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Modes of engagement: Reframing "sensing" and data generation in citizen science for empowering relationships

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Introduction

The dissemination of digital technologies has provoked a renewed interest in initiatives that seek to involve citizens and communities in the generation of data and in "citizen science." The aim of these initiatives is often to widen participation by including citizens in processes hitherto not very accessible to them, such as the collaborative mapping of human settlements (de Albuquerque et al. 2016), data collection for scientific research (Haklay 2013a), or the data gathering in Citizen Observatories (Degrossi et al. 2014), which can be used to support claims for environmental justice (Mah 2017). In the age of "big data" and "data-driven" decision making, the availability of mobile phones, often equipped with GPS receivers, gives rise to the alluring vision of 6 billion "citizens as sensors" – according to the influential term coined by Goodchild (2007) – who are able to generate "volunteered geographic information" with a level of precision that was only possible before with the aid of highly specialized instruments and by means of specific scientific practices (e.g., those of cartographers and surveyors).

The potential for democratization and empowerment through digital participation and citizen-generated data has not only been acknowledged by grassroots organizations and activist groups but is also being increasingly advocated by a

wide range of mainstream actors such as governmental agencies involved in disaster risk management (Wehn et al. 2015), smart city initiatives (Townsend 2013), and humanitarian organizations working on crisis management (Givoni 2016), as well as international organizations involved in sustainable urban development such as the United Nations Programme for Human Settlements (UN-Habitat 2016). However, alongside this acknowledgment of the potential benefits of citizen-generated data, there is a growing body of literature that offers more critical perspectives. For instance, a number of researchers have pointed to structural barriers in society that may prevent some social groups from producing or interpreting big data (Mah 2017). This could create a "delusion of democratization" (Haklay 2013b) by only extending participation to a relatively homogeneous group of citizens, and is thus unable to effectively overcome the problem of marginalization (Dourish 2016). Furthermore, the designed technologies may involve externally defined "programmes of participation" (Gabrys 2016), that carry out predefined practices of data production which do not necessarily allow contestation or empowerment (Perkins 2014).

In summary, recent research studies have made clear that citizen sensing projects are ridden with an ambivalent character. From one perspective, the production of data by citizens is associated with *empowerment*: digital technologies can enable citizens to produce data that reflects alternative and counter-hegemonic views of the world, and thus lead to the opening up of more inclusive and polyvocal information spaces. From another perspective, the digital technologies and data collection processes may entail *instrumentality*: citizens are invited to act as mere "data providers," as kinds of ersatz sensors – that is, their role is confined to capturing environmental signals, which are then used in ways that are frequently opaque and outside their control and accountability. In our view, these contradictory perspectives can be attributed to the intrinsic ambivalence of citizen sensing. This ambivalence is embedded in the connotations of the very terms used to describe this activity: the sensor metaphor when applied to citizens can mean either a *heightened* capacity to perceive phenomena and articulate an alternative worldview (and thus results in *empowerment*); or it can connote a *reduction* in citizens' capabilities that are constrained to mimic a technical sensorial device and capture (mostly predefined) environmental signals (and thus implies *instrumentality*).

In this chapter, we argue that this ambivalence can only be properly understood by reframing the way we think about citizen science and citizen sensing so that it includes considerations about the *process* and *mode* in which citizens are engaged, particularly in data generation. This is a topical issue since it has been suggested that we live in a "post-truth" era, which implies that the most common justification for data gathering – based on the grounds that data constitutes the

epistemological basis of scientific "truth" – can no longer be taken for granted by everyone as being self-evident.

By resorting to the critical pedagogy developed by the Brazilian educator Paulo Freire (Freire 1987, 2000, 2001; Freire and Faundez 1985), we seek here to provide a fresh perspective on the role of "sensing" and data generation within citizen science. This perspective will be able to account for the ambivalences outlined above by shedding light on the critical importance of the way citizens take part in these processes, particularly when they involve marginalized and disadvantaged groups of people. Furthermore, the purpose of our critical pedagogical approach is to contribute to citizen science theory and practice by proposing an additional set of ethical-methodological criteria that are aimed at establishing empowering relationships.

In the remainder of the chapter, we begin by putting forward our new perspective on citizen sensing by entering into a dialogue with Freire's critical pedagogy. Following this, we discuss particular insights that this perspective can bring to citizen sensing through three groups of concepts based on Freire's work. Finally, we suggest conclusions from our arguments.

Citizen sensing from a critical pedagogical perspective

We believe a change is needed in the conceptual approach to citizen sensing if we are to properly understand the nature of the ambivalence discussed in the previous section. The generation of data by citizens is usually viewed through an *epistemological lens*: digital technologies enable the generation of new data, which acquire the epistemic function of information by providing access to a "reality" which was previously unknown or inaccessible. This is frequently referred to as the citizen's "local knowledge." However, we believe that this epistemological lens is insufficient for understanding and designing citizen sensing initiatives for two key reasons.

First, there is a need to understand "sensing" as being embedded in a wider set of "sense making" practices. The practice of sensing the environment using digital tools involves a specific "framing" (Callon 1998; Lury 2004) of the complex relationships established in citizen sensing initiatives, which include objects, citizens, technologies, coding schemes, researchers, and so forth. This epistemological framing is generally used to explain and foster citizen sensing projects and highlights the practices that render the sensed objects knowable (through data generation) at the same time as constituting citizens as knowing/knowledgeable subjects. However, a number of other relationships established in citizen sensing initiatives necessarily fall outside the epistemological framing, in particular those

that include the relationships established between citizens and the researchers who designed/deployed them (understood here as the leading agents of the citizen sensing initiative, who could be scientists, government policy makers, or grassroots leaders). In other words, this framing acts as an epistemological lens that magnifies some specific aspects of the citizen sensing practices related to the sensed objects, data, and citizens; however, it devotes much less attention to other aspects, such as those related to the role of researchers and their relationship with citizens.

Second, we seek to investigate here the *process* by which these relationships between citizens, digital technologies, and researchers are established, thus going beyond epistemological concerns. For it is only through a careful analysis of this process – that is, of the *modes of engagement* between citizens and researchers mediated by digital technology – that we will be able to gain a proper understanding of the ambivalent perspectives regarding citizen sensing discussed earlier.

In light of this, we propose here a *pedagogical lens* to citizen sensing. This means departing from the traditional view of citizen sensing as synonymous with "data gathering" of the epistemological framing. In contrast, we think that citizen sensing should be embedded in a process of knowledge co-production, only one component of which is the generation of data, albeit an important one. However, it should be noted that "pedagogy" for us means more than a mere transfer of knowledge from teacher to learner; we seek to understand the active role and particular circumstances of citizens, as well as to recognize their value as co-producers of knowledge. To achieve this, we resort here to the critical pedagogy of the Brazilian educator Paulo Freire.

Freire developed his critical pedagogical approach, which is introduced in his seminal book *Pedagogy of the Oppressed*, in the 1960s and 1970s, when he worked on adult literacy programs for the poor communities of Brazil and other countries in South America. One of the key features of this approach is a radical opposition to what Freire calls the "banking model of education": a pedagogical conception in which the teacher acts as the sole custodian of knowledge and makes "deposits" into the empty minds of learners. Although the critique of conceptions of education as "knowledge transfer" are not confined to Freire, his concern with the particular circumstances of the "oppressed" and the way he structures his critical arguments are of great value to rethinking about sensing and data generation in citizen science, especially when marginalized groups of people are involved.

In the following sections, we explore three groups of selected conceptual contributions made by Freire's critical pedagogy which are particularly valuable in providing innovative perspectives on citizen sensing.

Toward a pedagogy of questions

Freire described his approach as a "pedagogy of questions" (Freire and Faundez 1985), which he contrasts with the traditional "pedagogy of answers" of the banking model of education, that is, a process of inducing the learners to provide answers in ways and at times that are determined by the teachers. An analogy can be made here with the instrumental modes of engagement in citizen sensing in which citizens are expected to provide answers – that is, input specific data – in response to a set of predefined questions that are prompted by the interfaces of the digital technologies employed. Thus, it will be useful to describe in some detail the terms in which Freire defines his approach.

In Freire's view, a kind of education that prepares individuals to give answers to predetermined questions is basically grounded on a *dehumanizing antagonism* between the educator and learners. On the one hand, the educator is the person who knows, thinks, speaks, and acts. On the other, the learners are considered absolutely ignorant, as they are thought (instead of thinking), hear (instead of speaking), and have the illusion of acting by means of the actions of the educators. As Freire argues:

> [T]here is an undeniable relationship between wonderment and asking questions, taking risks and existence. At root, human existence involves wonderment, questioning and risk. And, because of all this, it involves action and transformation. Bureaucratisation, however, means adaptation with a minimum of risk, with no wonderment and without asking questions. And so we have a pedagogy of answers, which is a pedagogy of adaptation, not a pedagogy of creativity. It does not encourage people to take the risk of inventing and reinventing. For me, to refuse to take risks is the best way there is of denying the human existence itself. (Freire and Faundez 1985, 51, own translation, compared with Freire and Faundez 1989, 40)

The state of passivity imposed on learners by a "pedagogy of answers" thus degrades them into "adaptive beings." By being confined to receiving "deposits," and then storing them and filing them, the learners "tend to adapt to the world, to the partial aspects of reality contained in the received deposits" (2005 [1970], 68). In this kind of relationship, the learners are only expected to memorize but not reflect, and thus their role is confined to giving answers to questions made by others, who are the only ones able to assess if they are correct. Learners are thus deprived of a capacity to ask questions and hence to wonder and marvel about their environment. From Freire's standpoint, these are the necessary conditions for the creativity and risk-taking that characterize not only a true pedagogical process but human existence itself. This is why the antagonistic

relationship established by the "pedagogy of the answer" *dehumanizes* not only the learners (oppressed), but also the teachers (oppressors).

Freire's critical arguments and sharp distinctions in his pedagogical concepts are useful to our analysis of citizen sensing. In this context, when pedagogical issues are raised, they tend to center on critiques of expectations put on citizens to receive "training" so that they can act as competent "smart citizens" (Gabrys 2016, 2010). This is connected to the frequent concerns with the quality of data resulting from citizen sensing (Degrossi et al. 2018), in response to which some initiatives include the training of citizens in the ability to carry out high-quality data collection (Bordogna et al. 2014). However, the task of decision making about which data to collect and defining the criteria for assessing the quality of the data are often assumed to be the sole remit of researchers, as pointed out by Haklay (2013a). This is analogous to Freire's critical comments on the "pedagogy of the answer," and the resulting expectations from citizens bear a passive, instrumental character similar to those of sensor devices that must be calibrated to provide appropriate measurements of environmental variables.

However, it should be stressed here that we do not believe that this kind of passive/instrumental relationship with citizens only takes place when citizen participation is focused on data collection (even if it is perhaps most visible in these cases). A number of hierarchical typologies of tasks in citizen science were proposed in previous research – for example, by Haklay (2013a) and Cardullo and Kitchin (2017) – which commonly assume that effective participation can only be achieved when they are involved in "higher" types of tasks, such as research design.

In contrast, from our pedagogic perspective, the instrumental character of sensing is caused by a specific framing of the relations of citizens and digital technologies, which can also take place when they are expected to participate in other (and perhaps more complex or elaborate) tasks, including, for instance, the analysis of the data or the definition of environmental variables. Following Freire, we believe that the determining factor is not the particular task undertaken by citizens – in opposition to the typologies of participation defined by Haklay (2013a) and Cardullo and Kitchin (2017) – but the *mode of engagement* established and whether this enables citizens to wonder about and reflect upon their environment, and thus be prepared to take the risk of being creative and posing questions while engaging in citizen sensing. With a view to examining this mode of engagement in further detail, we now turn our attention to a different aspect of the role of citizens in the next section.

Asymmetry, directedness, and cultural invasion

Another important set of concepts that will be of value, when rethinking citizen sensing, comes from an important distinction. Although Freire's dialogical approach is fundamentally based on a critique of antagonistic relations between educators and learners and a reframing of their roles, these two roles are never fused into a single category. The distinctive roles in the pedagogical process (between educator and learner), as well as in citizen sensing (between citizen and scientist) are asymmetrical. This asymmetry should be considered carefully, as it is particularly important with regard to the contributions made by the participants in citizen sensing.

According to Freire, the raison d'etre of the pedagogical act means that educators must play a differential role which is distinctively marked by a *directive* character:

> A non-directive form of education does not exist because the very nature of education is based on directedness. However, even though the educators are not neutral and must direct, in their role of educators, this does not mean that they should manipulate the learner in the name of knowledge that they already know *a priori*, that is, *a priori* from the standpoint of the learner. (Freire 1987, 41, own translation)

The educator and the learner should educate each other in a dialogical process. This is indispensable to what Freire considers to be an existential human condition: that of mankind comprising "unfinished beings" or the "ontological vocation of human beings to be more" (Freire 1997, 14). Although they share the same existential condition, the roles of educator and learner do not coincide completely but retain an asymmetric character within the dialogical process (the word "dialogue" etymologically rests upon the distinction of two in the Greek prefix *dia*). By analogy, an asymmetrical relationship cannot be ignored in citizen sensing, as scientists and citizens do not play the same role.

Nevertheless, it should be noted that Freire is not suggesting that the asymmetry between educator/learner involves either a hierarchy or antagonism. A fierce critic of the antagonistic system of traditional education (examined in the previous section), the author even suggests using the binomial terms "educator-learner" and "leaner-educator" to make clear that both roles educate as well as learn from each other (Freire 2000). However, the use of a different order in the binomial for each role makes clear that they do not completely overlap. Freire points this out clearly and argues that if one assumes there is an overlap of educators and learners, it would simply change the error of authoritarianism, made in traditional conceptions of education, with an error of "spontaneism," in which

"with the aim of not imposing a truth, we end up having nothing to propose and if we simply refuse to do this, nothing else is left to be truthfully done in the educative practice" (Freire and Faundez 1985, 41).

Freire argues that there is another consequence of denying the asymmetric condition of educators and learners, which is of particular relevance to our reflections on citizen sensing. If the two roles are assumed to be identical or antagonistic (in the sense explored in the previous section), it becomes impossible to take into consideration the cultural background of the learner, and as a result the "culture" of the educator is often the only one acknowledged in this relationship. Freire criticizes this position as resulting in a "cultural invasion":

> In cultural invasion (as in all the modalities of antidialogical action) the invaders are the authors of and actors in, the process; those they invade are the objects. The invaders choose; those they invade follow that choice – or are expected to follow it. The invaders act; those they invade have only the illusion of acting, through the action of the invaders. (Freire 2000, 152)

The culturally invasive character of an anti-dialogical pedagogical process is thus largely caused by a static concept of culture as accumulated knowledge (in the educator) which has to be transferred to those that are empty of culture/knowledge (the learners). This results in a process in which "with the goal of preserving culture and knowledge, there is no truthful knowledge nor culture" (Freire 2005 [1970], 79).

These arguments are of great significance when thinking about citizen sensing initiatives. Following Freire, the instrumentality of some initiatives in citizen sensing discussed earlier can be attributed to a "culturally invasive" mode of engagement. This is caused by paying insufficient attention to the specific cultural background and worldviews of the citizens and communities involved. Paying attention here means being sensitive to the "otherness" of the epistemic and cultural practices of citizens/communities, to what Jasanoff (2007) calls "civic epistemologies." In addition, it means acknowledging that the definitions of the environmental objects that have to be sensed, and their potential properties/attributes, are a part of "ontological politics" (Mol 1999), that is, the assumptions about the basic elements that constitute the world reflect particular worldviews and therefore carry political implications. It should be emphasized that these ontological assumptions are often unquestioned and regarded as universal and neutral frames of reference associated with "Nature," as argued by Latour (1993) and others.

However, as da Costa Marques (2014) sharply points out, frames of reference of better-off social groups, "colonizers" usually stemming from the West/the global North, often clash with the perspectives and knowledge practices of

the marginalized, or "colonized," who are often (but not entirely) located in the global South. As previous research in development studies has shown, digital technologies can embed assumptions and categories that are derived from the worldviews of the designers ("colonizers"), but these often do not coincide (or are not aligned) with the practices and perceptions of citizens from marginalized ("colonized") communities (de Albuquerque et al. 2013). Against this backdrop, it can be seen that Freire's critique of a culturally invasive pedagogy has an important bearing on the field of citizen sensing (particularly when it involves marginalized groups). The common assumption that scientific perspectives on the environment are neutral, and can thus form the basis for the design of digital sensing technologies, may, at the same time, lead to a devaluation of Indigenous/non-Western(ized) ways of knowing, living, and relating to the environment.

This resonates with the critical arguments made by Perkins (2014) when analyzing collaborative mapping platforms such as OpenStreetMap. Although these platforms enable individual and social mapping practices to be carried out with a degree of flexibility (e.g., "tagging" an object with freely defined labels), the mapping is in fact constrained by fixed structures based on underlying assumptions that are much harder to change (e.g., particular types of mapping that are scripted by the interface). A similar tension between flexibility/openness (of contributions) and rigidity/closeness (of structures) has also been found in crowdsourcing platforms such as Wikipedia (Tkacz 2014) and in the use of diagrams to model work practices (de Albuquerque and Christ 2015). In contrast, looking at this question from Freire's pedagogical perspective leads to a shift in perspective toward the relationships that are established between scientists, citizens, and the kind of structural/closed features of the digital technologies that are employed for citizen sensing. If there is an antagonism between scientists and citizens where the culture of the latter is not acknowledged or else is undervalued, the assumptions embedded in sensing technologies will indeed act as a culturally invasive instrument. Although citizens are given the opportunity to generate data and thus "speak," they do so by following the possibilities foreseen in extraneously designed digital technologies, which in turn rest on a set of non-problematized (and potentially problematic) ontological assumptions and interests. Citizens are apparently given a voice while in fact they are more likely acting as a ventriloquist's dummy for those who shape the sensing technologies and frame what is "sensed' and how.

However, Freire's thinking not only enables us to have a clear picture of the perils of establishing culturally invasive relationships in citizen sensing but, most importantly, it opens up pathways to forging more emancipatory and empowering relationships – a point we will explore further in the next section.

The "risk of openness" as a constitutive tension

Freire's approach to overcoming antagonistic and potentially invasive educational methods involves establishing what he calls a dialogical and "problematizing" type of relationship, which, in our view, is particularly useful as a foundation for a new approach to citizen science and sensing. As pointed out earlier, Freire's aim is not to obliterate the differences between learner and teacher. Rather, an asymmetry between learner and teacher is essential to his approach, since it is this asymmetry that can configure the two required elements in the dialogue. By analogy, we argue here that the asymmetry between citizens and scientists should not be blurred in citizen sensing, but reconfigured based on Freire's pedagogy; in other words, the distinction between these two roles should be leveraged so that they can reconfigure not only their reciprocal relationships but also their relationship with knowledge.

Freire firmly opposes a view of knowledge that assumes a type of objectivity which is independent and precedes the educational process. Objectivity acquires, for Freire, the status of a "problem," a challenge that must be addressed by teacher and learner working together: "to live in openness toward others and to have an open-ended curiosity toward life and its challenges is essential to educational practice" (Freire 2001, 120). This practice requires a pedagogical process which is open-ended and risky, or even more, that entails what Freire calls the risk of being open (or available) to reality: "It is in openness to the world that I construct the inner security that is indispensable for that openness. It is impossible to live this openness to the world without inner security, just as it is impossible to have that security without taking the risk of being open" (Freire 2001, 120). Openness to the world (which in Freire's original words in Portuguese would be literally translated as "availability to reality") also means being available for or willing to have encounters with other human beings and things in a way that recognizes "Otherness" and respects differences. It is only through this openness to the Other and openness to take risks that confidence (and thus objectivity) can be dialectically established. A pedagogical process becomes culturally invasive if there is a denial of the risk that comes from being open to a relationship with the Other and with the world.

Being willing to take the "risk of openness" is thus a mandatory requirement for establishing emancipatory relationships in a pedagogical process. Drawing an analogy, we argue that accepting risks and being "available" to the Other and to Otherness is a mandatory requirement for undertaking truly participatory and emancipatory citizen sensing projects. The process of citizen sensing can only be an effective and inclusive mode of knowledge production by means of a truly

dialogical process, rather than culturally invasive practices that instrumentalize and silence individuals and communities behind a facade of participation.

Freire's dialogical perspective reveals an intrinsic asymmetry (between the roles of scientist and citizen) and requires dealing with this asymmetry through openness and willingness to take the "risk of openness." Together, the intrinsic asymmetry and risks amount to a *constitutive tension* that must be acknowledged and embraced in citizen sensing practices that are inspired by a critical pedagogy. In our opinion, it is only by accepting this constitutive tension as an essential feature, and making it productive, that we will be able to carry out citizen science initiatives which lead to truly dialogical, emancipatory, and empowering forms of knowledge production.

Conclusion

We have sought to provide a new perspective on "sensing' in citizen science which departs from a widespread view that is focused on epistemological concerns, by entering into a dialogue with the pedagogical works of Paulo Freire. Initiatives that are based on citizen-generated data start with an encounter between two roles: the scientist (or leaders of the digital sensing project) and citizens (or the people who will generate the data). We established an analogy between these two roles and the roles of the pedagogical process: educator and learner. This analogy allows us to draw on concepts from Freire's critical pedagogy to reframe citizen sensing and, as a result, reveal an underlying "constitutive tension": the asymmetric condition between scientists and citizens requires an openness and willingness to face the risk of Otherness so as to be truly inclusive. Understanding the participative production of data, from Freire′s perspective, entails paying attention to the form and means with which the *relationship* between scientist and citizen is established as a dialogical process – to the *modes of engagement* between citizens, scientists, and digital technologies.

By focusing on the modes of engagement engendered in citizen sensing, a new perspective is opened up on the ambivalent effects of citizen sensing between empowerment and instrumentality. Some of the previous critical studies of this question seem to suggest that this ambivalence can be explained by means of a differentiation between "good" and "bad" citizen sensing projects: if a project is designed to involve the "right" groups of people, taking part in the "appropriate" tasks of the process (data collection, analysis, or design), it entails empowerment; otherwise, instrumentality. However, Freire's dialogical perspective allows us to challenge this view by arguing that the ambivalence between empowerment and instrumentality reflects a *constitutive* tension that

underlies *all* initiatives based on citizen-generated data – even if this tension has not been explicitly articulated nor theorized. The tension originates from the asymmetric roles of scientists and citizens and from the differences in their cultural and epistemic practices. Following Freire, it is only by acknowledging this constitutive tension and being open/"available" to face the risk of Otherness that citizen sensing will be able to promote a critical and inclusive knowledge production process that is truly empowering and capable of giving people a voice.

The exploration of citizen sensing through dialogue, on the basis of Freire's critical pedagogy, can elucidate areas in citizen sensing that bear some similarity to current critical studies of participation in citizen science and of recent "citizen-centric" smart city projects (Cardullo and Kitchin 2017; Gabrys 2016; Haklay 2013b). However, these studies represent an orthogonal line of argument to the points we made earlier, since the former focus their criticism on the lack of representation of certain social groups and on the types of tasks carried out by citizens. In contrast, the reframing of citizen science and sensing advocated here encompasses a critical appreciation of the extent to which current initiatives are establishing empowering relationships by taking account of the modes of engagement of citizens.

Clearly, the prevailing citizen science projects vary considerably in this regard: they range from projects based on environmental data gathering with digital technologies that are designed to supply scientific or government projects in largely instrumental ways – for example, in the Citizen Observatories reviewed by Wehn et al. (2015) – to environmental justice movements, where citizens play a leading role in community-based participatory research (see Brown; Allen; this volume). However, upon a closer look, the modes of engagement of the different people involved may vary even within a strongly participatory, citizen-led project. More often than not, a small group of people (often, white and male) is much more actively engaged in shaping the project and making its most critical decisions, which then form the basis on which the contributions of a much larger number of participants are made (see, for instance, the discussion of this issue in Wikipedia, in Tkacz 2014). Our Freirean perspective is thus not only aimed at highlighting the perils of disregarding the different types of asymmetries and inequality in citizen science projects (e.g., with regard to education, gender, economic power, and worldviews), but also proposing a dialogical approach as a means of dealing with them in a productive way. This approach can enable a "data pedagogy," with ways of carrying out citizen science projects that are able to leverage the realities, worldviews, and epistemologies of marginalized and disadvantaged people, which is likely to be particularly important in the "global South."

Furthermore, we hope that our critical pedagogical approach will pave the way to establishing new methodologies and ethical-methodological criteria for

participatory research and practices in citizen-generated data and citizen science. These should not replace the existing concerns/framings about validity (e.g., on the quality of the generated data and its ability to serve as scientific evidence) but, rather, supplement them. In doing so, they should make it possible to take account of the modes of engagement of citizens and of the extent to which the research is "available to the risk" of the Other and sensitive to asymmetries and inequalities – as was initially attempted in the research study by de Albuquerque et al. (2019). In doing so, it is hoped that this approach can contribute to the establishment of empowering and "humanized" dialogical relationships, and thus enable us to regain the confidence needed to collectively undertake truth-building processes for the co-production of knowledge.

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References

Bordogna, G., Carrara, P., Criscuolo, L., Pepe, M., and Rampini, A. 2014. On predicting and improving the quality of Volunteer Geographic Information projects. *International Journal of Digital Earth*, 1–22. DOI: 10.1080/17538947.2014.976774.

Callon, M. 1998. An essay on framing and overflowing: economic externalities revisited by sociology. *The Sociological Review*, 46(1_suppl), 244–269. DOI: 10.1111/j.1467-954X.1998.tb03477.x.

Cardullo, P. and Kitchin, R. 2017. Being a "citizen" in the smart city: Up and down the scaffold of smart citizen participation. NIRSA, National University of Ireland Maynooth, County Kildare, Ireland, PP. 1–24.

da Costa Marques, I. 2014. Ontological politics and Latin American local knowledges. In E. Medina, I. da Costa Marques, and C. Holmes (eds), *Beyond Imported Magic: Essays on Science, Technology, and Society in Latin America*. Cambridge, MA: MIT Press, pp. 85–110.

de Albuquerque, J. P. and Christ, M. 2015. The tension between business process modelling and flexibility: Revealing multiple dimensions with a sociomaterial approach. *Journal of Strategic Information Systems*, 24(3), 189–202. DOI: 10.1016/j.jsis.2015.08.003.

de Albuquerque, J. P., Cukierman, H. L., da Costa Marques, I., and Feitosa, P. H. F. 2013. *Challenging the Ontology of Technoscientific Artefacts: Actor-Network Theory in Developing Countries*. Manchester. http://hummedia.manchester.ac.uk/institutes/cdi/resources/cdi_ant4d/ANT4DWorkingPaper7AlbuquerqueEtAl.pdf (last accessed March 16, 2020).

de Albuquerque, J. P., Herfort, B., and Eckle, M. 2016. The tasks of the crowd: A typology of tasks in geographic information crowdsourcing and a case study in humanitarian mapping. *Remote Sensing*, 8(859), 1–22. DOI: 10.3390/rs8100859.

de Albuquerque, J. P., Yeboah, G., Pitidis, V., and Ulbrich, P. 2019. Towards a participatory methodology for community data generation to analyse urban health inequalities: A multi-country case study. In *Proceedings of the 52nd Hawaii International Conference on System Sciences* (3926–3925). DOI: 10.24251/HICSS.2019.476.

Degrossi, L. C., de Albuquerque, J. P., Fava, M. C., and Mendiondo, E. M. 2014. Flood Citizen Observatory: A crowdsourcing-based approach for flood risk management in Brazil. In *Proceedings of SEKE 2014 – 26th International Conference on Software Engineering and Knowledge Engineering, Vancouver, Canada*. Skokie, IL: Knowledge Systems Institute Graduate School, 570–575.

Degrossi, L. C., de Albuquerque, J. P., Santos Rocha, R. dos, and Zipf, A. 2018. A taxonomy of quality assessment methods for volunteered and crowdsourced geographic information. *Transactions in GIS*, 22(2), 542–560. DOI: 10.1111/tgis.12329.

Dourish, P. 2016. The internet of urban things. In R. Kitchin and S.-Y. Perng (eds), *Code and the City*. London: Routledge, pp. 27–48.

Freire, P. 1987. Sobre educação popular: entrevista com Paulo Freire (On popular education: interview with Paulo Freire). In *Educação Popular: um encontro com Paulo Freire* (*Popular Education: An Encounter with Paulo Freire*). São Paulo: Edições Loyola.

Freire, P. 1997. Papel da Educação na Humanização (The role of education in the humanization). *Revista Da FAEEBA*, 7(Jan/Jun), 9–17.

Freire, P. 2000. *Pedagogy of the Oppressed*. New York and London: Bloomsbury Academic.

Freire, P. 2001. *Pedagogy of Freedom*. Lanham, MD: Rowman & Littlefield.

Freire, P. 2005 [1970]. *Pedagogia do Oprimido* (*Pedagogy of the Oppressed*) (9th edn). Rio de Janeiro: Paz e Terra.

Freire, P. and Faundez, A. 1985. *Por uma Pedagogia da Pergunta* (*For a Pedagogy of the Question*), ed. R. M. Torres. Rio de Janeiro: Paz e Terra.

Freire, P. and Faundez, A. 1989. *Learning to Question: A Pedagogy of Liberation*, trans. T. Coates. Geneva: WCC Publications.

Gabrys, J. 2016. *Program Earth: Environmental Sensing Technology*. Minneapolis: University of Minnesota Press.

Givoni, M. 2016. Between micro mappers and missing maps: Digital humanitarianism and the politics of material participation in disaster response. *Environment and Planning D: Society and Space*, 34(6), 1025–1043. DOI: 10.1177/0263775816652899.

Goodchild, M. F. 2007. Citizens as sensors: The world of volunteered geography. *GeoJournal*, 69(4), 211–221. DOI: 10.1007/s10708-007-9111-y.

Haklay, M. 2013a. Citizen science and volunteered geographic information: Overview and typology of participation. In D. Sui, S. Elwood, and M. Goodchild (eds), *Crowdsourcing Geographic Knowledge*. Dordrecht: Springer, pp. 105–122.

Haklay, M. 2013b. Neogeography and the delusion of democratisation. *Environment and Planning A*, 45(1), 55–69. Retrieved from http://www.envplan.com/abstract.cgi?id=a45184.

Jasanoff, S. 2007. *Designs on Nature*. Princeton, NJ: Princeton University Press.

Latour, B. 1993. *We Have Never Been Modern*. Cambridge, MA: Harvard University Press.

Lury, C. 2004. *Brands: The Logos of the Global Economy*. London: Routledge.

Mah, A. 2017. Environmental justice in the age of big data: Challenging toxic blind spots of voice, speed, and expertise. *Environmental Sociology*, 3(2), 122–133. DOI: 10.1080/23251042.2016.1220849.

Mol, A. 1999. Ontological politics. A word and some questions. *The Sociological Review*, 47(1_suppl), 74–89.

Perkins, C. 2014. Plotting practices and politics: (Im)mutable narratives in OpenStreetMap. *Transactions of the Institute of British Geographers*, 39(2), 304–317. DOI: 10.1111/tran.12022.

Tkacz, N. 2014. *Wikipedia and the Politics of Openness*. Chicago: University of Chicago Press.

Townsend, A. M. 2013. *Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia*. New York: W. W. Norton.

UN-Habitat. 2016. *Urbanization and Development: Emerging Futures. World Cities Report 2016*. Nairobi: United Nations.

Wehn, U., Rusca, M., Evers, J., and Lanfranchi, V. 2015. Participation in flood risk management and the potential of citizen observatories: A governance analysis. *Environmental Science & Policy*, 48, 225–236. DOI: 10.1016/j.envsci.2014.12.017.