of science, policy, and education and in wider society. It is establishing itself as a field of research and a field of practice, increasing the need for overarching insights, standards, vocabulary, and guidelines.'

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While we fully agree with the rising importance of citizen science, we are much less convinced by blanket statements such as '[c]itizen science fosters an open and participatory approach to science, reducing the distance between science and society, and contributing to the goal of an inclusive society' (Vohland et al. 2021: 1). Indeed, 'citizen scientists *can* play a role in developing society, improving communities, and promoting public participation' (Vohland et al. 2021: 1) (emphasis added) – but they can also, perhaps even at the same time, play a role in deepening existing inequalities and creating new ones.

Haklay (2018), for example, argues that top-down scientist-driven citizen science projects claim to foster citizen participation in scientific research, yet participants' roles are often limited to data collection with little input as to the objectives, design, and methods of data collection (Mueller and Tippins, 2012: 3). A good example is the renowned eBird project, which is 'among the world's largest biodiversity-related science projects, with more than 100 million bird sightings contributed annually by eBirders around the world and an average participation growth rate of approximately 20% year over year'. In the project, citizen scientists 'document bird distribution, abundance, habitat use, and trends through checklist data collected within a simple, scientific framework. Birders enter when, where, and how they went birding, and then fill out a checklist of all the birds seen and heard during the outing.' (eBird 2022)

Those who participate in citizen science are, by and large, from higher socioeconomic backgrounds and are more likely to have completed tertiary or graduate level education (Haklay 2018). These demographic realities of citizen science can reinforce stereotypes and reproduce broader systemic inequities in science participation (Herzog and Lepenies 2022). For example, short-term, top-down models are not likely to (and perhaps not intended to) provide lay citizens with the skills and capacities to significantly engage in—or affect—scientific and technological developments in meaningful ways (Irwin 2006).

We also disagree with the idea that citizen science should necessarily 'become a part of modern science' and with 'integrating its methods, models, and results into conventional ways of thinking in the different branches of scientific practice' (Vohland et al. 2021: 1). We see this as a clear case of postdigital epistemic violence, which.

> refers to ways of knowing, knowledge acquisition, the conveying of knowledge, or any communicative practice concerned with knowledge creation, production, or dissemination that actively or symbolically forces compliance with dominant modes of knowing. Alternative epistemic practices may be wilfully or carelessly suppressed or forgotten, embody practices that refuse to acknowledge, or which disqualify or denigrate non-dominant knowledge. (MacKenzie 2023)

As testified by diverse groups of people(s) over the centuries, including indigenous groups, LGBT + people, and many others, epistemic violence is not just about ideas. It also gets personal as '*a harm committed against knowers* on account of systemic prejudicial stereotypes about them as a class of disadvantaged identities resulting in unfair epistemic practices and communicative distortions in the knowledge economy' (MacKenzie 2023) (emphasis added). Even though we sincerely believe that the advocates of scientific integration do not purposefully (and even

consciously) push towards discrimination and harm, this clearly indicates that postdigital citizen science requires clear normative guidance that looks far into possible consequences of its foundational ideas and practices.

This paper provides a brief overview of the history and the current state of the art of citizen science. We then outline some pressing postdigital challenges of citizen science and begin to reimagine citizen science in and for the postdigital condition around three key questions: What is postdigital citizen science? Who (or what!) is the postdigital citizen scientist? How to conduct postdigital citizen science?

Citizen Science: An Overview

The practice of citizen science has been around for quite some time; only since the 1990s has it been more systematically referred to as 'citizen science' (Vohland et al. 2021). Citizen science has been acknowledged as a 'key pillar' of open science, enhancing public understanding of science through broadening participation (Eitzel et al. 2017). Some have understood the relationship between scientists and participants in citizen science as a two-way street, where scientists gain data and citizens gain scientific skills and knowledge (Bonney 1996). Others have raised questions about the potentially exploitative elements of citizen science, i.e., participants contribute free labor in the form of data collection and receive little in return for their contributions to scientist-led studies (Weinstein 2011).

Citizen science is often touted for its potential to democratize science, yet recent scholarship has raised questions about its participatory potential (Herzog and Lepenies 2022). Participants primarily collect data for scientists rather than collaborate with scientists, democratize protocol and equipment, assess ideas, and work in relation to others (Mueller and Tippins 2012: 3). Citizen science scholarship over the past decade has shed light on the various nuances and complexities of citizen science research and practice. Certainly, the participation of 'non-scientists' in science or science-related activity has always been a central goal, if not guiding ethos, of citizen science (Strasser et al. 2019).

Those who are credited with originally coining the term citizen science (Alan Irwin and Richard Bonney) represented different understandings of citizen science's potential to be science 'for the people' and a science 'by the people' (Strasser et al 2019: 53–54). Bonney's (1996) approach to citizen science has been primarily concerned with enhancing the public understanding of science through engagement in scientific research, i.e., participatory data collection. Irwin's (1995) approach was more about 'empowering participatory grassroots research' (Thomas et al. 2021: 2) and reflected a commitment to making science more responsive to public concerns as well as inclusive of local/community knowledge. Whether or not citizen science is participatory in its involvement of citizen scientists in research practice; or in its consideration of whose interests should guide the research topics, questions, and methods; or in its inclusion (or exclusion) of local knowledge and expertise, is an ongoing debate.

A variety of typologies have been developed to characterize diverse approaches to citizen science. Shirk and colleagues (2012: 32), for example, put forth a framework of five models of citizen science, which they refer to as Public Participation in Scientific Research (PPSR) models, represented as a progression from less to more participatory:

1. Contractual – communities seek out the help of researchers to conduct a specific investigation.
2. Contributory – scientist-led to which members of the public contribute data they have collected.
3. Collaborative – scientist-led to which members of the public collect and contribute data as well as participate in other aspects of research such as data analysis and/or dissemination.
4. Co-created – co-designed by scientists and members of the public.
5. Collegial – led and largely conducted by 'non-credentialed' members of the public and advances scientific knowledge. (Shirk et al. 2012: 32)

Wiggins and Crowston (2011) put forth an empirically grounded typology from existing directories of citizen science. They generated five categories of citizen science:

1. Action – citizen science projects that engage community members in using citizen science to address grassroots, often civic, concerns.
2. Conservation – projects in which participants engage in data collection, often environmental monitoring, as part of ongoing conservation or preservation efforts, often affiliated with public agencies.
3. Investigation – projects which engage participants in ongoing data collection and observation within the physical environment, such as within meteorology, astronomy, biology.
4. Virtual – ICT-mediated projects with no actual 'physical' elements but rather in which participants ('citizen scientists') engage in citizen science activities online, such as to analyze images from space (e.g., galaxies, celestial bodies).
5. Education – citizen science projects in which the primary goal is learning and outreach, whereby participants engage in 'doing citizen science' predominantly for educational purposes rather than for the production of scientific knowledge. (Wiggins and Crowston 2011)

While there are many different forms of citizen science, the most common and widely recognized has been that in which community members ('non-scientists') collect data for studies led by experts, what has been characterized as *contributory citizen science* (Bonney et al. 2009).

Some have argued for alternative conceptualizations of participatory science, decoupled from citizen science (Weinstein 2011). The rationale for such a decoupling is often driven not only by citizen science's more common affiliation with contributory vs. fully participatory research projects but also by the historical exclusions associated with terms such as 'citizen' and 'science' (Eitzel et al. 2017). Liebenberg and colleagues (2021) argue that citizen science, in both name

and practice, overlooks Indigenous knowledge and for this reason propose that the terminology of 'tracking science' versus citizen science would better represent diverse knowledge practices. They argue that 'tracking science' captures the local knowledge of communities who have land-based expertise not formally recognized in science, such as tracking weather patterns or animal migration patterns.

Additionally, the experience and knowledge of older generations on disaster are rich with local warning indicators. Stories about past natural disasters are found in oral literatures, songs, poems, and even lullabies. Such past knowledge can not only reduce disaster risk but also prevent human casualties. However, Indigenous knowledge is often discarded as 'unscientific'. Such local knowledge needs to be integrated with the scientific early warning system and could help in disaster risk reduction and increase the resilience of vulnerable communities (Haokip 2022).

Many alternatives to citizen science offer a liberatory potential that citizen science seems to lack. These include 'civic science', where people's participation in community science is about 'questioning the state of things' (Fortun and Fortun 2005: 50), or *ciencia popular* (people's science) which emerges from participants' a priori social justice commitments and where expertise is derived from within the community (Weinstein 2011). Similarly, 'community citizen science' connects citizen science with social issues 'by empowering communities to produce scientific knowledge, represent their needs, address their concerns, and advocate for impact with the long-term goal of sustaining community-driven research beyond the initial citizen-researcher collaboration' (Hsu and Nourbakhsh 2020: 31). 'Citizen social science' is also an emerging term more widely applied to social science research drawing on citizen science and using participatory research methods to address social challenges such as housing, mental health, and climate action (Thomas et al. 2021).

We agree with Strasser and colleagues' (2019: 53) point that 'understanding what kind of science, but also what kind of society, this particular mode of public participation in science is producing will require joining the epistemological with the political'. We argue that understanding this particular mode of participation necessitates particular attention to the under-theorized dimensions of postdigital participation and citizen science. Therefore, we extend Strasser and colleagues' (2019) assertion to include joining the epistemological and political with the postdigital.

The Postdigital Challenge

During its long history, citizen science has undergone significant transformations. The latest transformation, postdigital citizen science, is a rupture and continuation (Jandrić et al. 2018: 895) of earlier practices. Postdigital transformations are everywhere, as the postdigital age touches upon almost every aspect of contemporary life. To get a hold on these transformations, we explore three postdigital challenges that are particularly relevant for citizen science: the challenge of technology, the challenge of political economy, and the challenge of participation.

The Challenge of Technology

According to Silvertown (2009: 467), '[t]he characteristic that clearly differentiates modern citizen science from its historical form is that it is now an activity that is potentially available to all, not just a privileged few'. This increase in potential availability is correlated with many social changes such as the expansion of basic literacy and the global spread of compulsory schooling. In the late twentieth century, however, the expansion of information and communication technologies in the form of cheap, available, and easy-to-use consumer devices such as computers and smartphones has opened a whole new era for collaborative research (Peters et al. 2020) and citizen science (Newman et al. 2012; Hsu and Nourbakhsh 2020).

New and emerging technologies (e.g., mobile apps, digital sensors, gaming, social media) within citizen science have significant potential to expand the frontiers of participatory research, knowledge production, and public engagement (Newman et al. 2012). Emerging technologies are more easily accessible than specialized tools traditionally used in field research and are more affordable, thereby lowering 'the barrier to entry' into citizen science participation (Chari et al. 2017: 7). Rey-Mazón and colleagues (2018: 973), drawing on the environmental justice work of Public Lab,[1] highlight how open source digital tools and other do-it-yourself technologies have enabled 'citizens' veillance' or 'novel, collective forms of knowledge generation towards some shared, common purpose–typically, the securing of rights, resources, and/or solidarity among members of a community' (see also Boucher et al. 2018).

Emerging technologies not only have the effect of broadening participation in citizen science; they also enhance data collection capabilities, support the more widespread corroboration of results, and reduce timelines for decision-making (i.e., from research to policy or practice) (Newman et al. 2012). However, the rapid growth and increasingly expansive use of postdigital technologies in citizen science are also in and of itself a 'wicked problem' (Hsu and Nourbakhsh 2020).

In one form or another, postdigital citizen science often involves collecting and processing data. The increasingly widespread use of emerging technologies in citizen science and crowdsourcing data collection has led to the creation of enormous online databases (Chari et al. 2017). And, as D'Ignazio and Klein (2020) have pointed out, data are never neutral. Depending on the database and the sources of data, data collected by either humans or machines can oversample some communities or populations over others. For instance, '[h]istorically, medical studies have excluded female participants and research data have been collected from males and generalized to females. The gender gap in medical research, alongside overarching misogyny, results in real-life disadvantages for female patients.' (Merone et al. 2022: 49)

The problem with data goes beyond sampling, as data collection can often reflect age-old power relationships and inequalities. In a poignant example, Kukutai and Cormack (2020: 25) write: 'For Māori, the mass production, collection, storage and use of data in Aotearoa NZ can be understood as a "replaying" of a familiar colonial experience, whereby "resources" are seen to be open for exploitation and extraction of profit, with little regard for Indigenous knowledge systems and ways of conceptualizing benefit.'

[1] See https://publiclab.org/. Accessed 26 October 2023.

Some proponents of postdigital theory strongly push back against the uncritical dominance of data. Most recently, in *Human Data Interaction, Disadvantage and Skills in the Community: Enabling Cross-Sector Environments for Postdigital Inclusio*n, Hayes and colleagues (2023) launched

> a powerful counterattack to reinstate critical praxis in a postdigital context. Working with a mixed group of authors from academia, the public sector and industry, they have created a space that allows the re-emergence of praxis in one of the most important aspects of community life: inclusion. (Jandrić 2023a, b: vi)

The chapters in the book take a creative and alternative approach to the traditional, linear route, where a theory-led disciplinary framework simply informs the direction of policy and practice. The Human Data Interaction framework (Mortier et al. 2014) was designed primarily to guide the practices of those developing data-intensive systems, but the book highlights the different ways to engage with the intersectional complexities of human interactions with data and reminds us of the inseparability between theory and practice.

Indeed, data are inseparable from their usage. 'Governments can and do use biased data to marshal the power of the matrix of domination in ways that amplify its effects on the least powerful in society.' (D'Ignazio and Klein 2020: 39) That can be done on purpose: one typical example is the European Parliament's ban of using 'invasive mass surveillance technologies in its Artificial Intelligence Act' on EU citizens, while '[t]he Parliament failed to ban discriminatory profiling and risk assessment systems, as well as forecasting systems used to curtail, prohibit and prevent border movements' (Amnesty International 2023).

To add insult to injury, even the most equity- and emancipatory-oriented data (usage) can turn into its opposite. As they develop 'into a new independent stage; high levels of automation bring about a situation in which even designers of these technologies cannot predict their behavior!' (Mañero 2020: 490) Prominent early examples of this problem, such as Google Images tagging black people as gorillas and Amazon's male-favoring recruitment algorithm, are clear examples of 'best intentions gone wrong' (Jandrić 2019a). The introduction of practices such as algorithm auditing (Jandrić 2019a) and the development of concepts such as 'AI hallucination' (McQuillan 2023; McQuillan et al. 2023) clearly shows that algorithms just do not always follow the intentions of their makers. Benjamin (2019a, b) has extensively analyzed how technologies operate as the 'new Jim Code' to reproduce or even exacerbate social inequalities, documenting the multiple ways in which human social bias and the logics of racism and disparity are engineered into supposedly 'unbiased' technologies such as AI.

Other prominent examples of the wider 'algorithms gone wrong' genre, such as Eubanks' *Automating Inequality: How High-Tech Tools Profile, Police, and Punish the Poor* (2018), show that the line between deliberate and non-deliberate AI discrimination is sometimes hardly discernible. As we read the official governmental presentation of underlying technology as 'neutral tools for optimization of public spending' and Eubanks' horror stories of how these tools have created the 'digital poorhouse', we are left wondering: Was the 'digital poorhouse' created on purpose, or is it an unintended (and unforeseen) consequence of introducing new technology?

This brings about a plethora of questions about human agencies, non-human agencies, and their relationships.

Adopting a postdigital perspective also involves taking a broader, more inclusive approach to 'science' than is usually used in the English language, which encompasses the social sciences and the humanities. Therefore, it is at this point that we consider how the social sciences and humanities (SSH) can help with understanding the human dimensions in citizen science and 'open a broad methodological spectrum for enriching scientific research with new approaches and for boosting public participation' (Tauginienė et al. 2020: 1). It is the reflective role of SSH and the (inter/trans)-disciplinary skills in undertaking, for example, interviews and evaluations, that can add to an increased sustainability for citizen science. SSH frameworks provide insights on the socio-technical character of some citizen science challenges

> such as climate change or the loss of biodiversity, where value systems, economy, and governance systems are in fact underlying factors, and, on the other hand, methodologies and skills from especially social sciences are applied to understand the motivation and learning processes of participants better to increase their self-efficiency, and the project outcomes and impacts (Tauginienė et. al. 2020: 9).

Such interconnections are a defining feature of postdigital society and cannot be omitted from credible studies in citizen science.

As observed by Jandrić et al. (2018: 895), 'the postdigital is hard to define; messy; unpredictable; digital and analog; technological and non-technological; biological and informational'. A key feature of postdigital research is a 'more-than-human' entanglement of human beings and technologies or the inseparability between the researcher, the technologies of conducting and disseminating research results, and the research subject (Jandrić et al. 2018: 895). In our postdigital condition, the promise of emerging technologies in citizen science (Newman et al. 2012; Rey-Mazón et al. 2018; Hsu and Nourbakhsh 2020) needs to be carefully thought through postdigital theoretical lenses based on sources including critical philosophy of technology, science and technology studies (STS), feminist science and technology (D'Ignazio and Klein 2020), critical race studies of technology (Benjamin 2019a, b), and posthumanism (see Jandrić et al. 2018).

The Challenge of Political Economy

We now live in the age of the global 'knowledge economy,' 'knowledge capitalism,' or 'cognitive capitalism.' These terms describe

> a new form of capitalism sometimes called the third phase of capitalism, after the earlier phases of mercantile and industrial capitalism, where the accumulation process is centred on immaterial assets utilising immaterial or digital labour processes and production of symbolic goods and experiences. … The core of cognitive capitalism is centred on digital labour processes that produce digital products cheaply utilising new information and communications technologies that are protected through intellectual property rights

> regimes which are increasingly subjected to interventions and negotiations of the nation states around the world. (Peters and Bulut 2011)

Knowledge capitalism strongly dominates contemporary production and dissemination of knowledge, and this domination has some deep consequences for the nature of new knowledge.

To take just one of many examples, this one from Hayes and Jandrić (2023: 785): 'Blue skies research is roughly defined as abstract research, driven by intellectual curiosity, and without immediate real-life application. Applied research, as the name says, is hands-on research with an expectation of a relatively quick real-life application.' In a neoliberal university, research opportunities are directly linked to external funding. In their calls for projects, funding agencies determine what type of research will be funded and what type of research will not be funded. Most of these agencies are open to the market; expecting a financial return of investment, they strongly prefer applied research over blue skies research. According to Braben, this results in some disturbing consequences:

> New scientific fields are not being created. Today's technologies are short-lived variations on seminal discoveries made decades ago. Intellectual capital is therefore being consumed faster than it is being replaced. Furthermore, the faster industry uses up intellectual capital, the more it will appear that we are experiencing healthy growth. … If the portfolio of intellectual capital is not expanded, preferably with generic technology, the New Economy brings diminishing returns and puts us on a fast track to global economic stagnation. (Braben 2002: 770-771)

Political economy largely determines what we research, how we research, and to what end.

While the neoliberal political economy significantly narrows down the nature of developed knowledge, knowledge capitalism is far from the only game in town. New technological opportunities such as the rise of peer production, open access, open science, and novel forms of collective intelligence and social innovation have given rise to an alternative conceptualization called knowledge socialism. According to Peters and colleagues,

> [w]hereas knowledge capitalism focuses on the economics of knowledge, emphasizing human capital development, intellectual property regimes, and efficiency and profit maximization, knowledge socialism shifts emphasis towards recognition that knowledge and its value are ultimately rooted in social relations. (Peters et al. 2012: 88)

Citizen science has always been predominantly driven by curiosity, and most citizen scientists are not paid for their work. This form of knowledge capitalism has also been discussed as 'digital prosumer capitalism' where consumers are put to work as prosumers in all kinds of contexts (Ritzer et al. 2018). Yet if these forms of production are reimagined in the form of knowledge socialism, there are powerful opportunities to disrupt prosumer capitalism towards an interesting prosumer socialism. 'Unlike knowledge capitalism, which relies

on exclusivity—and thus scarcity—to drive innovation, the socialist alternative recognizes that exclusivity can also greatly limit innovation possibilities.' (Peters et al. 2012: 88) Put differently, citizen science does not just enable us to reach places and phenomena; it also enables the creation of fundamentally different and arguably more creative (ways of) knowledge (development). It offers an opportunity to explore where 'digital prosumer capitalism' might meet with 'postdigital prosumer socialism'.

Vohland et al. (2019) recognize the dynamic between knowledge capitalism and knowledge socialism in the context of citizen science:

> The neoliberal turn in science has led to the economisation of knowledge, economic criteria for evaluating research, and a retreat of the state from governance of the scientific system. These steps have important ramifications for citizen science. On one hand, citizen science may add to the neoliberalization of science by filling gaps in 'traditional science,' such as providing free environmental data or delivering public goods such as education or environmental knowledge. On the other hand, citizen science may provide a way to buck the trend of neoliberalization, by promoting new forms of societal cooperation and mutual learning that may lead to more social cohesion and sustainability, as well as safeguard a non-economized sphere. In this way, citizen science is ambivalent: It can either strengthen or challenge neoliberalization of science. (Vohland et al. 2019)

While they fail to recognize links between political economy, epistemology, and creativity, Vohland et al. (2019) do send an important message. Postdigitial citizen science is not just another 'branch', or 'extension', of professional science. Instead, postdigital citizen science is a place of struggle between the fundamentally different models of knowledge capitalism and knowledge socialism, an opening in the tight structure of the ivory tower that allows for different views, approaches, and types of knowledge, as well as a reconsideration of 'digital prosumer capitalism' as a form of 'postdigital prosumer socialism'.

The Challenge of Participation

At the level of the individual, knowledge capitalism and knowledge socialism can be represented through two conflicting figures: *homo economicus* and *homo collaborans*. Representing knowledge capitalism, *homo economicus* is governed by 'controlling assumptions of rationality, individuality and self-interest' (Peters and Jandrić 2018: 82). Their opponent, *homo collaborans,*

> is committed to three assumptions that tend to run counter to the collective learning processes that characterize the digital environment. The assumption of individuality is counter posed by collective intelligence … The assumption of rationality is contradicted in a networked environment as the ontological basis is contained in the relations between entities … the assumption of self-interest again tends to be offset or decentred by forms of collective responsibility. (Peters and Jandrić 2018: 342–343)

It is important to emphasize that 'conceptual pairs such as *knowledge socialism* and *knowledge capitalism*, *homo collaborans* and *homo economicus*, are no more than imaginary, idealised, black-or-white contraries; we live most of our lives in various shades of grey between those extremes' (Jandrić 2020: 85) (emphases from the original).

The challenge of participation has many faces that can be only touched upon in this conceptual article. According to Weich and Macgilchrist (2023: 5), 'we can differentiate between participation as (1) taking part in something and as (2) having a (more-or-less decisive) say in decision-making processes'. Taking part in research roughly corresponds to the concept of *contributory citizen science* (Bonney et al. 2009) and the *homo economicus*, while having a (more-or-less decisive) say in decision-making processes roughly corresponds to *participatory citizen science* and the *homo collaborans.*

Weich and Macgilchrist (2023: 6) argue that 'we should not only take into account whether or not participation is actually being achieved but also which aims and values go along with it'. They ask: '[W]ho should even participate and to what end?' This question opens up the epistemic and normative aspect of postdigital citizen science. What kind of knowledge may result from a full participation of citizen scientists in scholarly research? Which values underlie such knowledge production; which values does this knowledge reflect?

This set of questions can be broken down in many different directions. Participation is an epistemic issue, as different ways of participating lead to different types of knowledge. It is an educational issue, as most citizen scientists have completed higher education (Haklay 2018). It is an economic issue, as most citizen scientists arrive from higher socio-economic backgrounds (Haklay 2018), and an issue of technological development, as many citizen scientists' tasks of yesterday (such as measuring rainfall or counting animals) are now being replaced by machines (Peters et al. 2019).

Participation is an ecological problem, because the 'postdigital ecosystem of our era is, importantly, contextualized in and productive of new bioinformational reconfigurations in capitalism, imperialism, colonialism, and ontological and political hierarchies more generally' (Jandrić and Ford 2022b: xiii). Participation, then, is also a problem of gender (Hurley 2023), race, ethnicity (Benjamin 2019a, b), religion (Savin-Baden and Reader 2022), location, and other forms of identity, intersectionality, and belief.

The Postdigital Challenge: An Overview

The postdigital condition is ubiquitous. It appears in human relationships with technologies, each other, and the planet; it reaches all the way to fundamental questions such as human nature and the nature of knowledge. Different postdigital challenges cannot be separated from each other, so attempts at reconfiguring citizen science for the inclusion of this or that group, or focusing citizen science to certain needs or communities, will never fully address the postdigital challenge of citizen science. What we need, instead, is a deep reimagination and reconfiguration of citizen science in and for the postdigital condition.

What, Who, and How?

We start our reimagination by asking three questions: What is postdigital citizen science? Who (or what!) is the postdigital citizen scientist? How to conduct postdigital citizen science?

What Is Postdigital Citizen Science?

The concept of the postdigital defies definition, and for good reason. In words of Siân Bayne (in Networked Learning Editorial Collective et al. 2021: 332), '[t]o define a field is necessarily to put boundaries around it, to determine which writings, conversations, people are "inside" and which are "outside."' The creation of boundaries is directly opposed to the postdigital spirit of openness, so Jandrić and Ford (2022a: 707) decided to turn this into a guiding principle and ensure that 'the postdigital remains—for as long as it is productive—a concept that constantly resists any final definition'. This position has inspired some resistance (see Haecker 2023) and a lot of caution. 'In a world where power derives from naming, defining, and demarcating, this resistance to definitions could lead to a discursive weakening of postdigital theory and needs to be negotiated carefully.' Jandrić (2023a, b: 12) Writing about postdigital sensibilities, however, Jopling (2023) argues that the postdigital position might require us to be vulnerable but not weak—somewhat paradoxically, its vulnerability is its main strength (see Büchner 2023; Poltze 2023).

Postdigital citizen science operates in the context of global knowledge capitalism. It reaches objects and phenomena far from research centers and cuts costs of research, thus enabling important (and difficult to fund) projects such as the global tracing of birds. This leads to the common model of *contributory citizen science* (Bonney et al. 2009): citizen scientists are primarily engaged in data collection, while the epistemic positioning of research, research design, and the interpretation of results is firmly with the experts. In this context, the expert is the rational, individualistic, profit-oriented *homo economicus*, while the (unpaid, voluntary) citizen scientist is the community-oriented *homo collaborans*.

It is possible to embrace the contradictory position where postdigital citizen science is positioned in and against capitalist modes of production and dissemination of knowledge at the same time as it contemplates the role of 'postdigital prosumer socialism'. In this, it reflects Lefebvre's (2014: 503) association of contradiction with creativeness: 'Contradictions give rise to problems, and thus to a set of possibilities and to the need to find a solution.' It opposes the dominant model of knowledge capitalism and *homo economicus* with a radically different model of knowledge socialism and *homo collaborans*. Postdigital citizen science is a struggle for egalitarian, collaborative, open research directed at producing knowledge aimed at emancipation and freedom.

Postdigital citizen science is not about 'adding a community touch' to existing models of knowledge production; it is a fundamental change aimed at epistemic and social change for a more just present and future. According to John Holloway (2016), the position of citizen science 'in and against' current models

of knowledge production cannot be resolved from within. Therefore, postdigital citizen science aims at reaching beyond its current state of the art and developing new models of knowledge production.

Who (or What!) Is the Postdigital Citizen Scientist?

For most of human history, scientific research had been conducted by people of financial and other forms of privilege (such as aristocracy and priests), who did not have any outside support for their work. In the nineteenth century, however, 'the proliferation of scientific societies, journals, and opportunities for advanced research and education led to the professionalization of the physical sciences and the formalized structure of specialization, publication, and academic training that characterizes modern scientific scholarship' (Encyclopedia.com 2023). With the institutionalization of scientific research and increased opportunities for paid work, science has slowly begun to democratize. However, today's barriers to entry into academic positions are still considerably high, and today's average scientist still arrives from the position of privilege. Furthermore, Morgan et al. (2022) show that the sociodemographic characteristics of the professoriate have remained 'stable across the past 50 years'.

The institutionalization and professionalization of science have significantly transformed the role of the scientist:

> The traditional model of the independent, self-driven scientist led by his or her own curiosity and value placed on knowledge is being replaced by a model of the scientist as a professional, providing a necessary service in response to a well-defined need and guided by society's priorities and funding incentives. (Guidotti 2016: 245)

This position brings about many challenges including the steering of scientific research towards the priorities of funding organizations, the prioritization of applied research against blue-skies research, the organization of universities and research organizations according to managerialist principles (Jandrić and Hayes 2019; Hayes and Jandrić 2023), and, above all, a strong push towards 'measuring excellence' (Hayes 2020). While many of these developments can be attributed to the neoliberalization of scholarly research, their deep foundation lies in the institutionalization and professionalization of science.

The professionalization of science brings about a plethora of effects that reach beyond the scope of this article. However, some of these effects are very relevant for citizen science. First, '[p]rofessionalization is expressed in social closure. A profession internalizes the discussion and processing competition for problems of a certain type.' (Mieg 2022: 71) This closure has various manifestations: the rise of professional associations, the development of codes of professional conduct (such as the Hippocratic Oath), and so on. Discourses of professionalization can act as mechanisms for social reproduction and suppress dissent (Tolbert and Eichelberger 2016). Professional scientists are an elite club based on institutionalized credentials. In literature, the difference between institutionalized

and non-institutionalized scientists can be found under various names including 'low science' and 'high science'; 'scientific centers' and 'scientific margins' (see Jandrić and Hayes 2019 for a detailed analysis of relationships between scientific centers and margins). Paradoxically, some of the key scientists in human history belong to 'low science' or the 'scientific margins'; examples include Isaac Newton, Karl Marx, and Nikola Tesla.

According to Jandrić and Hayes (2019: 391), '[o]ur postdigital age is one of cohabitation, blurring borders between social actors and scientific disciplines, mutual dependence, shifting relationships between traditional centres and margins, and inevitable compromise – and this calls for deep reconfiguration of politics and practice of knowledge production'. Following this argument, a postdigital reconfiguration of citizen science does not accept elitist closures and dichotomies such as 'professional scientist' vs. 'lay scientist' or 'citizen scientist'. While it is clear that professional scientists have more resources, citizen scientists can play a significant role in scholarly research. The postdigital age is about openness and inclusivity; professional scientists and citizen scientists need to be accepted as equals.

Of course, this does not imply an 'anything goes' approach, where my ignorance is of equal value to your knowledge. However, postdigital theory does insist on conceptual equality of various types of knowledges, regardless of their origin in institutional or lay circles. In this paper, we still use the terms 'professional scientist' and 'citizen scientist' to distinguish between those two very different sets of circumstances. These terms do not presuppose a hierarchy: knowledge is knowledge, regardless of its origins.

In our age of rapidly developing artificial intelligences, we need to emphasize the postdigital entanglement between human and non-human actors. While it is a stretch to claim that non-human entities can be placed on an equal plane with human researchers, technologies do have their own agency in many research processes (especially those related to big data and algorithms). Already in 2002, Steve Fuller and Bruno Latour staged a popular public debate with the motion: 'A strong distinction between humans and non-humans is no longer required for research purposes.' (Barron 2003: 78) While this debate (and other similar debates) has not yielded a definite answer, postdigital community science does need to seriously engage with the many questions of posthumanism.

Another important effect of the professionalization of science is the emergence of disciplines:

> With professionalization, science has received a tacit administrative mandate for systematic knowledge acquisition and emancipated itself from further-reaching appropriation. Many inner-scientific responsibilities, such as method development or quality assurance, have risen over time and passed into institutional hands, namely to the disciplines. In the past, science was embodied in the individual scientists and scholars, whereas today it is embodied in the disciplines. (Mieg 2022: 87)

Postdigital theory recognizes that most of today's problems belong to more than one discipline. Therefore, it advocates a postdisciplinary understanding of scholarly research and encourages approaches such as multi-, inter-, and transdisciplinarity (Jandrić et al. 2023a, b).

We thus arrive at an important problem of terminology, which reaches back all the way to the inception of the *Postdigital Science and Education* journal, book series, and encyclopedia.[2] In *Postdigital Science and Educatio*n, the word 'science' reflects the German (and by extension continental European) concept of *Wissenschaft*. This has much broader application than the English term in that 'it is used to denote any disciplined approach to the generation of knowledge, and it thereby encompasses subjects that English speakers would intuitively classify as sciences and as humanities' (Lewens 2016: 36).

In the Anglo-Saxon world (and English language), the use of the word 'science' was increasingly restricted to the physical and natural sciences from the mid-nineteenth century, creating a division between science and the humanities which was captured most enduringly in Charles Percy Snow's *The Two Cultures* (Collini 1993). In contrast, *Wissenschaft* is used both more expansively and more precisely in German, not as a discrete term but in a series of lengthy compound nouns which include not only *Naturwissenschaften* (natural sciences) but also *Geisteswissenschaften* (humanities) and *Bildungswissenschaften* (educational sciences). The direction of travel in postdigital research reflects this broader ethos. This could lead to a recognition in postdigital citizen science that research from all disciplines and by all actors should be placed on an equal plane.

Being problematic in so many ways, the term citizen science can be retained (same words, different meaning), replaced (by a completely different term), or supplemented (for instance, with prefix postdigital). Based on the idea that our postdigital age brings about a rupture and continuation (Jandrić et al. 2018: 895) of earlier practices, we opted for simple supplementation in the form of *postdigital citizen science*.

How to Conduct Postdigital Citizen Science?

With the recent publication of *Postdigital Research: Genealogies, Challenges, and Future Perspectives* (Jandrić et al. 2023a) and *Constructing Postdigital Research: Method and Emancipation* (Jandrić et al. 2023b), postdigital research has matured into an established field of inquiry and practice. In these books, the postdigital community has set its own understanding and agenda for postdigital research. These can be used as points of departure for inquiry into postdigital community science. The task is far from easy: 'Postdigital research can employ any research methodology, yet not all research is postdigital.' (Jandrić et al. 2023a: 6) Therefore, we will merely outline some characteristics of postdigital research that are particularly relevant for citizen science: postdigital positionality, postdigital sensibilities, and relationships between method and emancipation.

According to Hayes (2023: 4), postdigital positionality 'includes exploring different stances that a human postdigital researcher might take and the critical reflexivity that is incumbent upon them to exercise'. Using the most obvious example, professional scientists and citizen scientists have different employment positions. This translates into having various levels of access to scholarly literature and research apparatus, with the most obvious distinction being whether their work is paid or not.

[2] See Postdigital Science and Education Book Series, https://www.springer.com/series/16439 and *Encyclopedia of Postdigital Science and Education*, https://link.springer.com/referencework/10.1007/978-3-031-35469-4. Accessed 2 November 2023.

However, that does not mean that all citizen scientists are in a worse position than professional scientists. A millionaire citizen scientist can purchase what they need and enjoy research without the stress of employment. A professional scientist who lives from paycheck to paycheck may find themselves overwhelmed with administrative duties and little or no time for research. They may answer to incentive structures within academia that are out of line with the role that academia should play in democratic societies. The hunt for grant money can 'push scientists into a survival mode in which publications in high-ranked journals matter more than either fundamental research that the scientists find genuinely interesting and important, or research that matters for addressing urgent problems in society' (Herzog and Lepenies 2022: 504).

The example of postdigital positionality could therefore be developed almost indefinitely to include aspects of context as well as age, gender, ethnicity, race, and many other factors. As a rule of thumb, however, none of these aspects should be addressed in isolation, as they all strongly influence each other.

Another important question is: 'how we might perceive the postdigital positionality of other "entities" that are not (obviously) human, but that impact on humans and each other?' (Hayes 2023: 4). For example, Kaeser-Chen et al. (2020: 704) point out that although 'positionality is a person's unique and always partial view of the world which is shaped by social and political contexts', it is necessary to acknowledge that '[m]achine learning (ML) systems have positionality too, as a consequence of the choices we make when we develop ML systems'. They argue that when groups form a shared view of the world, as a group positionality, they have the power to embed and institutionalize their unique perspectives in artefacts such as standards and ontologies. Thus, 'being positionality aware is key for machine learning practitioners to acknowledge and embrace the necessary choices embedded in machine learning by its creators' (Kaeser-Chen et al. 2020: 704).

Postdigital research is always in flux. In the realm of theory, that translates into a resistance to definitions (Jandrić and Ford 2022a). In the realm of practice, such lack of clear guidance can lead to uncomfortable uncertainty. In his recent review of *Postdigital Research: Genealogies, Challenges, and Future Perspectives* (Jandrić et al. 2023a), Büchner describes his own mixed feelings about postdigital research:

> Despite its charisma, I often felt let down by the postdigital. I found no clear definitions of what it is, what analytical potential it holds, or what world phenomena it is (not) capable of describing. As an emerging scholar in the qualification phase, I wanted unambiguity, stability, and reliability—qualities that postdigital research consistently eluded. (Büchner 2023)

Similarly, in her review of *Constructing Postdigital Research: Method and Emancipation* (Jandrić et al. 2023b), Poltze (2023) reflects: 'for emerging researchers like me, the "postdigital" was a multifaceted, challenging concept, that led to many frustrating, but also inspiring moments'. Jopling (2023: 156) describes this amalgam of feelings as 'postdigital vulnerability' and argues that 'as postdigital and educational researchers, as human beings, we might address the uncertainty captured in the postdigital by accessing, rather than denying, our vulnerability and integrating it into our praxis as researchers'. Opening up to our own vulnerability is also 'about opening up research to the unclear and indeterminable' (Büchner 2023). In this way, vulnerability becomes an important strength of postdigital research.

Büchner (2023) cuts his emotional Gordian knot with a conclusion that '[p]ostdigital research confronts a societal condition characterized by ambiguity, uncertainty, and fundamental hybridity. And it does so with a term that holds this complexity in abeyance. Postdigital's abeyance is productive, because of the postdigital community's belief in dialogue and collaboration.' Poltze (2023) finds her inspiration in a postdigital 'spirit of hopeful critique' and argues that '[h]olding the postdigital in abeyance is challenging, yet it encourages researchers to apply the postdigital constructively within our research practice, reflect on our researcher selves, and develop hopeful alternatives, (future) designs, and pathways for change'.

The position of the postdigital citizen scientist is much less structured than that of the professional scientist. On the one hand, the combination of little or no institutional support, and little theoretical guidance, can lead to even more ambiguity, mixed feelings, and frustration than that expressed by professional scientist reviewers of postdigital research books. On the other hand, most postdigital citizen scientists need not worry about institutional constraints such as annual reviews, project bids, and other forms of monitoring and measuring academics. For a citizen scientist, postdigital sensibilities are both a curse and a blessing: every ambiguity, and every frustration, is both nuisance and opportunity.

Poltze's (2023) accent on 'hopeful alternatives, (future) designs, and pathways for change' opens up the fundamental relationship between method and emancipation. True to its roots in critical pedagogy, postdigital research is always about changing the world. Situated in the community, scattered all over the globe, and positioned at the fringes between institutional and non-institutional research, postdigital citizen science has strong, well-recognized potentials for education about scientific research and its democratization. However, this potential is often tamed by hierarchical, non-reciprocal practice (Wiggins and Crowston 2011; Herzog and Lepenies 2022). Borrowing again from critical pedagogy, postdigital citizen science needs to walk its own talk in the form of critical praxis.

What Comes Next?

This position paper develops our initial ideas about postdigital citizen science drawn from an intersection between available literature on citizen science and postdigital theory. They present our first stab at the theme: a point of departure for further research, food for thought, and a provocation for postdigital dialogue (Jandrić et al. 2019b).

Postdigital citizen science is a growing field that requires a lot of dedicated attention and a praxis that cannot just be explored theoretically. It is a community effort that needs to be explored by all scientists regardless of their position or employment status. Inspired by the concept of 'mansplaining', or 'the practice of a man explaining something to a woman in a way that shows he thinks he knows and understands more than she does' (Oxford Dictionaries 2023),[3] we have coined term 'sciencesplaining': the practice of professional scientists explaining something to citizen scientists in a way that shows they think they know and understand more.

[3] The development of the term 'mansplaining' was inspired by Rebecca Solnit's (2014) essay 'Men Explain Things to Me'.

All authors of this article are professional scientists, yet we are firmly against science-splaining. Therefore, we invite everyone who identifies as a researcher, human and non-human, employed or not, to join us in an exploration of postdigital citizen science and its role in building the world we would like to live in.

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