17th CIRN Conference, Monash Centre, Prato Italy, 6 Nov - Friday, 8 Nov 2019
Refereed Paper

Citizen Sensing Communities: From Individual Empowerment To Collective Impact

Aldo de Moor

CommunitySense, Tilburg, the Netherlands

Abstract: Citizen sensing offers much promise in engaging citizens for the common good, such as working on wicked problems like climate change or air pollution. By citizens becoming involved in citizen sensing communities, they can increase their impact. To get truly empowered and reach collective impact, citizen sensing communities need to build effective working relations with institutional scientific and regulatory powers. One way to do so is through citizen science collaborations. However, collecting, vetting, and analyzing data is not enough: in many cases, the insights derived from the data lead to calls for political action. This is the weakest link in the collective impact chain, especially when citizen sensing results suggest collective (political) mitigation of causes instead of just individual adaptation to effects of wicked problems. We illustrate these notions with various cases and end with a tentative reconstruction of citizen sensing empowerment.

Keywords: Citizen sensing, citizen science, empowerment, collective impact

Introduction

This paper is an outcome of a presentation I gave at a discussion panel on "Nudging for Climate through Citizen Sensing" organized by the Tilburg Institute for Law, Technology, and Society (TILT) in October 2019[1]. It is not a "finished" research paper, if that were ever possible. Rather, it starts with my personal experience of getting introduced into the world of citizen sensing as a citizen, and then applying my community informatics researcher and practitioner's lens to generate some initial thoughts on how citizen sensing might achieve more collective impact. By weaving together strands of personal observations with theoretical work on communities, technologies, empowerment, and collective impact, it suggests some directions for future research and practice on how a multitude of bottom-up citizen sensing actions might reach more impact at scale. As both the fields of citizen sensing and community informatics are so deeply focused on strengthening the common good, as well as on communities effectively using their technologies - these reflections may help in making them become more aware and supportive of one another.

The Tilburg citizen sensing community case

The Tilburg Public Library recently re-opened as the main tenant in a former Dutch Railways locomotive maintenance hall (hence, its name the "LocHal"[2]). It is not the classical library where the book collection takes center stage. Instead, it acts as a true third place, creating broader community networks and supporting local communities beyond existing users and the library building (Houghton et al., 2013). How successful it is in this mission is shown by the library already having received two prestigious global awards: 2019 World

[1] https://www.tilburguniversity.edu/campus/academic-forum/night-university/program/nudging-climate-through-citizen-sensing-14
[2] https://www.lochal.nl/

Building of the Year[3], after earlier having been named one of the four Best New Libraries of the World in 2019[4].

As part of its programming formula, the library has created a number of thematic "labs" within the LocHal, in which citizens can learn about and experiment with various cultural, technological and societal developments. The labs include a DigiLab, FoodLab, TimeLab, GameLab, WordLab, and FutureLab. In this last lab, citizens come together to work on social innovations around wicked societal problems, such as climate change.

One field where citizens, technologies, and society meet is citizen sensing: a form of citizen participation in environmental monitoring and action which is bottom-up, participatory and empowering to the community (Woods et al., 2018). A citizen sensing kickoff workshop – the first of an ongoing series - took place in the FutureLab in April 2019. For these workshops, citizens are invited to come and build their own sensor station, based on open source blueprints (Figure 1). Initially, these sensor stations can measure only temperature and relative humidity. However, in future follow-up workshops, they could be outfitted with additional sensors, e.g. to measure fine particulate matter.

Figure 1: The author and citizen colleagues building their own sensors

The citizen builders are to place their sensor station in, for instance, their gardens back home. To send measurements to the server, LoRa[5] technology is used. This is a low-power wide-area network, which only intermittently reads results from distant measuring stations, allowing for those stations to be powered by just a small battery. As it needs to be replaced only once in a while, it makes LoRa a very useful networking technology for citizen sensing.

Building and installing the sensors is only a means to an end. Each sensor gives a continuous flow of local measurements, about once every 15 minutes. As the network of sensors grows, an increasingly fine-grained measurement network covers the city (Figure 2). Although the sensors are far less precise and reliable than those of, say, the National Institute for Public Health and the Environment, they can provide valuable data at the very local level. This is useful, since the official government measurement grid is much coarser and depends on theoretical model-calculations to estimate what measurements may apply locally.

[3] https://edition.cnn.com/style/article/waf-building-of-the-year-2019/index.html
[4] https://www.iamexpat.nl/lifestyle/lifestyle-news/library-tilburg-named-one-best-world
[5] https://www.semtech.com/lora/what-is-lora

Measuring results are collected and made available city-by-city on a national, open source server[6]. As more sensors are becoming operational in Tilburg, their results will also be shown on the "Monitor of the City" screen wall in the FutureLab, for public analysis and discussion.

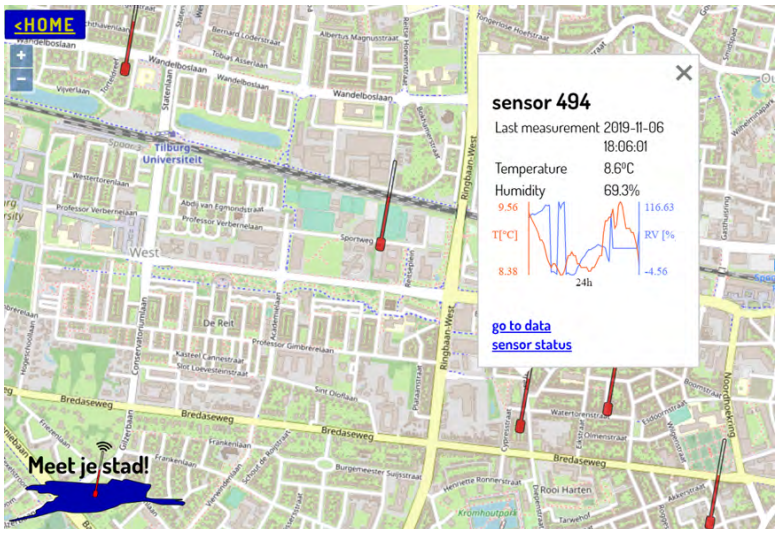

Figure 2: The author's sensor up and running in the Tilburg citizen sensing grid

This impressive technical infrastructure tells only part of the story. Just as important is the social dimension. Citizen sensing may sound like an isolated endeavor by app-supported individuals, but consists in fact of an intricate community network: a network of multiple communities, each with its individual socio-technical context, as well as the common socio-technical context in which those communities are embedded and linked (De Moor, 2018). In our case, the sensor building workshops were a joint initiative of the Tilburg LoRa/IoT community, a local group of enthusiasts who aim to explore the potential of the LoRa networking technology in conjunction with the Internet of Things; the Meet Je Stad (Measure Your City) collective, a Dutch network of volunteer-citizen sensing experts, which started in the city of Amersfoort to measure local climate change-related data and hosts the national server; and the Tilburg public library as a facilitator and connector of many local Tilburg citizen communities via, for instance the thematic LocHal labs. The Tilburg municipality is also involved, as a co-sponsor of the sensor stations. The city is interested in this experiment to explore how the data may be used to inform policy making on, for example, local climate action. And, of course, there is the global community (network) of advocates of citizen sensing for citizen engagement and empowerment.

Citizen sensing communities

Such complex socio-technical networks come with a host of operational, social, and political issues, which is the domain of community informatics and related literature. For example, Sheth sees an explicit sensing role for both the machine and the human, resulting in complex socio-techncial citizen-sensor networks enabled by the Internet and mobile data. Whereas technical sensors are good at continuously measuring and reporting encoded observations, humans are very good at turning those data into meaning by adding available background knowledge and using their experience, common sense, and complex reasoning abilities, even with fuzzy or inconsistent data or inconsistent information (Sheth, 2009).

[6] https://meetjestad.net/

However, there are also larger socio-political dimensions of these emerging socio-technical community networks. Think, for instance, issues like the self-organization, distributed governance and fractal scaling of such community networks (Graham, 2016) and what are effective mechanisms for commons-oriented peer production initiatives creating common pools of knowledge for even the whole of humanity (Bauwens and Kostakis, 2014).

Like the national platform and educational services provided by the Meet Je Stad collective, many efforts are underway all over the world to increase the effectiveness and impact of citizen sensing community building. For example, Smart Citizen Kits enable local communities "to create local maps of noise and air quality; use it to raise awareness and find solutions for issues that matter to your community."[7] Related initiatives focus more on the methodological side of effectively using such kits. The Making Sense Framework, for instance, provides detailed methodological support to run citizen sensing projects through the following steps: *Scoping, Community Building, Planning, Sensing, Awareness, Action, Reflection*, and *Legacy*. In doing so, the methodology abides by four cross-cutting principles: *Empowerment, Co-Creation, Changemaking* and *Openness* (Woods et al., 2018).

Citizen sensing communities need to ask themselves some important questions, beyond the infrastructuring socio-technological ones: What data should be measured and how? What do the data mean? How can these insights lead to action with impact? Citizen sensing is often heralded as an approach that will empower users by providing more informed and data-driven feedback for decision making (Ottaviano et al., 2019), and that is bottom-up, participatory and empowering to the community (Woods et al., 2018). How this empowerment is to come about is far from trivial, however, as these communities do not operate in a power vacuum (Figure 3). There are at least two powerful institutional worlds that citizen sensing communities need to build fruitful and lasting relationships with to find an empowered and impactful role: science and government. Traditionally, science has been the authority defining the validity and meaning of data, whereas government is the origin of the laws and policies that define and regulate legitimate/legal actions, at least in theory grounded in the data, information, and knowledge produced by science.

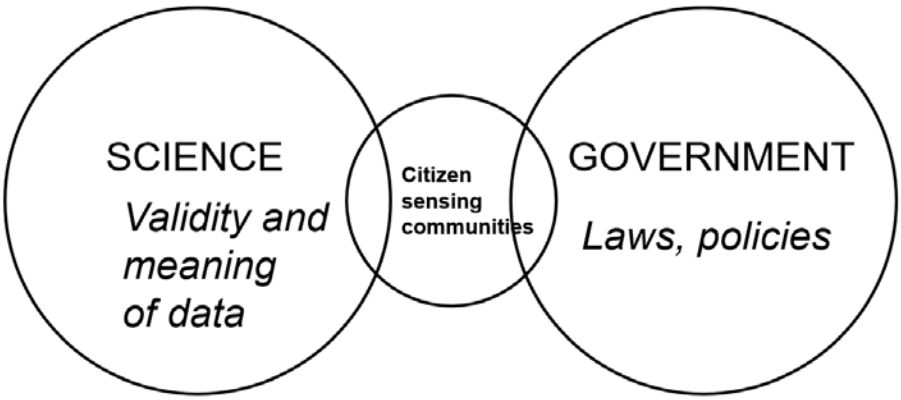

Figure 3: The institutional power context of citizen sensing communities

Citizen science: beyond sensing?

The link between citizen sensing and science is quite well developed, in the form of citizen science. In this form of science, citizens gather, share, and try to understand the information about themselves and the environment that surrounds them, supported by scientific models, methods, and tools that support the data generation and processing, including the systematic

[7] https://smartcitizen.me/

acquisition and vetting of the collected data (Ottaviano et al., 2019). Much of the current literature on the link between citizen sensing and science focuses on this data collection, validation, and analysis stage of the scientific process. Examples are approaches to use citizen sensor data to complement professional sensing platforms in sparse sensor networks (O'Grady et al., 2016), and combining citizen-generated data with official sensing data into specialized predictive analytic solutions to provide decision makers with planning information, and citizens with personalized urban, environmental, and health recommendations (Ottaviano et al, 2019). Still, there are many additional (inter)active peer roles that citizens and other societal, non-scientific stakeholders could play. In De Moor (2014), we gave an overview of such roles for all stages of the academic research process: research question framing; data collection and analysis; authoring; review; dissemination; and impact assessment. We also proposed possible socio-technical designs - grounded in community informatics insights - to support these "bridges between academia and society. For example, by having academic researchers actively participate in citizen sensing communities, citizens could be more instrumental in research question framing and impact assessment. Citizens could also author, review, and disseminate their own findings in the local press and on social media, as well as help “translate” peer-reviewed scientific articles into language and local examples that the general public can understand.

The very essence of community informatics is that research continuously meets practice. "Citizen sensors" as researcher-practitioners can act as important counterparts to professional scientists in at least the following ways:

- Citizen sensors can be *additional eyes and ears*: there is simply too much to be done, scientists cannot be everywhere at the same time, all the time. Citizen sensors can help scale up the number of observations, like producing densely distributed micro-climate measurements. They can also alert their professional peers to potentially interesting phenomena happening in their local area.
- Citizen sensors can *ask interesting questions*: they have often unique knowledge of what is (out of the) ordinary in their own local environment and what may be possible causes of the data patterns observed. Furthermore, professional scientists are often biased in the kind of research questions they ask, because they are working from within existing research paradigms, frameworks, networks, and projects. Citizens can help frame new questions, as they look at reality from a different perspective, and are not hindered by existing research constraints. In the Netherlands, this role has even been formally acknowledged by using citizens’ questions as an important input in the construction of the Dutch National Research Agenda[8]
- Citizen sensors can be influential *science ambassadors*: in the era of fake news, anti-vaxxers and Flat Earthers, there is an increasing public distrust and misunderstanding of what science is and its fundamental role in society. This is a dangerous development and hard to counter. Citizen sensors can form a first line of defense here. Through engaging in science, based on their own observations, they themselves get a first-hand, deep understanding of the complex and subtle nature of the scientific process. This background may help prepare and motivate them to educate and to try and convince their circles of peers that science does not provide “just another opinion”, but forms the bedrock of modern, diverse society and is worth protecting. This is not to say that scientists are infallible and what they say should be taken at face value. However, a scientifically engaged citizenry can provide constructive criticism to strengthen science rather than destroy it.

[8] https://wetenschapsagenda.nl/national-science-agenda/?lang=en

Citizen sensing - from individual adaptation to collective mitigation

Community informatics as a field of research and practice focuses on how to build, empower, and link communities through the effective use of information and communication technologies. Citizen sensing is an excellent example of technology-supported local, national, and global communities of engaged citizens working together on a common interest. However, such communities are about much more than just measuring: they really mean to foster engagement towards collective impact: the commitment of important actors from many different sectors to a common agenda for solving a specific social problem (Kania and Kramer, 2011).

No community can address huge, "wicked" problems like climate change on their own. As we have seen, citizen sensing communities need to be embedded in rich stakeholder networks to become effectively empowered. In the previous section, we explored the ties that citizen sensing communities can and need to form with the scientific community through citizen science. However, collaborating with professional scientists to generate, validate and analyze data is only a necessary condition for achieving collective impact. Citizen sensing communities also need to grow strong connections – without losing their independence and critical voice – with government regulators, as ultimately it is creating and enforcing effective and just laws and policies that make the difference in addressing systemic wicked problems that no actor can solve on their own.

Still, this relationship between citizen sensing communities and government regulators is complicated. Regulators often dismiss citizen sensing observations as being inaccurate, hence feeling not required to take action (Gabrys and Pritchard, 2018). We illustrate this tension with two cases. The first one, on individual citizens taking personal adaptive action is often promoted by government regulators, one reason possibly being that this is not very contentious politically. The second case shows how sound data collection and analysis may not always be sufficient, especially if the political will to act on the data gathered is lacking. This is a common occurrence when painful collective mitigative actions are required in terms of creating and enforcing adequate laws and policies.

Citizen sensing empowerment case 1: involving citizens to take personal adaptive action

Citizen sensing initiatives abound in which citizen sensing communities collaborate with - often local - governments. One example of many is the PulsAir mobile citizen sensing application and data ecosystem model being rolled out in cities across the world (Ottaviano et al., 2019). The goal of the approach is to help overcome information gaps on environmental and health data, especially in local areas, serving both the information and planning needs of local authorities and the health information needs of citizens. To this purpose, it fuses both official and vetted citizen data sources in an "urban data lake", and uses this to generate customized information, including recommended health actions for citizens to reduce their pollution exposure. One community aspect, besides many stakeholders being involved in the system development, is that gamification is used to motivate citizens to use the PulsAir app.

From a citizen sensing/science perspective this mobile app is key. It consists of two modules:

- A "*Me" module* containing information about the citizen. It gathers information from wearables and through surveying the user, and provides personal activity reports and customized health risk, educational and action recommendations.
- A *"My city" module* containing all the data relevant to the city and neighborhood of the users. It includes summaries about, among other things, the pollution status of the city; but also allows the user to enter questionnaires on the status of the neighborhood,

Empowerment is an important overall goal: the approach helps "empower the citizen through perceptual sensing of urban environmental and health data (p.3)", provides an "appealing interactive data layer that aims at providing data value and empowerment to citizens (p.6)", and is about "empowering the citizens with personal tools that estimate and manage their pollution exposure, and thus take healthier actions (p.10)" (Ottaviano et al., 2019).

Citizen sensing empowerment case 2: citizens campaigning for collective mitigative action

There is increasing scientific consensus on how dangerous woodsmoke is as an - especially at the residential/hyperlocal level extreme - source of fine particulate matter and numerous other, often carcinogenic, pollutants (e.g. Trojanowski and Fthenakis, 2019). Although the science is clear, regulators are not. The Dutch government, aware of the studies, does not want to take mitigative action. The national government says complaints have to be resolved at the local level, whereas municipalities say that there is no legal framework on the basis of which they can enforce woodsmoke air quality measures. The Dutch Minister for the Environment, against the advice of her own experts, continues to state that there would be no support for stringent measures and that it would lead to unacceptable financial costs for citizens, companies, and municipalities (Bolink et al., 2020).

There is an increasingly vocal Dutch national community of concerned citizens who demand tougher government action. One of the main ways they self-organize is through a number of twitter hashtags, #houtstook (woodburning) and #houtrook (woodsmoke). Another attractor is the @houtrookvrij twitter account of the Stichting Houtrookvrij (Association Woodsmoke Free), which as of February 2020 had close to 2,000 followers and which retweets many incoming reports, and suggestions for action.

This vibrant, growing online community is a good example of a citizen sensing community, as some of its core members are committed citizen sensors who are measuring local fine particulate matter and other emissions, and sharing and discussing the results in online publications and via social media with other community members and beyond. Several of the key members have professional backgrounds in building sensor platforms and doing chemical air quality analysis. They work together with reputable scientific institutes like the National Institute for Public Health and the Environment to validate citizen sensing measurements and integrate them in national pollution measurement models.

Like the development team in the previous case, the anti-woodsmoke community also works to increase awareness among individual citizens about the air pollution health hazards surrounding them. This includes discussing what individual adaptive steps citizens may take to address the worst hazards, such as closing windows in time or buying the right kind of air purifier. However, they want to go beyond this individual adaptive empowerment: to engage citizens in campaigning for collective political action to *mitigate* the source of the pollution, ideally resulting in a national wood burning ban. Given the lack of response and accountability of both national and local government officials, the question is: how? How to go beyond promoting individual awareness towards taking collective action resulting in collective impact?

Reconstructing citizen sensing empowerment

So, what exactly is empowerment? A classical definition is that is a process, a mechanism by which people, organizations, and communities gain mastery over their affairs (Rappaport, 1987). Mastery suggests being in control at a deep level. In order to do so, empowerment should help individuals, organizations and communities develop power and therefore empowerment should be explicitly linked to the development of power (Speer, 2008). Thus, empowerment is about being effectively able to get things done, not just at the individual, but also at the collective level. Further unpacking this, one could say that empowerment helps

people to take control of their lives, develop critical awareness and knowledge about their situation, as well as develop long lasting skills and capacities to participate and shape their own environment beyond the confines of a particular project (Zamenopoulos and Alexiou, 2018). Zamenopoulos et al. (2019) distinguish three interrelated notions of empowerment: loci of empowerment (individual / socio-political community empowerment); a number of conditions for empowerment, and finally four manifestations/types of empowerment resulting in a number of capacities needed to let stakeholders co-design the required interventions: *power over* (realigning power from the powerful to the powerless), *power to (*fundamentally change social, political and community contexts), *power with* (collaboration, mutual support and solidarity), and *power within* (self-knowledge and ability to recognise and mobilize our own assets).

Much of the current state of the citizen sensing art focuses on developing the technological infrastructure; citizen data collection, vetting, and analysis processes; (power with) community building; and (power within) individual awareness and empowerment of citizen to adapt their behaviors (as in the personal adaptive action case). Although these are necessary, they are not sufficient conditions to empower citizen sensing initiatives to address the thorny issues of how to achieve collective impact. Equally needed are the (power over/to) relations, skills and capacities to effectively build and exercise individual and community powers. This is related to the fundamental and long-running discussion in the community informatics field on the difference between digital access and effective use: whereas for a long time it was thought that just providing access would be sufficient to empower communities, there are many often hidden and systemic socio-political barriers that prevent the development of the capacities and opportunities needed for successfully integrating ICTs into the accomplishment of self or collaboratively identified goals (Gurstein, 2003).

Some citizen sensing initiatives are indeed working on expanding this community impact dimension. For example, the *Action*-stage of the Making Sense Framework aims to bring about policy change and to address problems affecting the community. Suggested forms of action include protests, artistic interventions and displays, and public forums and presentations (Woods et al., 2018). Important as they are, such individual community actions and projects may not always be sufficient for building collective critical mass to address systemic problems at the deep level.

How to go about this more systemic, impactful citizen sensing way of working together is still very much an open question. In the Making Sense project, transformation design and participatory sensing were combined in order to create awareness and actions for change to address environmental issues (Coulson et al., 2018). A related approach is the Bristol Approach to Citizen Sensing[9], which puts communities at the heart of socially innovating the city. Key to going beyond the individual community/project is their development of a 'city commons', where resources, tools, expertise and technologies are shared and used for the common good. To build that commons, city stakeholders are mapped and then actively co-design solutions. A complementary approach to both may be the CommunitySensor methodology to engage community networks in common agenda setting through a knowledge base-driven approach to participatory collaboration mapping (De Moor, 2018). Still, these are only some examples of many more methodologies. What they have in common is that they explore with stakeholders the larger societal context in which (citizen sensing) communities live and work. Further conceptualizing this collective empowerment dimension, as well as coming up with effective situated methodologies, tools, and practices - sensitive to the many subtle ethical, normative, social and political constraints of communities of many different types, shapes, and forms - is the essence of community informatics.

[9] https://urbact.eu/citizen-sensing-where-people-act-sensors

Towards citizen sensing collective impact

In this paper, we focused on citizen sensing communities, starting with the Tilburg citizen sensing community case as an example of the intricate, nested socio-technical community networks at play beyond the basic infrastructure of sensing tools and data. We examined how such communities are a stepping stone on the way from individual citizen empowerment to collective impact. We used a community informatics lens to get a better view on what are the issues at stake.

Citizen sensing is often said to be empowering, promoting bottom-up participation of individual citizens and the communities they self-organize in. To realize that potential, though, these communities need to come to terms with the institutional power contexts they are working in, with, and sometimes against, in particular those of science and government. As to citizen sensing and science, we argued that much of the current participatory efforts focus on the tools, data collection, validation and analysis. Still, there are many ways that citizen sensors could engage in other stages in the scientific research process as well.

The real conundrums are with how to *act* on the citizen sensing data, especially by the responsible government regulators. These regularly label those data as being inaccurate, whereas a more open regulatory view that sees them as "just good enough" data could open up multiple creative uses for political action (Gabrys and Pritchard, 2018). As our contrasting cases on individual adaptation and collective mitigation showed, other issues may need to be addressed that have nothing to do with the data per se, like lack of political will. Still, the data, if put to effective use, sometimes may help create that will.

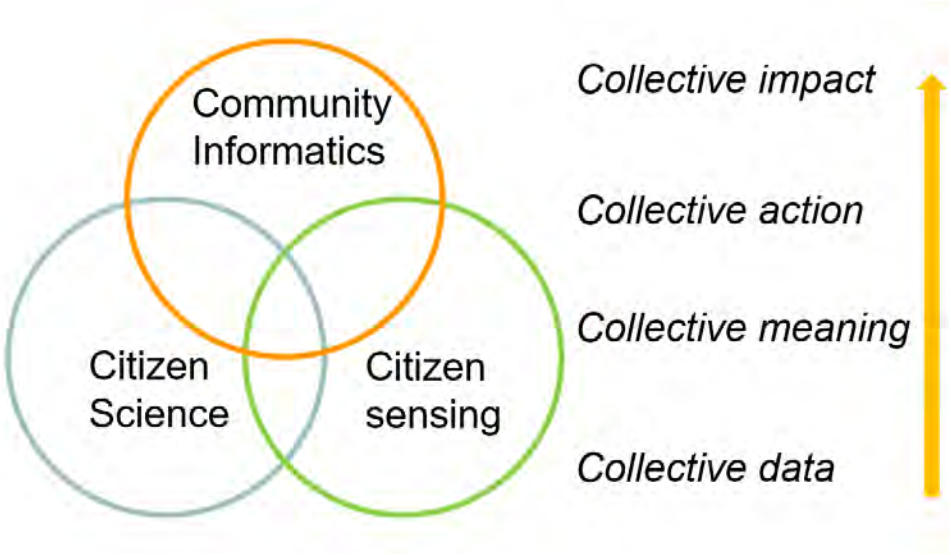

Figure 4: A collective impact framework for citizen sensing

The connection between citizen sensing and empowerment is problematic in the sense of how to bring about collective impact: how to develop meaningful and scalable solutions to wicked societal problems? We ended our paper with some initial thoughts on how to reconstruct this relationship (Figure 4). Much citizen sensing work is on collective data collection and on co-creating (scientific) meaning. (Far too) little is on collective political meaning making, let alone generating effective joint action with significant and lasting collective impact. It is clear that important pieces for solving this puzzle can be found in the overlapping domains of citizen sensing, citizen science, and community informatics. We do not claim to have provided the answers, far from it. Still, we hope that we have raised some interesting questions and thoughts that will inspire others to strengthen these links and turn more of that tantalizing citizen sensing potential into reality.

References

Bauwens, M., & Kostakis, V. (2014). From the Communism of Capital to Capital for the Commons: Towards an Open Co-operativism. TripleC: Communication, Capitalism & Critique. Open Access Journal for a Global Sustainable Information Society, 12(1), 356–361.

Bolink, J., Opten, N., & Van Raaij, L. (2020, February 1). Milieuminister negeert klemmend advies over aanpak van houtstook, terwijl het vele doden kan schelen. Het Schone Oosten.

Coulson, S., Woods, M., Scott, M., & Hemment, D. (2018). Making Sense: Empowering participatory sensing with transformation design. The Design Journal, 21(6), 813–833.

de Moor, A. (2014). Expanding the Academic Research Community – Building Bridges into Society with the Internet. In T. Denison, M. Sarrica, and L. Stillman (eds.), Theories, Practices, and Examples for Community and Social Informatics, Monash University Publishing, Melbourne. ISBN 978-1-921867-62-0

de Moor (2018), A. A Community Network Ontology for Participatory Collaboration Mapping: Towards Collective Impact, Information, 9(7): art.no.151.

Gabrys, J., & Pritchard, H. (2018). Just Good Enough Data and Environmental Sensing: Moving beyond Regulatory Benchmarks toward Citizen Action. International Journal of Spatial Data Infrastructures Research, 13, 4–14.

Graham, G. (2016). Cooperating community connections: An essay on a changing political reality. The Journal of Community Informatics, 12(1), 128–141.

Gurstein, M. (2003). Effective Use: A Community Informatics Strategy Beyond the Digital Divide. First Monday, 8(12).

Houghton, K., Foth, M., & Miller, E. (2013). The continuing relevance of the library as a third place for users and non-users of IT: The case of Canada Bay. The Australian Library Journal, 62(1), 27–39.

Kania, J., & Kramer, M. (2011). Collective Impact. Stanford Social Innovation Review, 36–41.

O'Grady, M. J., Muldoon, C., Carr, D., Wan, J., Kroon, B., & O'Hare, G. M. P. (2016). Intelligent Sensing for Citizen Science. Mobile Networks and Applications, 21(2), 375–385.

Ottaviano, M., Beltrán-Jaunsarás, M. E., Teriús-Padrón, J. G., García-Betances, R. I., González-Martínez, S., Cea, G., Vera, C., Cabrera-Umpiérrez, M. F., & Arredondo Waldmeyer, M. T. (2019). Empowering Citizens through Perceptual Sensing of Urban Environmental and Health Data Following a Participative Citizen Science Approach. Sensors, 19(13), 2940.

Rappaport, J. (1987). Terms of empowerment/exemplars of prevention: Toward a theory for community psychology. American Journal of Community Psychology, 15(2), 121–148.

Sheth, A. (2009). Citizen Sensing, Social Signals, and Enriching Human Experience. IEEE Internet Computing, 13(4), 87–92.

Speer, P. W. (2008). Social power and forms of change: Implications for psychopolitical validity. Journal of Community Psychology, 36(2), 199–213.

Trojanowski, R., & Fthenakis, V. (2019). Nanoparticle emissions from residential wood combustion: A critical literature review, characterization, and recommendations. Renewable and Sustainable Energy Reviews, 103, 515–528. https://doi.org/10.1016/j.rser.2019.01.007

Woods, M., Balestrini, M., Bejtullahu, S., Bocconi, S., Boerwinkel, G., Boonstra, M., ... Seiz, G. (2018). Citizen Sensing: A Toolkit. Making Sense. https://doi.org/10.20933/100001112

Zamenopoulos, Z., & Alexiou, K. (2018). Co-design As Collaborative Research. Bristol: Bristol University/AHRC Connected Communities Programme.

Zamenopoulos, T., Lam, B., Alexiou, K., Kelemen, M., Sousa, S. D., Moffat, S., & Phillips, M. (2019). Types, obstacles and sources of empowerment in co-design: The role of shared material objects and processes. CoDesign, https://doi.org/10.1080/15710882.2019.1605383