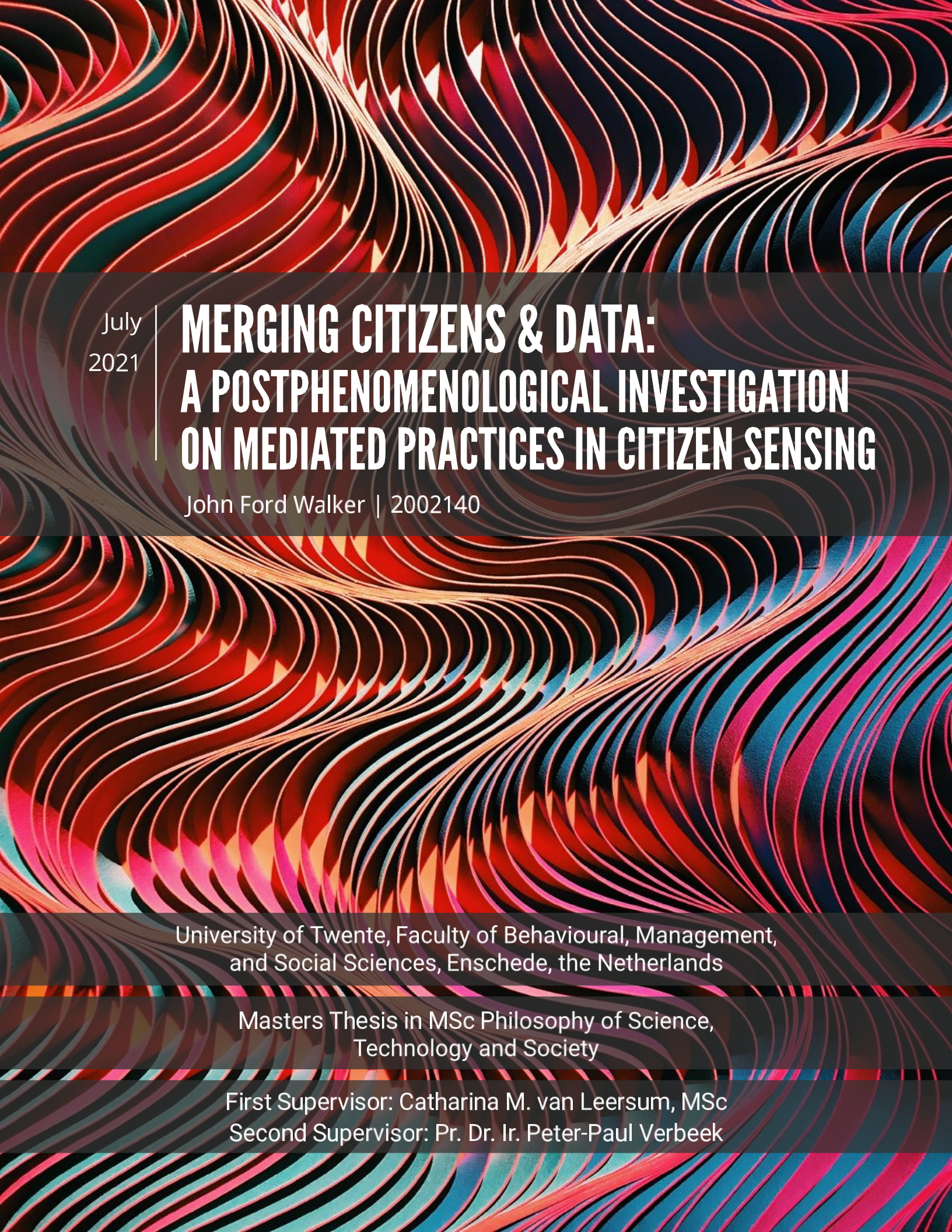

July
2021

MERGING CITIZENS & DATA: A POSTPHENOMENOLOGICAL INVESTIGATION ON MEDIATED PRACTICES IN CITIZEN SENSING

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Summary

The history of philosophy has long questioned what human senses are actually capable of capturing about the world and often raised doubts about what is really known through the senses. Today, instead of just our eyes, ears and nose, humans rely on technical sensors to sense a vast array of features about the world from PH levels in water, to traffic movement, to the small twitches in your eye as you drive a car. We now not only rely on technical sensors to help us navigate and see the world differently, but also in order to sense things about the world we do not consciously feel. Dustbox is a sensor that senses particulate matter in the air, specifically particulate matter that is considered harmful to humans. The Dustbox is used in Citizen Sense, a citizen science project focused on work in citizen sensing. Technologies like Dustbox actively shape and reveal parts of the world we cannot do through our average senses. Thus, in order to better understand the role of technologies in citizen sensing, this thesis seeks to develop both the relations found between citizens and sensors in citizen sensing practices, as well as develop a postphenomenological account of citizen engagement with sensor data.

This paper first takes a postphenomenological position that bridges the work of mediation theory into citizen sensing and sensing practices; weaving together both various relations from the field of mediation, while also tying in recent findings from the material hermeneutics in the philosophy of science. This first part of the investigation builds on a concept of meditated sensing practices which are shaped through and with the Dustbox sensor and seen as shaping the work of citizens in citizen sensing. Building from this, questions regarding citizens and the data they gather from these sensing practices are considered in order to better account for how citizens relate to and work with data in unique and novel ways. In order to account for the qualitative and experiential work of citizens, it is argued that data must be accounted for beyond a representational way. The relational view of data is brought into the work of citizen sensing and developed as a promising way in which to understand how citizens relate to, understand and learn from the data they themselves gather. Within this new conception of data, the postphenomenological account raises questions regarding how data as a technological artifact itself is shaped through transmission, curation, manipulation and interpretation.

The mediating role of technology in the relational view of data raises new questions about the possibility of how to understand hermeneutically mediated data from the relational framework. From here, citizens and researchers can move forward with more novel and robust approaches to citizen sensing.

What is found within this discussion is twofold. One, that both the role of technology in shaping our interpretation and relation to data cannot go unrecognized; citizens and researchers alike are, as it were, living within the values created from a data-centric and a technologically shaped world. Second, that by embedding the relational view in citizen sensing; the work of sensing practices becomes more full-bodied and able to combine different imaginaries of data use, which in turn provide the necessary parts of both qualitative reports and experiential concerns. The paper concludes by proposing a workshop that attempts to actualize the theoretically informed concerns raised throughout the thesis. Inspired from current work being done in citizen sensing, the workshop attempts to show both mediated sensing practices and shed light on how citizens engage with data. The hope is that citizens will become more active in their own understanding of the sensor as a functioning tool, as well as begin to understand how their practices and gathered data are mediated by the actual technologies that they use.

Acknowledgments

I would like to acknowledge the people that helped make this project possible during such an unusual and chaotic year. Dr Karin van Leersum has supervised me during this project and has helped me realize the potential I had to complete it; she is an incredible and compassionate leader. Dr Peter-Paul Verbeek has guided me into and through a new framework of thought. His work inspired me to come to Twente and has contributed to me feeling both confident in my ideas, but also more open as an academic. Dr Andreas Weber also has created an educational space that I both appreciate and admire; he shaped my work for the better and offered help in critical moments. Special thanks to my friends for sticking with me throughout the long writing days, you all shaped this work each in your own way through our walks around campus. The support for this project has come from so many directions, it's hard to express how encouraged I feel.

Introduction

Creating, playing and manipulating our environments sparks relationships with places that are often unwarranted or unforeseen. Many people feel connections to places that they struggle to explain or communicate to others. Perhaps it was something inane they found there, something memorable they saw, or someone they miss that once spent time there. They value a place for inherent features, smells, 'vibes', traditions or even a brief encounter they once experienced. People engage with their environments that in turn creates a relationship with it, but not only that, the environment itself also shapes that relationship. This is not a one-sided creation, but a dynamic, give and take correspondence from a certain subject's perspective. It is a collision of the phenomenal experience and material composition that pushes, pulls, and mixes together in order to change behaviors, attitudes, and values. With that, this master's project explores from the (post)phenomenological position these portrayed relationships between subject, world, technological devices and the relations between them in citizen sensing practices. Questions arise regarding the ways in which sensors shape the practice of citizen sensing, and further, what are ways in which citizens interact with data gathered through these mediated practices? Moreover, when looking closer at data in citizen sensing, can a relational view help describe better the relationships citizens form with their data?

Citizen sensing practices solicits people to go back out into the world, and to monitor the environment around them through devices. Chapter 1 introduces the topic and practice of citizen sensing in citizen science including an intimate depiction of it in use. This chapter will introduce the overall case study of this thesis, Citizen Sense based in London. The project Citizen Sense was developed around the Deptford and Creekside areas of London and used the 'Dustbox' air monitoring sensor. With this in mind, the first chapter also introduces Emerson, an imaginary citizen participating in the Citizen Sense project. Emerson will provide a reasonable basis for which to extend the descriptions and claims of this thesis onto the actual experiences of citizens doing work in Citizen Sense. The character Emerson lives in and experiences the Deptford and Creekside area as someone who watches the community change and become increasingly populated. They also perform citizen science work with the Citizen Sense project and take on the role of

co-researcher with the team at Citizen Sense. Part of this methodological choice to use an imaginary character comes from the philosophical lens used throughout this thesis, postphenonmenology. Through their experiences, Emerson's interactions and labor with the Dustbox will begin to raise and formulate questions that a postphenomenological lens on technology can help work through. These questions will lead to the investigation and exploration of mediated sensing practices in chapter 2.

Following in the discipline framed as 'ethics from within', a meditating framework will be applied to citizen sensing practices in chapter 2. After introducing postphenomenology as a framework, parallels are drawn from current works in philosophy of science on the hermeneutics of scientific instruments in order to bridge these findings into citizen sensing. The relations between citizen and sensor then develops from embodiment, alterity and hermeneutic relations. Indeed, citizen sensing practices that take seriously the role of technology can recognize the co-shaping position of Dustbox. From this practice analysis with the physical sensor itself, the investigations go further down into the data collected by citizens themselves in chapter 3.

From air pollution molecules to the pH levels and acidification of water in the soil; data is out there in the world. These different information points are collected by citizens by their efforts in local environments; where they live, work, send their children to play and invest in with their taxes. Chapter 3 pivots the conversation to better understanding how citizens engage with the data they produce and gather for (scientific) intrigue and research. This chapter will argue that a better understanding of the data gathered by citizens and the ways in which those citizens 'make sense of' that data is key to digging deeper into this human-technology relationship. That relationship to data will be considered as a relational view of data in citizen sensing by citizens. Moreover, chapter 3 acknowledges that this relational view of data in which citizens are engaging with must also fall under a mediated relationship as well. The implications of this mediated relationship between citizen and their conception of data lend to new ways of understanding the relational view and is of particular interest in future work on the hermeneutics of data. It will be shown that when data is considered from the relational framework within citizen sensing, citizens' experience, engagement and interpretations can all be accounted for at a richer and deeper level.

The final chapter reviews the previous findings of each chapter and ties them together with some final thoughts in order to expand on future research possibilities and final conclusions. Chapter 4 ends with a workshop proposal that attempts to bring the mediated relationship between citizen and sensor to the foreground. Moreover, the workshop aims at creating a stage on which data can be reflected from the relational view with citizens.

1 Sensing, Stories and Practices

The work of science is no longer only for the scientists who are paid to do interpretation, observation and data analysis. Citizens have become invaluable to the pursuit of scientific knowledge, information collection, and the overall pursuit of better scientific communication through ‘citizen science’. Citizen science is an activity of citizens engaging in the process of scientific methods such as observation, data collection, monitoring, or even simply taking notes which all brings benefits to both citizens and the scientific community (Cappa et al., 2016, pg. 375). Projects in citizen science range from citizens watching out for seasonal birds, collecting data about radioactive material in the community, and even gathering information about noise pollution in their environment (Cappa et al., 2016; Kuchinskaya, 2019; Suman and Geenhuizen, 2020). Citizens are often trained by an expert in the field of which they are studying or helping or take on the effort themselves to gather the data as best they can. Once collected, the information gathered by the citizen is then normally sent into a database that is used for research or data production. Citizens therefore are helping scientists in whatever endeavor they may be pursuing, meaning that traditionally, citizen scientists never really know how the data they send in is used (Conrad and Hilchey, 2010, pg. 281). Nevertheless, even without always knowing where their collected data goes, citizen science remains popular. This is especially true in environmental monitoring, where the tools of citizen science such as sensors, collect information about a specific feature of the environment such as pH water levels, air quality and more. The work done in environmental monitoring in citizen science is tied to ‘citizen sensing’; one of the predominant topics of this thesis. Chapter 1 pursues deeper into the realm of citizen sensing; what it is, what kind of technologies are used to

do it, how citizens are involved in projects with it, and what kind of practices form around the sensor.

Hailed as nothing short of becoming a technological “revolution” comparable to the internet, sensors for environmental monitoring are transmitting, collecting and connecting data points across Earth (Gabrys, 2016, pg. 46). Sensors are now enveloped in landscapes, cities, forests, water, and of course, space, in order to gather some kind of data about substance, place, or inhabitants of it. There are massive projects of sensor networks underway and implemented in order to harvest data points that are used to direct resources, interest and assume particular relations about the world through institutions like DARPA, NASA, and even private companies like IBM’s “A Smarter Planet” (Gabrys, 2016, pg. 48). Earth and its diverse collection of inhabitants, features and substances in turn have become entities in which to be sensed and transformed into data (Gabrys, 2016, pg. 49). Coming down from this global scale, citizens too have become part of the network of sensors used at a more local level through programs and or research projects.

Citizen sensing entails projects that bring on citizens as volunteers or paid helpers that then obtain sensors which are used to measure a targeted interest or gather information passively while being monitored by the citizen (Gabrys, 2019; Grijns, 2020). These projects drive forward both massive amounts of data collection, but also the use and communication of scientific work and practices. Citizens begin to engage with sensors for scientific research and learn new ways of interacting with the sensors and functions they afford. Moreover, citizens have been known to actively appropriate or use ‘workarounds’ with the tools they are given in order to find new or better ways or gathering the information they seek (Houston et al., 2019, pg. 849) Often, the data gathering by citizens enters as a way to make up for a lack of resources and time spent by governmental or private entities which do not monitor enough or make data accessible enough to the public (Citizen Sense, 2017; Gabrys et al., 2016). Sensors, the interactions with them and the ways in which they uncover relations between humans, non-humans and the environment, can all be comprehended as developing through sensor practices. To understand what sensor practices are, it is important to first use an example story that connects us to the citizens’ perspective in citizen sensing.

In her work on citizen sensing, Jennifer Gabrys develops the term “Data stories” to capture the perspectives of citizens and how they are used in data analysis (Gabrys et al., 2016). These Data stories develop into full blown reports and research projects that help communities see new areas of improvement and problematic environmental traits of their cities or ecosystems. Data stories look to both encourage democratic engagements about findings, but also situate sensor data in its “lived material conditions” (Gabrys et al., 2016, pg. 2). For this thesis, Data stories as a method for gathering experiential data of citizens will break open discussions on the meditating role of technologies in citizen sensing. Data stories will also represent another example of thinking of data differently, one of relations and social framing in chapter 3. In this thesis, the Data stories are found at Creekside in London (Citizen sense, 2017). This section will look at the Creekside area, what issues were found there, and how citizens both raised concern as well as took action to curb the poor air quality of the area. A perspective of a citizen that lives in the area named “Emerson”, an (imaginary) local, will characterize the situation and its recent history.

Let’s Meet Emerson

Emerson takes their daily walk through Creekside as a routine to keep them healthy. They’ve lived in the area for over 25 years and seen a lot of change over that time. New stores, new neighbors and new projects always changing the landscape of the inner residential and industrial side of London. Emerson takes their walks along Deptford creek, up north to Union Wharf, and then back down along the residential areas near the A2209 speedway. Over the years the walk has changed from a quiet retreat, to a livelier jaunt avoiding cars that have little patience and new construction zones that stand with literal barriers. Emerson doesn’t see these new changes in their neighborhood as necessarily bad; it is a sign that things need improving and change as a constant to accept.

On the other hand, Emerson can’t help but notice changes around the community that do raise concern. While going for their walk, Emerson now notices the sooty deposits in windowsills and surfaces like public benches, or visible dust in the air that gets on their

shoes and comes into their home (Citizen sense, 2017). Their neighbors grumble of the respirational harm they feel, and which is new and not noticed before. Emerson worries the noises from local cranes that keeps them, and others awake during the late afternoons and scares the local dogs into barking non-stop. Friends and families of the local neighborhood discuss with Emerson of the changes they see as well; that they even reached out to local authorities about the particulate in the air and the dangers it poses for local health, but with little or no response from community governance (Citizen sense, 2017). Emerson chooses one day to take the matter into their own hands and volunteer for a local citizen sensing program called 'Citizen Sense' that uses the 'Dustbox'. They would be considered Dustbox 103; one box of about thirty in the local area.

Citizen Sense

The community air-quality-monitoring program in Southeast London that Emerson joins aims to both measure pollution levels in the local area of Deptford and neighboring Creekside, but also interact with residents of the area who engage directly with these sensors and local environmental problems (Houston et al., 2019, pg. 853). The program, aptly called 'Citizen Sense', encourages citizens like Emerson through meetings with researchers to design the research program and to observe and document dust and noise pollution in their neighborhood. The Dustbox, a low-cost sensor, was designed as well from a small group of residents in the area through, "drawing on and extending residents' Do-It-Yourself sensing practices" (Houston et al., 2011, pg. 12). The Dustbox is able to identify harmful and hazardous particulate in the air which generally is particulate matter (or PM) the size of $PM_{2.5}$. $PM_{2.5}$ is understood as harmful due to its size and contents of microscopic solids, whereby contrast, usual human hairs are about 30 times larger than these particles (*Particulate Matter Basics*, 2016). This makes the $PM_{2.5}$ impossible to see via the naked eye alone. They are often emitted from construction sites, unpaved roads, and industry. The effects of these particulates are recognized as contributing to environmental damage such as acid rain effects and a large problem for human respiratory health (*Particulate Matter Basics*, 2016). Citizens like Emerson could already see these negative effects of heavy industry, idling automobiles and waste taking effect on their friends and neighborhood territory (Houston et al., 2019, pg. 13; Citizen sense,

2017). Although also agreed on as harmful by local municipalities of London, these pollutants do not receive attention in small neighborhoods and instead are only monitored by statutory instruments in very select sites in the city (Gabrys, 2019, pg. 854). In reality, the Citizen Sense program in Deptford did find a cause for concern (and action) in high levels of particulate matter in the Deptford area that has not been addressed (Citizen Sense, 2017; Citizen Sense, 2017b).

Creekside, the neighboring Deptford area and many other locations that have gone through similar experiments with environmental modeling are samples of Data Stories (Gabrys et al., 2016; Gabrys, 2019; Houston et al., 2019). Ingeniously named, data stories relay and disclose ways of accounting more fully for stories told with data; across citizen and scientist engagements, with a bit of storytelling as an inventive practice (Gabrys et al., 2016, pg. 2). Data stories such as Creekside and Deptford Park in London are informed by the data that the citizens collect, but also uses software such as Airsift web tool in order to visualize the same data in a variety of ways to help communicate the information to concerned parties (Houston et al., 2019, pg. 863). This creative and rather novel approach to doing citizen sensing research opens citizens up to new ways of seeing their local neighborhoods. The sensors, data and information they tinker with, the experts they meet and work with, the conversations that arise; all of these factors make data stories an interesting and consuming method of research for all stakeholders involved. In other words, through data stories the most involved stakeholders (i.e. local citizens and researchers) take on both new ways of viewing the local environment via data, but also through each other. With data stories, citizens are able to participate in and be incorporated during meetings (both casual and more professional), conversations and design recommendations. For instance, in the Creekside case, the citizens volunteering their time are able to narrate to researchers what they experience around pollution events, what they were like in recent weeks and which traffic accidents had caused significant and intolerable vehicular idling (Houston et al., 2019, pg. 861). These discussions also lend to volunteers feeling comfortable with asking more open questions such as how the network of monitors worked and what the future effects of pollution may be like (Houston et al., 2019, pg. 861). For researchers, these questions show that not only is a project like Citizen Sense succeeding in igniting conversations surrounding the often-ignored

environmental issues in the Deptford area, but they are also realizing what is possible for the future of citizen involvement in scientific practices (Cavalier and Zachary, 2016, pg. ix).

In this way, citizens also feel as though their situated knowledge of an area is put to use, a citizen-based contribution, and sometimes even produce visualizations of data that general scientists would not (Gabrys et al., 2016, pg. 10). This is also seen with local data that citizens gather and offer that is considered more “rich and entangled” in the engagements with the environment compared to the episodic measurements of an expert researcher (Gabrys et al., 2016, pg. 11). Local citizens are invested both financially and affectionately to their communities, making their work in data gathering feel “worth it” and motivated by the betterment of the place (Houston et al., 2019, pg. 857). Moving beyond the bare minimum of regulatory processes and data comparison, data stories too develop accounts from lived experiences that could be considered as ‘more than empirical records’ and take citizen experiences seriously (Gabrys et al., 2016, pg. 11). The considerations that are brought about by data stories in how to treat citizen participation and collaboration focuses a lot of attention on the experience of the person in the practice of data collection. For citizen science, this could be seen as a step in the right direction; the perspectives of citizens in interpreting and doing the practice of scientific inquiry is still yet to be fully recognized in many domains. In fact, it still isn’t clear why people volunteer their time and efforts for a lot of citizen science projects (Goodchild, 2007, pg. 219; Cavalier and Zachary, 2016, pg. 3). Perhaps, the issues and new perspectives that come from projects like data stories can help untangle some of the interests and motivations for citizens in science? Data stories brings in innovative ways of attributing space for citizen intentions and experiences, which could uncover for researchers unexpected reasons for citizen participation and commitment to projects.

Cultivating a better understanding of data stories will require looking at the actual sensors themselves and how practices form around and through sensor usage. The next section will put sensor and the practices informed by them in the spotlight and explore questions regarding how (sensing) practices might shape data stories, what experiences users like Emerson have with sensors in data stories, and how the relations between environment and technology are currently discussed.

Introducing Sensing Practices

Practices are the ways in which we engage with the world around us, the people we work with, and even express the various things about ourselves through motions and expression. These practices are not limited to humans necessarily, even a non-human animal wants to express themselves and shape things around them. This thesis explores sensors in citizen sensing, the ways in which they shape the citizen experience of science, and the human-technology relations between the two. From the perspective of this thesis, even the non-human entities expression of their practices will be framed and shaped by the citizen or human interpretation in order to be accounted for. This argument and perspective will be built on further in chapter 2. Forming this exploration leads to an important discussion on what Jennifer Gabrys has named “sensing practices”, which is an “analytical device for thinking through how experience and relations are reworked across entities, environments and technologies” (Gabrys 2019, pg. 724). In other words, Gabrys has created a linguistic tool with which encapsulates all the sensor-based practices of all ‘human and nonhuman entities’, and in turn they have given these practices a base with which this thesis will build on. By appealing to sensing practices here, this section will build up on the Dustbox sensor in the Deptford and Creekside examples, creating a more concrete illustration with which to work from. After working through some of the research on sensing practice, the term becomes an appropriate bridging tool for showing the need and developing vocabulary of the postphenomenological account of sensors in citizen sensing. Befittingly, the final section here on sensing practices makes a nod at the proceeding chapter on mediation theory and the postphenomenological work in the philosophy of technology.

Considered to be a guiding concept in the world of environmental monitoring and sensor research, sensing practices provide a diverse array of possible investigative modes and relational experiences that might be differently configured toward alternative political collectives and effects (Gabrys 2019, pg. 725). In their research, Gabrys accounts for sensing practices as a way to consider the underlying values, experiences, influences and involvement of entities that are usually unaccounted for in models solely oriented on ‘problem-solving’ directives (Gabrys, 2019, pgs. 724-725). Sensing practices therefore

are afforded a very flexible and participatory-oriented conceptualization that tries to capture the distinct ways in which entities work, play, and change with sensors. The result is that sensing practices "do not settle on a singular, fixed subject, entity, relation or outcome", alternatively they take on articulating environmental collectives that are "in the process of finding ways to live together in altered worlds." (Gabrys, 2019, pg. 727). In other words, for Gabrys, sensing practices attempt to account for the many ways in which sensors both sense features of the world as well as constantly interact with new and different inhabitants. These sensors in turn change, open, and create new ways of looking out to the world. For research purposes, sensing practices are a very interesting and effective way of discussing the intimate and ever-changing ways in which people create new ways of approaching the world with sensors. For citizens like Emerson, it is through their own experience of using, engaging with, and generating data with a sensor that will spark the dialogue of their own sensing practices. Between experiences and sensing practices, the co-shaped and shared developments of citizen sensing will be considered as one of technological mediation and a relation to data not considered in citizen sensing before.

Emerson's Practices

Dustbox 103 would be placed in the vicinity of Hainenny Hatch, a train track that runs across Creekside ride and over Deptford Creek. The Dustbox lives with Emerson and it inhabits a small chair outside their creaked open backdoor. Creaked open, because the Dustbox needs to be connected through cables to access power inside. This was a tough decision for Emerson, as this means they would need to keep the door creaked open all winter long, but they felt it was worth the high energy costs in order to gather the data (Houston et al., 2019, pg. 857). Emerson also had to consider that they may let critters in, have cables in the walkway, and even have to leave the door open to other unwelcome visitors.

Repurposing the space, Emerson finds a way to live with the Dustbox and learns how it behaves when treated incorrectly. The Dustbox would become the center of Emerson's attention if it started to flash a green light (indicating it was connecting to a wireless

network) or not properly positioned (Houston et al., 2019, pg. 858). Perhaps the device was not in the right position, or fell from the wind, or was moved by an unknowing neighbor; these situations all came to Emerson's mind as they setup the chair for their essential sensor. This negotiation of environment, such as where to put the Dustbox for the most effective use, where it could connect to WIFI and power, how it should be situated; all of these considerations have to be made by citizens like Emerson who gather the data. They are also used to inform the building blocks and design for the sensor itself (Houston et al., 2019, pg. 858).

The researchers made sure to have weekly reviews of each Dustbox via an internet portal. If they saw a sensor was offline, they would email the participant with advice on getting the sensor set back up (Houston et al., 2019, pg. 858). In order to get less patchy data sets and better-quality data, the sensor would need to be satisfied with all its conditions. In turn, citizens like Emerson begin to change their own environments and practices to meet these. Certainly, the Dustbox was not impervious to fault and would occasionally not respond to Emerson's troubleshooting. Luckily, Emerson could email or call on the researchers conducting the program to help with the situation. The troubleshooting with experts was always a moment for Emerson to get to know them better, ask questions about the research being done on pollution, and share a coffee if they had time. Emerson enjoyed collaborating with the researchers on troubleshooting the Dustbox such as finding cables to fix, repairing the frame of the sensor, or finding a defective plug (Houston et al., 2019, pg. 860). During these visits, Emerson would also share their thoughts or observations on new traffic and construction events that may be leading to more sites for data gathering (Houston et al., 2019, pg. 861). Afterall, the walks along Creekside always were changing.

Learning Further Through Citizens

Through Emerson's story, the data collected by Dustbox 103 is richer by way of experience, local knowledge, and intimate engagements with the sensor itself. The Deptford and Creekside Data stories produced by the Citizen Sense team engaged with citizens like Emerson for exactly these reasons. Through experiences of citizens and by

making room for exploring the new sensing practices that happen between citizen and Dustbox; new questions arise as to how we can account for the experiences and relations that percolate up from the co-created interactions. What human-technology relations should be considered when framing citizen sensing and sensors? How do sensors shape a citizen's perspective on their environment and scientific work? What language is needed in order to understand better how citizen sensing as a praxis of citizen science is shaped by sensors?

The work of philosophers in technology have created fundamental frameworks for questions like these. A postphenomenological account of technology considers that technologies frame our notions and experiences of both the world and of ourselves (Verbeek, 2005). This claim builds up the core of mediation theory and pivots away from a technology being 'neutral' or ineffective at shaping our experiences and worldviews. In order to better consider the questions that rise from citizen sensing and sensing practices, this paper will look to mediation theory as an applicable methodology.

2 Introduction to Postphenomenology

It's difficult to overstate the sheer amount of influence technologies have on peoples' ways of thinking, ways of living, and processes of creation. When faced with difficult problems, people often turn to their tools to offer a way of relieving some mental or physical burden and or even distracting themselves from the problem all together. Through interaction, people see the world through technologies, work alongside technologies, and even interact with technologies as if they were another being in the room. These lived relations that people have with specific technologies can be analyzed and developed as human-technology relations with the frameworks found in postphenomenology. Postphenomenology offers a detailed conceptual context for exploring how people and things interact together and mediate our experiences of the world (Rosenberger, 2008, pg. 63). Holding close to a more empirical history, the frame of postphenomenology places emphasis on investigating through case study examples and phenomenological accounts of peoples' experiences with technology.

This chapter will take the lens of postphenomenology and place it over the sensors used in citizen sensing. Before doing so, postphenomenology will be briefly introduced as a critical lens with which to diagnose human-technology relations. It is then important to relate the topic to work done in the hermeneutics of scientific instruments. By way of relating to and acknowledging the current work done in the hermeneutics of scientific instruments, this chapter will begin to 'leave the laboratory' and pivot towards citizen sensing in citizen science. This opens the doors to looking at the hermeneutics and other mediating roles sensors play in sensing practices of citizen sensing. This second part of this chapter will build on the progress made in extrapolating these human-technology relations and start analyzing the practice of citizen sensing as a mediated experience. To start, it is important to understand some of the fundamental principles of postphenomenology as a tradition.

Postphenomenology: An Impression

Postphenomenology is founded on important basic beliefs, starting with understanding of relations. The interactions between subject and object is a relational one, which is not just interactional but also co-constitutive (Introna, 2017, pg. 19). In turn, there are only indirect relations between subject and object, which bring technologies in as co-constituted mediators of those indirect connections. As co-constituted mediators, technologies begin to take on a much more active role in shaping the world around them and the experiences of individuals. This leads to mediated relations between subjects and objects that are typically human-technology-world relations, with the mediation as the original source from which a specific subjectivity rises from and which is part of a specific situated practice (Introna, 2017, pg. 20). In other words, technologies in use are not simply just objects, but are mediators that shape the environment and experiences between users and their world (Introna, 2017, pg. 20 – 21; Rosenberger, 2018; Kudina and Verbeek, 2019).

Importantly, not only will technology shape environments and the experiences of them, but the roots of postphenomenology (i.e. phenomenology) holds that "Technology is not the artifact alone, it is also the technological attitude or disposition that made the

artifact appear as meaningful and necessary in the first instance." (Introna, 2017, pg. 36). In other words, this position on human-technology relations lends to a more in-depth critique into how the technologies we use shape meaning and can influence how people perceive what is valuable. This view of technology has also had interesting implications in the field of science and scientific instruments.

Postphenomenology & Philosophy of Science

Recently, the critical work of Postphenomenology of technology and the Philosophy of science has bridged into the work of scientists and the technologies they use (de Boer et al., 2018; de Boer et al., 2020). De Boer (2018) argues for the importance of acknowledging how the "active shaping [of technology] cannot be cut loose from the scientists that [use the] instrument" (de Boer et al., 2018, pg. 741), which leads to a larger investigation into the relation between human and technologies, scientist and instrument, and the co-created roles found between them. Underpinning science in postphenomenology is the instruments; in other words, scientific knowledge is instrumentally dependent on the tools they use (de Boer et al., 2020). Similar ideas have been tackled by Don Ihde as well in his work on instrumental realism, where contemporary sciences are essentially embodied technologically in instruments (Ihde, 1991, pg. 103). Postphenomenologists then, want to make the entry point for creating and understanding scientific knowledge as beginning at the instruments and practices that surround them. By recognizing and attempting to understand the character of these relations for interpretation, a hermeneutic perspective is prompted (de Boer et al., 2020, pg.7). This 'hermeneutic relation' can be traced back to Don Ihde's proposed list of four human-technology relations; where with the hermeneutics, the technologies we use become sources of interpretations about the world (Scharff and Dusek, 2003, pg. 508).The postphenomenologist looks to these relations in the context of specific technologies such as fMRI scans that mediate not only, to some extent, what counts as knowledge of the brain but also shapes the interpretation of it (de Boer et al., 2018, pg. 746). From the fMRI example, professional interaction and in turn the relation, to the machine to accessing the brain is through the machine itself. These fMRI machines only show a window into the brain in terms of blood flow in very specific areas. Reinforcing this specific kind of brain

research is the assumption that blood flow seen on the scans are correlated to neural activity in some way (de Boer et al., 2018, pg. 746; de Boer, 2019).

This is not to say that only these physical things are considered, but so are the active choices and involved actions of the researcher who choose how to manipulate the image of the brain in certain ways so as to get a 'clearer' image or detect specific activity (de Boer et al., 2018, pgs. 746-747). This leads also to the first example of a *multistable* object or image; something that which can be interpreted in several ways (Rosenberger, 2008, pg. 65; de Boer et al., pg. 747). For de Boer and many postphenomenologists that work with this term, the relation *in and to* the fMRI-image example is to make a specified choice about the relevant features which one considers important for brain activity. What this means for work in neuroscience is that the very model by which researchers use to investigate the brain and its activity is necessarily shaped and influenced by the ways in which the brain is presented by these technologies (de Boer et al., 2018, pg. 747). These technologies bring about certain kinds of activities and practices from scientists too, those which are afforded by the technology itself through limitations, interpretations and technicalities of the instrument (de Boer et al., 2020, pg. 7). Here too, intentionality and intentional relations between human consciousness and the world are important to consider. In (post)phenomenology, consciousness and human experience are understood as always being directed at or toward something (Smith, 2018; de Boer et al., 2020, pg. 7). The roots of Postphenomenology, that is phenomenology, have a specific way of understanding human attention. Later sections will discuss the implications of working through attention in this way and how it can be understood when introducing a sensor to the picture. In other words, how does a sensor like Dustbox shape citizens' attention towards particular air particles, measurement and even their perspective of health within their neighborhood?

Intention and Consciousness

Phenomenologically, we experience, live through, and perform conscious states (Smith, 2018, pg. 5). This does not mean we actually experience some raw form of consciousness, but instead a shaped, influenced, and filtered version of it through our

own senses, thoughts and cultural backgrounds. Thus, it is “part of what it is for the experience to be experienced and part of what it is for the experience to be”, ontologically speaking (Smith, 2018, pg. 5). In turn, phenomenology puts attention on attention, and studies experience as it is experienced from the subjective point of view (Smith, 2018, pg. 2). The postphenomenologist agrees to this and moves towards trying to understand the links between our own experiences and the co-constitutive relations between subjective experience and technologies (Introna, 2017, pg. 2).

Moreover, these experiences are mediated by the technologies themselves which help to see such phenomenon or have such experiences (de Boer et al., 2020, pg. 7). The postphenomenologist sees mediation between technologies and persons as the “original source from which a specific subjectivity and objectivity emerges” given any situation (Introna, 2017, pg. 20). For de Boers work, the examples of this are how we would not understand germs in the ways we do if not for a microscope which constitutes a view into the microscopic world not seen before; nor would Galileo be able to relate Jupiter’s moons in novel ways if not for a telescope (de Boer et al., 2020, pg. 7). In turn, the technologies we use to generate and formalize these conceptions of reality co-constitute a certain type of scientist that work in relation to technologies which again, give rise to specific scientific practices (Rosenberger, 2008, pg. 66; de Boer et al., 2018, pg. 753; de Boer et al., 2020, pg. 7). The very scientific conceptions of reality that we have as people are built on and mediated by the technologies with which we look out to the world and see it through.

With this mediated conception of scientific practice in mind, the discussion in this paper generates new questions regarding citizens and their relation to citizen sensing. What kind of technologically mediated relationships are citizen scientists engaged with in sensing practices and what are examples of new interpretative frameworks generated by these sensing practices?

Leaving the Laboratory

From the work by de Boer (2018, 2020), we learn that practices, observations, and the overall scientific perception of the world are co-created and mediated by the

underpinnings of technological invention. Their writings focus almost exclusively on the work done between professional scientists and their instruments, with little room allotted to amateur interpretations of scientific findings or experience. The lessons learned from de Boer's research then, can lead to interesting and new ways of thinking about citizen scientists and their sensing practices as discussed in the previous chapter. This section will leave the professional scientists with their contraptions and adventure out to the realm of citizens and sensors in citizen sensing. The next section examines the technologically mediated relations in citizen sensing and sensing practices.

The Relations with Dustbox

There are many mediated relations to consider when developing a network of different connections and shaped experiences citizens have with sensors. The Data Story of Creekside and Deptford will provide both an empirical report of how citizens experienced their lives and practices with a sensor like Dustbox, as well as some intimate details about their mediated experience of their community. Dustbox as an example will reveal how citizens 'live through' sensors that shape their experience of the community in new ways, 'live with' sensors as something which attracts their attention, and ultimately as something which they 'understand' their own findings from. By considering the relations between citizen and Dustbox, questions regarding citizen sensing as a mediated practice necessarily arise. Later on, how to interconnect sensing practices and a mediation framework becomes apparent.

Living through Dustbox: Embodiment

Postphenomenologically speaking, there are ways in which the users of technology experience the device, tool, or even application as an embodied experience; where the technology can feel as though it is part of oneself (Gertz, 2019, pg. 66). The notorious example used is that of a glass's wearer; where the glasses are not actually seen by the wearer, but instead are ignored and enhances the ability to see. This embodiment relation develops further when viewed from the perspective of citizens engaged with Dustbox.

Dustbox as a sensor is a rather mundane instrument. It does not attract much attention but does allow for a new lens of the air around you. By using Airsift, citizens are

able to see particulate matter not recognizable by the human eye (*How to Airsift*, Citizen Sense, 2016; Houston et al., 2019, pg. 854). Dustbox does not move, nor does it have any moving parts; it is a kind of sitting model of a mechanical, box-shaped 'lung'. The lung of one Dustbox is connected via a network of other sensor lungs, and when put together with polar plots, creates a digital version of the ecosystem of what it is like to live in Creekside or the Deptford area. In other words, through Dustbox(s) citizens engage with a totally new, possibly unknown, version of the air and community they live in. In this relation, the technology not only becomes a part of the human in some way, but also enhances and extends human abilities (Gertz, 2019, pg. 67). From this evaluation, this relation can be closely tied to the hermeneutic relation, where technologies mediate between the "immediate referent [and] to something beyond itself" (Introna, 2017, pg. 21). Instead, the embodiment relation described in this section touches on how Dustbox can transform a citizens' perspective of the world from a perceptual sense and be *felt* in the bodily sense. The 'lung' that Dustbox represents in the community both enhances the citizens ability to see what is out there in the neighborhood, but also becomes part of the ordinary ways in which to understand the features of the community at a magnified level (Introna, 2017, pg. 20). In other words, the sensors like Dustbox both literally magnify the molecular level of particulate matter, and on a different level increases awareness about things like particulate matter, dust, and so on as part of the community itself. Dustbox, and sensors like it, bring out abilities in citizens to see more than what they normally perceive, as well as interpret it with their own co-created relation with the sensor (de Boer et al., 2020, pg. 16). Likewise, the embodiment relation can also foster a kind of dependence (Gertz, 2019, pg. 67).

Dustbox sensors, and sensors like it, give us a new view on the world around us that customarily impact how we feel about our environment. With dependence, for example, a citizen could begin to only find it 'safe' to go outside when the data reads with the right measurement or calculation and ultimately begin to question their own senses outside of the sensor. This sort of paranoia could develop from having a newfound relationship to the technology. On the other hand, a person may feel that this is the only way to 'know' that it is healthy to breath the air in the neighborhood, still becoming more reliant on the tool.

The project of Dustbox in Creekside and the Deptford area asks that citizens live with the sensor in and around their homes (Houston, et al., 2019, pg. 856).

Figure 1 from Houston et al., (2019), pg. 856; an example of a Dustbox inside a box.

Dustbox requires some setting up with power and WIFI, maintenance, weatherproofing, and some checking up on. Sometimes, it is not always easy to balance finding both a good connection to a WIFI hotspot, a power connection, and or maintaining a depleting battery supply for the sensor whilst also trying to gather consistent data (Houston et al., 2019, pg. 858). Citizens then tend to begin to worry about the sensor, that it is not working, or is not in the 'right' place for collecting data. These kind interactions between citizen and sensor fall into a category called alterity relations; where technologies "draw attention to themselves by simulating the actions of living beings" (Gertz, 2019, pg. 69). Another example shows how Dustbox does not always 'behave' as it is supposed to and can cause much stress in citizens that feel they must take care of the sensor tool (Houston et al., 2019, pg. 858).

Citizens want to take care of their new Dustbox and make it 'happy'. Living with Dustbox could often become a tedious task of managing whether the data gathered by

the sensor was ‘sensible’ and or if the sensor was still functioning; requiring a small team of researchers to babysit the project in the beginning for errors or dead sensors (Houston et al., 2019, pg. 856-858). Citizens also change their living situations to ‘help’ the sensor gather its important data by pulling cables across their entrance hallways or leaving the kitchen door open so the sensor can receive power (Houston et al., 2019, pg. 858). In turn, citizens must also conform their social arrangements to the sensor as well, depending on the needs of the Dustbox; you may need to leave right when it’s the best part of the day to capture particulate matter data. That important data, and the way in which it is curated for the citizen is also a curious relation.

Understanding through Dustbox: Hermeneutics

Dustbox as a sensor gathers information about the world and presents it to citizens and researchers in various ways depending on the chosen model. In postphenomenology, hermeneutic relations are understood as technological interactions that expand our abilities to interpret and even perceive the world around us by enabling access to qualities of it not previously obtained (Gertz, 2019, pg. 67). Tools such as measuring devices and monitoring technologies direct our attention to very specific features of the world and help us ignore the rest. In other words, Dustbox does not capture all features about the dust itself, only what is modeled in the data sent to Airsift or accounted for in spreadsheets. Nor does Dustbox need to capture humidity levels, sunlight strength or other factors that might impact dust density; the device captures and displays what the technicians of it believed would be relevant for the agreed-on output. In this way, hermeneutic relations make us feel very close to the world, and we begin to trust them deeply as a way of understanding the things around us. Dustbox helps citizens see and interpret the air around them in a very specific way; $PM_{2.5}$ become spotlighted and the center of attention.

Citizens choose to look through data obtained by Dustbox in order to grasp some understanding of when the air is ‘healthy’ in their neighborhood. This data is a representation of reality and is necessarily interpreted by its readers (Verbeek, 2008, pg. 15). The sensor also develops its own model as a “material interpretation” of reality that comes from translating what it “perceives” or sees out there into a specific model of understanding (Verbeek, 2008, pg. 15). With environmental monitoring like Dustbox, the

sensor mediates the lens with which particulate matter in the air is given emergent inquiry and is discussed within the community. Through Airsift, particulate matter is modeled in various ways, including polar plots, time-series graphs, and even scatter plots that show the relationship between PM2.5 concentrations and wind direction (Citizen Sense, 2016). The times and areas that are chosen can indicate a multistable image that can be interpreted as a very 'healthy' time to go on a walk in the neighborhood or paint a very scary image of the unhealthy air during rush-hour in Deptford and Creekside.

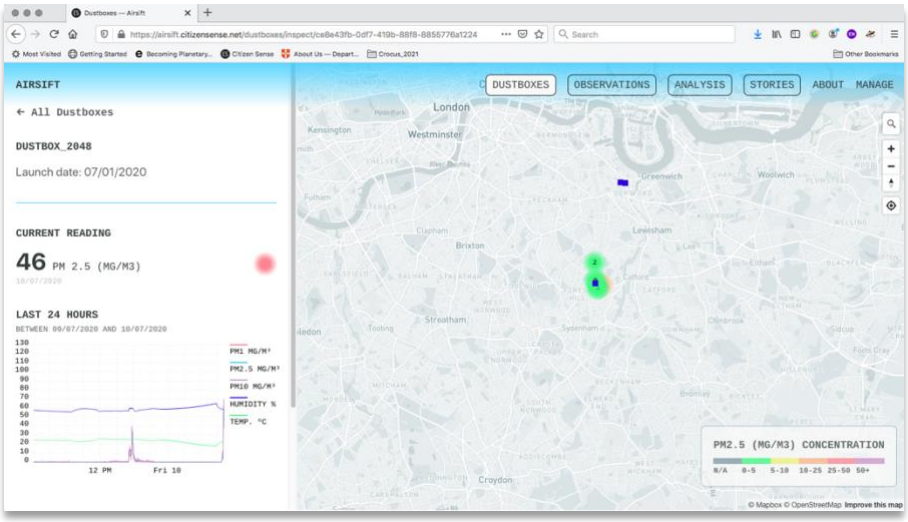

Figure 2 from Citizen Sense (2016);

an example of Airsift modeling.

With these abilities in mind, it is good to remind ourselves that a hermeneutic relation has risks as well. On one hand, these sensor data create a portrait, or glimpse in time that can be used as a way of identifying interesting and crucial information about the community around Deptford. On the other hand, hermeneutic relationships also leave open the possibility for misinformation (Gertz, 2019, pg. 68). Not necessarily intentional, misinformation in hermeneutic relations can arise from situations like misreading data or even from flaws in the technologies themselves. In situations like these, Dustbox must rely on both the good-will of citizens, as well as the shared understanding of the current community situation when reading data. Dustboxes do break, so there must be shared communication (Houston et al., 2019, pg. 861) Dustboxes do have data gaps in their collection times, so there must be shared reasoning of why or how it happened (Houston

et al., 2019, pg. 859). In the Citizen Sense project, citizens and researchers work together to make sense of the data so that there is a more shared understanding of the situation the neighborhood faces, and the sensing practices engaged with. Dustbox is not a neutral instrument, therefore it actively organizes the sensing practices that come from its use and role in the process of environmental monitoring.

Mediated Sensing Practices

So far, this chapter has reflected on Dustbox as a mediating sensing instrument that influences, shapes and enhances the abilities and lives of the citizens that choose to engage with it. The human technology relations that can be drawn out between a sensor such as Dustbox and the experience of a citizen in citizen sensing shows that there is something about the engagement with a technology that should be considered important to the persons' understanding of two large topics. These topics are what science is as a practice in citizen sensing and how citizens' relation to the world through the practice of citizen sensing is shaped by the technologies such as sensors. Regrouping, the main focus of this text is that of citizen sensing and the work done with sensors; where sensing practices as a term and analytic device has been equipped for citizens doing citizen sensing. This section will revisit sensing practice as a term and show that it can be investigated within the work of mediation theory and inquire the hermeneutic relation as playing a key role in sensing practices.

As described in the previous chapter, sensing practices are cultivated as a device or term for, "thinking through how experience and relations are reworked across entities, environments, and technologies", which in turn is an attempt to capture the changing formations and relations that occur between the various entities, subjects and environmental collectives that are found within sensor projects (Gabrys, 2019). Researchers such as Jennifer Gabrys (2019, 2020) have concentrated on new ways of understanding sensing practices as beyond "the senses as fixed in the usual human-focused classificatory framework" and breaking into the other non-human perspectives (Gabrys, 2019, pg. 732). While this notion of sensing practices raises interesting questions for the Science Technology Studies, such as how technologies stabilize

relationships between entities; it also bares important questions for the focus of this thesis with a mediated approach to sensing practices. Can the information produced by sensors in citizen sensing be understood from a position without a citizen perspective?

The participatory and practice-based approach to sensing work has shown to be influential in obtaining new ways of doing experimental and novel approaches to research for citizens and experts alike (Gabrys 2019, 2020, 2020b). Yet, the questions of how technologies, like sensors, shape these practices have not been explored thoroughly. With Gabrys's sensing practices definition in mind, the next section will ask how Dustbox can be understood as mediating the actual practice of doing citizen sensing for citizens.

Mediated Practices: Dustbox

Dustbox senses, interprets and reveals new characteristics about the world around it that a citizen may engage with. The mediating relations explored earlier can further inform sensing practices, moving beyond just capturing, "changing formations of experience", to a more robust and deeper human-technology co-created interaction (Gabrys, 2019, pg. 724). Indeed, Gabrys' definition wants to "decoupling sensing from its exclusive human orientation", while still maintaining the practice-based approach (Gabrys, 2019, pg. 723). The approach of data stories is the culmination of both the perspectives of citizens doing citizen sensing and the findings of sensors as interpreted through citizen engagement. Importantly, the work found in data stories and Citizen Sense are sensing practices that do show emergent relations between human and non-human entities; but that they are mediated relations cannot be ignored. The data stories are in turn, mediated by the technologies used within them.

This section will begin to interweave the work found of data stories and mediation theory. The section will show how the work done in data stories and the work in sensing practices shapes the ways in which citizens engage with the praxis of citizen sensing. Questions arise regarding how mediation theory could cultivate a deeper understanding of sensing practices in citizen sensing, What is a data story understood as from a postphenomenological standpoint? And finally, what are the ways in which the data produced in sensing practices correspond to playing a role in the mediated practice?

After projects like Creekside and the Deptford, the Citizen Sense team results are that of engagement with diverse distributions of experiences which work together to present something important about the sensing practice itself (Gabrys, 2019, pg. 726). Together, the experiences and data coupled from a range of destinations in London become a crucial piece to understanding the ongoing exchanges between human and world through technology. A practice, or a way of doing things, shows the connectedness and interrelatedness between humans and things (Aagaard et al., 2019, pg. 220). Like the mediating relations earlier discussed in this chapter, what is actually afforded by the technology as a practice in citizen sensing is of crucial interest for the discussion. Technological mediation can be found beyond the individual – technology processes and can be seen in a more "macro-dimension, where social practices and cultural frameworks of interpretation are formed." (Verbeek, 2020, pg. 9). In other words, the domains of citizen science and environmental monitoring are exceedingly technologically mediated, and the ways in which we evaluate or proceed in investigation will be remarkably framed by the values and affordances of the sensors used. In this case, Dustbox can influence and shape not just the mediated relationships between human and world, but also the actual processes of doing sensing work in citizen science.

Citizen Sense as a project sets up citizens to become part of a larger research program. While doing so, the project also enables citizens to engage with citizen sensing as a practice; a practice where citizens gather data about the world around them through a mundane technology like Dustbox. Mundane, because the sensor is quiet, unobtrusive, and can be left alone when set up properly. The work done by sensors with citizens also has a sort of improvisational side to it, where the approach for Citizen Sense stems from improvising with sensors as activities that are the "generative practices out of which new technologies are made" (Houston et al., 2019, pg. 851). Not only technologies, but to move beyond this is to understand how these improvisational activities with sensors generate new practices in citizen sensing as well.

The sensor Dustbox attunes the attention of the citizen towards data concerned with the air. The referent, the air, is displayed as the Airsift technology may see it, but not as it actually is. Dustbox collects the information as 0's and 1's, as data points with a place in time and at a certain level or range of sizes in different patterns (Houston et al.,

2019, pg. 863). The data is localized to the Deptford area, it does not attempt to capture the entirety of London, but instead on a particular neighborhood, at various times, from various points of interest. On one hand, this project cultivates the citizens' attention to "matters of fact", where the foundation of concerns for political activity may be nurtured (Verbeek, 2020, pg. 8). And on the other hand, it presents data as a part of a story or version of the community possibly not seen before and or in need of further investigation. From the latter perspective, sensor practices begin to attune citizens to both new feelings and sensitivities to their local environments, but also to the normally inaccessible work of researchers. Indeed, citizens who partake in the work of the Citizen Sense project found themselves asking more detailed and intimate questions about the health and dealings with urban life around them (Houston et al., 2019, pg. 861).

The relation between Dustbox, world, and citizen are encapsulated in the practices of sensing. The output of data stories is the hermeneutic story with which both sensor data and citizens engaging with world and collapsed into a cohesive, co-constructed story about Deptford neighborhood. As citizens work with and craft new ways of understanding with these sensors and data, they become accustomed and directed towards new and deeper questions. Citizens become engaged with their surroundings in ways that beg for exploration, experimentation and new ways of living. Data stories that capture qualitative or experiential remarks of citizens are on the one hand shaped by what comes to the citizens' attention and on the other hand attempt to capture the phenomena of actually doing citizen sensing. In another way, questions and intentionality of citizens become more focused and detailed on specific areas of interest that are based on what information is accessible. Part of what mediates data stories is the data that citizens work so hard to gather and make sense of. Difficulties from this arise, such as what sort of relationship is required with data to be able to infer relevant information about one's own role in the community? Moreover, how can data be both shaped by and actively shape the conceptions citizens have about their communities? These questions are appropriated to the next chapter. For now, the sensing practices from Dustbox are mediated by the technology which in turn shapes new practices and realizations within the tradition of citizen sensing. These new practices in turn enable citizens to ask deeper more intimate questions about their community and their livelihood in it.

Conclusion & Shifting

Sensor practices and the projects in citizen sensing show that the collaborative efforts of citizens in citizen science are mediated by the technologies they use. This chapter has introduced Postphenomenology as a framework with which to develop the human technology relations found between citizens and sensors. From the research in Philosophy of science and the mediation of scientific instruments, the chapter draws out the relevant pieces to 'leave the laboratory' and look towards citizens engaging in scientific work. The Dustbox sensor is then analyzed as a mediating tool, which in turn shapes the experience of citizens engaging with the practices of citizen sensing. The final section reiterates the importance of technologies as mediating the actual practice of sensing in citizen science work. With sensing practices regarded as a mediated activity, the Dustbox begins to take a more active and upfront role in the actual collection and understanding of data.

The next chapter will revisit data stories as a mediated understanding of the data produced by the processes and practices of citizen sensing. Data stories as hermeneutic interpretations of data will be developed as a next step in the postphenomenological understanding of citizen sensing. From here, the next underlying layer of data stories will be investigated. Namely, the data that is collected and interpreted. Citizens who participate in projects like Creekside and Deptford not only improvise and try new sensing practices, but also develop new relationships to their communities via the data they themselves gather. How this data is related to and what sort of mediated interpretations come from such a relationship to data is established.

3 Questions Regarding Data and Citizens

The previous section worked with both theory, practice and the project example of Citizen Sense with data stories. Weaving together the postphenomenological conception of scientific instruments, the relations and role of technology in citizen sensing and finally tackling praxis analysis of sensing usages; the previous chapter develops a fuller and more detailed picture of human-technology relations in citizen sensing. A piece of this

richer picture that requires more investigation *is the data itself* collected by the citizens, their relationship with it, and the role technology plays in shaping data into understandable or relevant information.

Chapter 3 will first bring back data stories and Emerson's experience after the program Citizen Sense is done. Through Emerson's perspective, the practice and experience of data collection will be more detailed experientially and shown to be shaped by the technologies they use, such as Dustbox. Dustbox sensors play an interesting role of engagement in the community of Deptford for citizens like Emerson, which leads to the data that is gathered by said sensor. From the practice of gathering data through citizen sensing, the interactions between community members and researchers in Citizen Sense and the personal connection to the data gathered; citizens will be shown to understand and work with data from a relational view.

The *relational view* as a framework of understanding data is described in the second section of this chapter and then connected to citizen experiences of data in citizen sensing. This description leads to the *affective value* of data which raises important considerations for an argument of new connections between a domain of citizen science and data relations. Ultimately, the crucial understanding of the relational view for citizen engagement with data opens up the possibilities for re-contextualization of data to place, reason and person that uncovers new and novel ways of doing both citizen sensing practices and imaginaries of data use from citizens.

From this relational view of data in citizen sensing comes new questions regarding the role of technology. With a relational view of data framework imbedded into citizen sensing practice, the final section will investigate how the mediating role of technologies raises key questions for citizen engagement with the data they collect. In what ways are the stories and qualitative accounts of data from the relational view shaped by the technologies of citizen sensing? What is the value of seeing the relational view of data through the postphenomenological lens? The following section *Data Stories and Hermeneutics* bridges both the hermeneutic relations found in citizen sensing projects and a reflection of citizen experiences.

Data Stories and Hermeneutics

A hermeneutic relation was described in chapter 2 of this thesis as a relation to a technology that expanded our abilities to interpret and perceive the world. One way to understand this relation better is to revisit the data stories described earlier and reflect with Emerson on their experience of the project after it has been resolved. The reflection from Emerson reveals that citizens not only perceive the output of these projects as part of their labor or efforts, but that the data is shaped by the tools they use. The shaping comes through different visualizations supplied by Airsift, a tool that can translate the data from Dustbox into graphs, charts and other imaginings of data use (Houston et al., 2019, pg. 863). By curating the data in different ways, citizens like Emerson both learn through play as well as engage with their community through the work they do for the project.

Reflecting on the Deptford and Creekside Experience

After about ten months of interacting with, learning from and living with Dustbox, Emerson had learned a lot about their neighborhood's air quality. The Citizen Sense program was coming to a close, and it was a good time to reflect on what had been learned and brought to the attention of Emerson about their local area. The monitoring activities of Dustbox and the many interactions with researchers had built up both new ways of collaborating for Emerson and ways of seeing the world around them through the data they collected. There were multiple parts that made this project so impactful for Emerson; *the interactions* with researchers, *the tools* given to them for data analysis, and *the new relationship* found to the data itself. The next subsections explore these multiple features of Emerson's experience with Citizen Sense in order to capture from the subjective viewpoint how data has been encountered, used and rationalized between different stakeholders and technologies.

Citizens and Experts

Emerson's experiences with researchers were mostly situated around the "drop-in" workshops (Houston et al., 2019, pg. 855). These in-person workshops not only helped citizens like Emerson learn hands-on skills with the tools they had, but also forged

meaningful relationships with researchers. Citizen Sense as a project relies on the ability to interact with citizens as active participants in both the collection of data, as well as the analysis of it (see acknowledgements, Citizen Sense, 2017; see acknowledgements, Citizen Sense, 2017b). The collection and interpretations by citizens are valued and encouraged through tools like Airsift, but also through the discourse at the end of a project.

Emerson then feels included in the work being done in their community, but also in their own volunteered time spent at home working with the data collected. What was understood was that through the volunteer work that they and the other community members were doing, new and relevant findings could be uncovered in the project area. Emerson wondered what would happen to these findings, the information they collected and if it would be used in the community in the future. Concerns about what happens with citizen data is not uncommon, and Emerson felt similar. Ten months of monitoring, collaborating and babysitting their Dustbox may just pay off in policy action or useful insights for future research.

Citizens and Data Interaction

After working many months with Dustbox, Emerson had begun to understand the ins and outs of data collection with it. Instead of fighting to get the Dustbox to work correctly, Emerson began to actively use the sensor to notice patterns and changes in the data based on new information. For example, Emerson begins to notice how weather conditions would influence the data, such as high winds throwing up more particulate into the air (Citizen Sense, 2017b, pg. 9). Through Airsift, Emerson would check the new readings when they felt curious and soon begin to see patterns emerge. They felt as though they could begin to see their community breath in the air; like when a passerby coughed, Emerson would think of their data and if it was a ‘bad day’ for particulate matter in the air. In some ways, Emerson as a citizen began to see connections between themselves and the local area through the data, they themselves collected by giving contextual emphasis and meaning to the collected figures. The Dustbox begins to challenge Emerson to consider when they should even go outside, how they should travel in more ‘clean’ ways and even what to avoid when taking a walk

such as busy streets. Within these changes to mundane practices, Emerson's data and citizen sensing work shapes and directs their attention to concerns about the world. Moreover, all of these changes are valuable to consider within the data story that Emerson logs for research; uploading maps, walking itineraries and even smells all become integral parts of the story (Citizen Sense, 2021).

The data that Emerson collected felt important and relevant to their own life as a citizen of London. It was not meaningless or deprived of context, it was wrapped in stories and experiences of themselves and others. The data that Emerson would look at through their computer would be from a time, a place, and given a set of parameters such as wind speed, temperature and weather conditions. These contexts worked to create answers for Emerson that they could hold onto as well as share with researchers, fellow neighbors, or local government officials; developing a relationship to both the sensor as a hermeneutic lens to the community's air quality, but also a relation to the reasons why people may need to act in accordance with health and safety laws. In many ways, technologies like Dustbox begin to shape the very character of political issues; the data organized through Dustbox collects 'matters of fact' that form citizens' basis for concerns in the community (Verbeek, 2020). This data provided reasons to act, more reasons to care, and an engaging inquiry into the neighborhood that Emerson loved. From their own desk, Emerson could see what had been gathered by Dustbox that day, that week or even that month. These past data points are conveniently compiled by Airsift into an intelligible and accessible assortment of charts, graphs and tables. Between Dustbox, Airsift and the Citizen Sense program at large, Emerson had engaged with their community in a very different way.

Hermeneutics, Data and Engagement

Emerson and citizens like them have experiences with data stories through the Citizen Sense project in Deptford and Creekside areas; their experiences are relevant to the discussions previously had regarding hermeneutic relations. Earlier examples of the fMRI disclosed how the technological instrument directs attention not to itself, but to the actual brain processes as seen through the machine's interface (de Boer, 2020, pg. 14). So too, does the sensor data coming through Dustbox direct the attention of citizen scientists

towards that of particulate matter through their computer. Citizens' interactions with the data through an interface like Airsift too, creates a new line of reasoning or way to appropriate the data. By allowing for play and the feeding into a model their own inferred background information, citizens relate to the data they collect on a richer level. In other words, the hermeneutic relationship found within the mediation of Dustbox data and citizen is not simply random data, but context-filled information that citizens themselves have worked with to make sense of.

Researchers from projects like Citizen Sense have coined the term 'just good enough data' to discuss the ways in which citizen data, "gives rise to alternative ways of creating, valuing and interpreting datasets" (Gabrys et al., 2016). As was described earlier in chapter 1, the definition is helpful for positioning citizen experience as a valuable point of information, but also raises questions regarding how citizens actually relate to the data they collect and work with. From the postphenomenological position described in chapter 2, the technologies used by citizen scientists in citizen sensing would shape the intentionality of citizens in practice. In turn, mediating the relationship to the community, or world, around them in which they want to study (de Boer et al., 2020, pg. 8) Thus, the work done in mediated citizen sensing practices becomes a discussion about the role technologies play in shaping the interpretations, or hermeneutics, of the information when it is curated and delivered by the tools at hand. In order to move forward with this discussion, a look at the next layer of citizen sensing, the relation to data itself, is required. Following through with the value placed on citizen experience, the data layer should be viewed from a perspective that can take seriously the qualitative or experiential viewpoint of citizens. The framework argued for that will meet this condition is the relational view of data which will be discussed in the next section, first it is important to consider what data is more often referred to as from the *representational view* and why it falls short when concerned with citizen sensing.

Representational Data and Citizen Experience

This thesis has pressed hard on the idea that the citizen engagement with data which they gather is key to understanding and justifying better the scientific claims that propagate from the collected information. Unfortunately, it is still common to find the way

of thinking of data as necessarily being “raw” or “objective information” in many professional scientific circles (Longino, 2020, pg. 397). This way of thinking about data can be found originating from both philosophers of science, but also from the purely egoist perspectives of traditional western scientists.

First, the (past) philosophers of science tended to rely too much on data “as a given” rather than created or made (Leonelli, 2016, pg. 73). In other words, philosophers of science have often put up the perspective that the empirical information content of data is immutable or fixed, regardless of how it is used. Second, a common approach is to consider data as a way to test and validate theory in a structured, supposedly controlled environment. In this way, data is seen as direct observations of the world that are irrefutable facts of what is out there (Leonelli, 2016, pg. 74). This assumption too, builds from the theory-centric understanding of scientific knowledge production that values universal principles and mathematical axioms of deducted explanations. These two assumptions about data form the *representational view* as proposed by Sabina Leonelli (2016, 2020). In short, the representational view takes data as reliable representations of reality which are produced via the interaction between human and world (Leonelli, 2020b, pg. 18). It is important for this section to understand that the representational view is the current standard and contains the most recognizable background assumptions that people make when they talk about ‘data’ (Longino, 2020, pg. 391; Verbeek 2020, pg. 8). This is not to say that citizens gather unreliable data; instead this is a move to recognize the current conversations and conceptions around what data is and how citizen sensing may be impacted by this narrow consideration of data. This will not be the case when working with the relational view of data. What the representational view means for the current discussion is a lack of contextual attention to attributions that do not easily fit into this framework. For now, consider that the interactions, tools, and ‘packing’ of information that generate, transport and translate data between scientific domains are all ignored in a representational view. Attributes that would be beneficial and relevant to consider in the work of citizen sensing.

In order to account for the importance of citizen experience and their critical thinking, interpretative skills as a key quality of citizen sensing work, the relational view of data will be argued for. By using the lens of the relational view of data on citizens in

citizen sensing work, the ways in which citizens relate to, engage with, and generate concerns from data will be better understood. The representational view cannot account for much of what is discussed with citizen sensing practices, and some of this will be examined in the next section. In short, the relational view of data will be developed in the following section as an understanding of data that is both beneficial for citizens to better understand their relation to data in citizen sensing and beneficial for professional researchers as a way to appreciate how citizens engage with data and the analysis of it. By grasping onto the complexities of data and moving beyond treating it as simplified givens for inference in theory, researchers too can gain traction in defending and creating novel data practices (Longino, 2020, pg. 398).

The Relational View of Data in Citizen Sensing

To start, this section begins with fleshing out Sabine Leonelli's work in the relational view of data. The framework will be described and then brought into the context of this paper, that of citizen sensing and sensor data collection. The added value of relational view of data will be argued for, specifically through focusing on what Leonelli describes as the *affective value* of data. Affective value is attributed to data by the feelings of "personal" or "private" worth by those who collect and use it; for this paper, that will be the citizens feeling of ownership to their data and themselves (Leonelli, 2016, pg. 64). With the affective value, the role and relation that citizens have to data can be seen more clearly and the projects of data stories will be used to show this. Finally, the section wraps up on the important considerations to be taken from the relational view of data imbedded in citizen sensing and what it means to move past data speaking "for itself". By drawing on parallels between what is described in the relational view of data and the data collection work done in citizen sensing, the framework created by Leonelli on data will be bridged into this new domain.

A Relational View of Data

Leonelli's relational view of data is concerned with multiple parts; a definition of data, the degree to which data can be used as evidence for knowledge claims and the *data journey*

(Leonelli, 2016, pg. 77). These parts combined start to setup the framework for Leonelli on how she believes data is to be considered in professional research domains. After exploring each part of this framework, the pivot towards citizens in citizen sensing will be made to try and make clear the parallels investigated in this thesis.

The Relational View: Defining Data and Data Journeys

The relational conception of data gives a hint in its name; that is, it is concerned with the relations between stakeholders and the products of research activities that they engage with. In this way, data is neither fixed to an intrinsic scientific value, nor given a mind-independent representation of a given phenomenon (Leonelli, 2016, pg. 70). This leads us away from the representative view of data as exclusive, immutable information about the world and instead towards prescribing evidential value to the data from their specific moments of inquiry (Leonelli, 2016, pg. 70). In other words, Leonelli's relational view of data begins to move us away from understanding data points as some 'undisputable source' and instead towards questioning what constitutes the data itself. We see this especially in debates regarding the defense for genetic engineering or the possible usefulness of geo-engineering projects; all part of the discourse and reliant on Big Data (Leonelli, 2020, v). So too during the Corona pandemic, we have seen data be 'undisputed' with vaccine effectiveness rates; we have also seen these published numbers challenged later when more data was known or the context of the studies were disclosed (Leonelli, 2021, pg. 22; Vox, 2021). The relational view then, invites researchers to identify controversies, strategies and even investments around the decisions they make regarding data collection and use.

Data journeys, literally, through domains of science and people and databases (Leonelli & Tempini, 2020). This too plays a part in the complexity of Big Data and scientific work reliant on it; so *data journeys* are, "in other words, the myriad of techniques, efforts, instruments, infrastructures and institutions used to process and mobilize data so that it can actually serve as evidence" (Leonelli, 2020, v). The movement of data then, is very much a social process as it is a technical process (Leonelli & Tempini, 2020, pg. 4). In other words, the processes, connections, and communities that move, manage and interpret data all have an impact on its features and or evidential power; data is not simply

immutable substance that moves perfectly and objectively between databases. Additionally, *data packaging*, or the way in which data is enveloped in order to be moved, read and understood in different databases also plays a role in data-centric sciences (Leonelli, 2016, pg. 70). Data packaging for Leonelli, is to be understood as not only playing a part in the movement of information from one domain to another but also, "for the sake of their repurposing to serve new scientific goals" (Leonelli, 2016, pg. 70). In short, Leonelli is trying to point out that data is interpreted and valued by different scientific domains, researchers and audiences for different reasons. Ultimately, data journeys through these different stakeholders in different ways based on the domains preferred packaging method. The preferred data packaging will be both the choice of an individual curator, as well as be curated based on the most efficient method of finding quick results and or a domain specific norm. These choices impact with whom, where and for what purposes the data will be used for as well as shape later dissemination or data journeys.

The Relational View: Value and Knowledge Claims

Within the framework proposed, a data point is an object that is, "treated as potential or actual evidence for scientific claims in ways that can… be scrutinized and accounted for" (Leonelli, 2020b, pg. 20). In other words, the meaning assigned to data comes from its provenance and many features; physical features, motivations behind collection, the instruments used to visualize the information and how they are used to defend an interpretation. Leonelli argues that even changes to data formatting such as data compression, can have legitimate impact on where, when and who uses the data as knowledge (Leonelli, 2020b, pg. 21).

The value of data then becomes an issue in the relational view, as one implication of this framework is that some data will be valued more depending on what role they are assigned to play in scientific inquiry and for how long. By assuming that data is some context-independent substance, an opinion from the representational perspective, an incompatibility arises of being able to use the same dataset for evidence of a variety of knowledge claims depending on how they are interpreted (Leonelli, 2016, pg. 79). 'Value' here is taken from Leonelli's work as capturing the complex notion of "modes and intensity of the attention and care devoted by given individuals, groups… and the motivations

underlying such attention," which includes interrelated concerns as well (Leonelli, 2016, pg. 63). An example of value in data collection can be seen with how data is discarded based on it being 'useless' or 'just noise' by an individual, and or stored away in ways that are impossible to access later; often in these cases the data is 'dumped', instead of being allowed access to new interested parties for new interpretation and possible fresh uses (Leonelli, 2016, pg. 79; Leonelli, 2021, pg. 10).

Leonelli also describes how data can be valued with *affective value* (Leonelli, 2016, pg. 64). Affective value is attributed to data as a way of trying to describe its value for individuals or groups that gather and put effort into working with that particular data. It is a feeling of ownership where, "to some extent [the researchers] identifies with [the data] as a creative, original achievement" (Leonelli, 2016, pg. 64). On one hand the affective value builds a kind of proud feeling around the achievements and awards assigned to new findings by scientists, such as Nikola Tesla or Edison. On the other hand, information in the now popular Open Data movement becomes more accessible and worries researchers that misleading interpretations by non-experts could arise (Leonelli, 2016, pg. 65). Within these considerations, it is good to remember how playing with and working with data is a constantly changing process. This is particularly important for the discussion in citizen sensing and projects like Citizen Sense, where manipulating open data is a crucial activity for citizens.

The Relational View: Citizen Sensing

Now that the stage has been set, the relational view of data can be discussed in practice. In other words, this section will begin tying together values and use of the relational view of data to the context of this thesis, citizen sensing. This section first draws on examples from data stories and Citizen Sense in order to discuss how the relational view adds key ways of understanding how citizens interact with data in various and valuable ways. After drawing on these examples of interaction, the affective value of data from the relational view will be connected to attributes of ownership or meaning to data work with citizens. This leads to both arguments for advocating more citizen engagement in citizen science practices, as well as developing the value of citizen interpretation as co-researchers.

Encouraging engagement in both co-researching capabilities and unconventional data practices of citizens.

Data Relation and Citizens

A relational view takes data to be objects of interpretation, manipulability, and as mutable (Leonelli, 2020b, pg. 20). An intriguing value within this framework is how it highlights the use and interpretation of data changing over time and through transmission between both people and networks. These transmissions, such as packaging discussed previously, inform the data confirmation and refutability power in usage with hypothesis. Socially as well, this framework of data brings with it questions about the connections between the social worries of impacts of sharing data and the scientific concerns with quality of information (Leonelli, 2020b, pg. 20). In turn, the relational view should be considered not just a way of understanding data in relation to the way data is used, but likewise how it is interpreted by others in order to make new claims about how the world may be. Considering data in this way also benefits the work of citizens in citizen sensing.

One benefit can be found in the Creekside example, where citizens are in direct contact with the sensor and the data it collects. From the Creekside data story, citizens look at data from the sensors not just as data points found somewhere in the world, but as data about their own community and territory. This could be seen as giving a richer perspective to the information behind the screen or data charts; and data stories as a methodology has tried to capture this through addressing limitations of 'official models' of evidence through new observations (Gabrys et al., 2016, pg. 8). The benefit of the relational view of data in citizen sensing then, is the ability to account for the data as mutable information that citizens with diverse arrays of context and backgrounds shape the information they themselves collect and evaluate. In this way, data can be seen as "broken free" from the context of their production, which leads to new appropriations of it for new purposes, maybe not considered by the researchers or professional experts originally (Longino, 2020, pg. 395). This is especially of use in cases where citizens are incentivized or encouraged to work with professionals on data analysis; creating a space for new ways of thinking and co-creation (Grijns, 2020; Suman and van Geenhuizen, 2020).

Furthermore, data in the context of citizen sensing may benefit from *not* stripping away details of lived experience of scientific investigation, and instead find new ways of working with what data is available or 'just good enough' (Gabrys et al., 2016, pg. 9; Leonelli, 2020b, pg. 19). This is in part due to the ability of citizens living in the area of concern, such as Deptford or Creekside, to feel and see the possible causes of their research interests such as high amounts of visible pollution or soot on windowsills (Citizen Sense, 2017). In turn, by living with and literally breathing the data you collect, you may begin to find it more and more important to include other perhaps, non-quantitative, data in your findings. This leads back as well to the affective value in Leonelli's relational view of data.

Citizens in data collection practices can feel a sense of personal ownership to data that also plays a role in the relation to data (Houston et al., 2019, pg. 854). With an affective value, the data that citizens collect and work with comes with a sense of ownership and authorship when curated or presented. Leonelli cleverly points out that this value can come in conflict with the *scientific ways of valuing data* (Leonelli, 2016, pg. 64). This conflict was hinted at in the previous section, with regard to the worries of researchers' and misinterpretations of accessible (open) data; here too, citizens' interests may come in conflict with professional opinion by using data in ways not anticipated. In many ways then, the ownership felt by citizens to their own data may actually be similar to that of the researchers, which raises concerns for balancing values in data analysis. Beyond privacy and security implications, open data and open access research does help circulate more information freely, which lends to the availability of more interpretative and creative evaluations (Leonelli, 2016, pg. 64).

The conflict above starts with the scientific value, where often professional researchers,

> "feel that individuals who have not participated in the production of certain kinds of data are not in the position to evaluate their quality and significance as evidence",

which leads to assumptions that the sharing of data like this could harm their work by way of misleading interpretations (Leonelli, 2016, pg. 65). While citizens in citizen sensing *do*

work with the production of certain data, they are still often considered volunteers, or have their engagement largely ignored past information submission (Taylor et al., 2015, pg. 2863; Phillips et al., 2019). The chafing of professional feelings is found time and again in the work in citizen science at the level of evaluation and data analysis. This leads to citizens not feeling apart of the conversation about how their data is used after collection processes are finished. Likewise, it is important to remember that many of the citizen sensing projects discussed in this paper start because researchers or professionals do not give enough due diligence to problematic areas; it is the citizens who often need help and activate the alarm before the researchers find the need to do any work (Cavalier and Zachary, 2016, vii). What is learned then, is that by acknowledging the different ways data is valued between individuals, groups, etc., the work of data collection in citizen sensing begins to take on the form of an open dialogue about data analysis shaped by these values and less on assumptions of supposedly 'objective' professional evaluation as the only assessment. This confrontation between citizen and researcher may be resolved through more dialogue in research design with citizens, but the resolution will also lie with researchers acknowledging the improvisational and complex relations between citizen and sensors (Cavalier and Zachary, 2016, pgs. 96-97; Houston et al., 2019, pg. 863). Lastly, the affective value brings in the importance of citizen engagement and feeling of ownership with data collection work, ultimately making more room for serious dialogue about how the findings citizens generate should be used.

This section has aimed at highlighting some of the benefits of acknowledging the relational view of data and how embedding it into citizen sensing may turn out. After setting up the relational view, it was argued that both citizens and researchers could gain value from working with data in a relational way. From the relational view, citizen engagement and interpretive analysis gains more footing in the discussions with researchers. With this, researchers can benefit from not just new co-researchers, but also the ability to account for data in a richer way. Instead of pretending that the numbers coming from citizens are simply the only way to engage with the world, citizen sensing projects can further benefit from working collaboratively with domain experts and relevant community members to develop socially beneficial solutions. Moreover, acknowledging that the re-contextualization of data to place, reason and person uncovers new and novel

ways of both doing citizen sensing practices, but also ways of understanding the data from citizens.

It is in the attentiveness of this thesis to move deeper into the relational view of data from a perspective that takes seriously the role of technology. Data are necessarily technological artifacts in the relational framework, and their interpretation depends on the extent to which people who use them may assess their conditions under which it was first produced (Leonelli, 2016, pg. 66). This view raises questions regarding how the interpretation of data from a relational view may be shaped by the technologies used to collect and present information. Staying close to the context of citizen sensing, this thesis will briefly tackle research questions concerned with what ways the stories and qualitative accounts of data from the relational view are shaped by the technology and practices of citizen sensing. In other words, if we are to assume that the data collected and engaged with by citizens is better understood through a relational view, then how is the relation to data shaped by the technologies used to gather and analyze it. Additionally, what is the value of seeing the relational view of data through the postphenomenological lens?

The Mediating Role of Technology in the Relational View of Data

In chapter 2, this thesis deliberated over the mediating role of sensors in sensing practices; where the Dustbox sensor is analyzed as a mediating tool, which in turn shapes the experience of citizens engaging with the practices of citizen sensing. Relations, such as hermeneutics, captures how the Dustbox begins to take on its own active role in both helping to interpret collected data, as well as how this particular kind of data is actually able to be collected in practice. In order to better understand how this information is engaged with by citizens and move beyond just the quantifiable level, this thesis imbeds the relational view of data into citizen sensing and its practices.

Through imbedding the relational view, data comes out of a pure, abstract notion of numbers on a screen and instead becomes both socially and technologically situated; translated across citizens, scientists and others as an integration to solve locally specific problems (Leonelli, 2016, pg. 191). The relation to data becomes an analysis, from a postphenomenological view, as something that is not simply given, but actively

transformed and co-created through the practice of relating through technologies. In other words, this section begins the investigation of trying to understand how the technologies used in citizen sensing shaped their connection to the data collected in their sensing practices focusing primarily on hermeneutics.

Hermeneutically Mediated Data in a Relational Framework

In order to target what exactly is the mediating factor in an already technological artifact, it can be helpful to stay close to the (mediating) relations already discussed such as hermeneutics. Earlier chapters discussed how the hermeneutics of sensing practices disclosed the interpretability and revealing capabilities of humans in the world. This is to stay, that the hermeneutic relation between human, technology and world are characterized by both the affordances of the technology itself to disclose particular information as well as its ability to expand our perceptions of what may be out in the world. For citizen sensing, the ability to expand citizen perceptions of air as something that could contain invisible particulate matter has been approached through both educational workshops and actualized by modelling software such as Airsift. What is still under particular inquiry in this chapter is the way in which the hermeneutic role with data could possibly inform some valuable insight while in consideration of the beliefs in the relational view of data.

The spark for such interest arises when reading Leonelli's work, where data is considered a technological artifact that is situated in relation to specific interpretive acts and which in the end, can count as evidence (Leonelli, 2016, pg. 189). In the relational view data journeys between different domains, people and networks with technologies in mind. For Leonelli's examples, they are in the biology domain, so data is exchanged through labeling centers, biocurators, archivists and other institutions (Leonelli, 2016, pg. 194). Here, the role of technology is stressed in shaping how data is packed, disseminated across communities, and even impacts their possible reinterpretations (Leonelli, 2016, pg. 194). From examples like these, the data is stripped of its context and commodified into different places for different reasons, including new domains perhaps not predicted nor realized. When recognized in the field citizen sensing, data collected also becomes recontextualized for new projects, people and communities.

Hermeneutics of data in this view of citizen sensing then, could attempt to capture how the translation of data between people, places and things is ultimately shaped by both the medium of choice and by the presentation or curation of the information through that medium. In the project Citizen Sense, the translation and packaging of data from citizen to scientist is going to first be mediated by the data collection practices discussed in chapter 2. These practices are in turn the outcome of both agreed on scientific methods of air quality collection and the affordances of Dustbox as a technology. Further down the path of investigation, citizens begin to engage with the data from Dustbox which is translated and curated through the Airsift interface (Houston et al., 2019, pg. 854). Airsift helps citizens take on assembling the data through a Data Stories tool, which in turn allows them to compile data, observations, and write narratives about pollution issues in the local community (Citizen Sense, 2021b). The interface informs assumptions about the world by citizens which are informed by both data and lived experience; these assumptions are more magnified or prioritized over others by way of directed intention (de Boer et al., 2020, pg. 14). This is in part due to the hermeneutical relation to Airsift, but also due in part by the citizen who has constant access to this data and therefore may be the first to see patterns in the data and draw conclusions. In turn, the contextualization and re-contextualization that Leonelli discusses is then less about humans attributing relevant properties to data and instead a discussion on how technologies shape both contexts, distributions and the newly attributed properties (Leonelli, 2016, pg. 195).

To make this clearer, the example of data stories is a methodology of data analysis that relies on both the possibility of conflicting and still perfectly adequate interpretations of models. Debates between citizens and scientists are not only encouraged but are even considered data in the end (Gabrys et al., 2016, pg. 12). Citizens not only bring challenges to researcher practices, but also can establish their own prominence through new findings not found in regulatory networks (Gabrys, 2020b, pg. 8). Attuning to new forms of data fits nicely in line with the relational view, where the evidential value of data is not predetermined and so the interpretation debate should happen on a very intimate, human level (Leonelli, 2016, pg. 195). Thus, acknowledging the hermeneutic lens or frame that encompasses data raises the ever-important consideration of the role of technology in what transformed or translated work has already occurred prior to human

perspective or adoption. Citizens and experts alike therefore must ask themselves what features of the dataset are being emphasized? What features are being concealed or kept? Do I know the provenance of this data or would it help to know its background? Why is this particular data being used instead of other possible structures or lines of inquiry? Of course, these questions are not completely ignored by Leonelli in her work, but taking on the postphenomenological conception of the hermeneutic relation of data aids in extracting relevant questions and concerns when it comes to data analysis.

From here, citizens and researchers can move forward with more novel and robust approaches to citizen sensing. What is found within this discussion is twofold. One, that both the role of technology in shaping our interpretation and relation to data cannot go unrecognized; citizens and researchers alike are, as it were, living within the values created from a data-centric and a technologically shaped world. Second, that by embedding the relational view in citizen sensing; the work of sensing practices becomes more full-bodied and able to combine different imaginaries of data use, which in turn provide the necessary parts of both qualitative reports and experiential concerns (Leonelli, 2021, pg. 21). These important parts fortify the role of citizen experience in sensing practices and calls for re-envisioning of how the future use of data should be handled when considering our relational connection to it.

Without acknowledging the mediating roles; technical manipulation, packaging curation and disclosure of data will not be given a serious enough look. In a similar sense, the postphenomenological position too, needs to continue to search for a way of discussing the mediation of information, which could be aided by a relational view.

4 Envisioning and Actualizing Mediated Citizen Sensing Practices

Within the discussions, research questions and methodologies interwoven together in this thesis, there are key takeaways and valuable insights that can be highlighted. This final chapter will conclude and synthesize the main points and arguments made in this thesis in the *Envisioning* subsection. From the envisioned theory to *Actualizing*, this chapter then

ends on a workshop proposal which describes and outlines a program with which mediated sensing practices are to be studied and possibly derived in the outlook.

Envisioning

Citizen science tasks and challenges citizens to take the extra step, to move beyond a passive, consuming model of knowledge and instead towards an engaging practice with the world around them. Through what Albert Borgmann (2000) calls *focal practices* which are practices that "disclose the world about us – our time, our place, our heritage, our hopes – and center our lives", citizen science, or in this case, citizen sensing, creates space for people to engage with a newly disclosed mode of their community (Borgmann, 2000, pg. 421). This means moving beyond passively consuming what is told by professional experts or the local news media as the only form of learning about scientific findings. It means playing, experimenting with and seeing through the challenges found within scientific work for yourself. At the heart of this, is the message that through encouraging citizens to take this extra challenge, or step, or measurement, we begin to form new appreciations for the communities we have.

Moreover, the practices that can encourage appreciation can be found in the citizen sensing practices described in chapters 1 and 2. These are sensing practices that involve a technology, one of sensors, but also the involvement of people in the critical use and creation of new knowledge from that technology. In other words, sensing practices show promise for not just the involvement of science in people's lives, but even more promising, the re-introduction of focal practices and things that are rewarding in their own right to do; practices that make you think, "there is no other place I would rather be" (Borgmann, 2000, pg. 422). What has been shown in numerous sensing projects is that the work of citizens in sensing projects is that of engagement with matters between social welfare and the design of cultural responsibility. Sensing practices that acknowledge the mediating role of technology not only actively engage citizens to recognize their own felt responsibilities to a community, but also uncovers engaging practices that may have been forgotten or replaced by presupposed care. Dustbox as a network of sensors enables the gathering of citizens to actively participate in the matters of air quality and shapes

conversations around the often political issues at stake possibly not realized in this form or configuration before.

From chapter 1 the stage was set for citizen sensing, where citizens engage in a form of citizen science that urges citizens to work with sensors in order to gather different forms of data about their neighborhood or community at large. The case of Citizen Sense, a project found in the city of London was raised as a real-world example of how citizens are treated, enabled and interact with researchers and the sensors they share. The real-world case is given a character, Emerson, in order for this thesis to develop a richer picture of the individual – technology relationship and a semi-personal recount of what it is like to live in the Creekside area as a concerned citizen. Citizen Sense as a program also mobilizes the framework of Data stories; a method of trying to grasp more qualitative information from citizens including experiences. Data stories as a creative and effective way of capturing citizen's exposure to pollution and other noticeable changes in their community lends to questions concerning the role of technologies in these new experiences. From here, questions regarding the human – technology relations formed, such as how the technology in question, Dustbox, could be understood as being able to shape the work and interpretive function of citizens when engaged in citizen sensing. In other words, sensing practices as a mediated practice were to be questioned and investigated as a new form of citizen sensing and scientific inquiry.

Transitioning to chapter 2, postphenomenology is brought to the fore as the choice methodology with which to tackle the questions brought up in chapter 1. Chapter 2 breaks down what postphenomenology is and introduces the reader to some of the crucial concepts of this unique field. Concepts such as multistable objects, which are able to have many interpretations associated to them and directed intentionality, the use of examples in fMRI brain scans is derived. Multistable objects and directed intentionality in this chapter references current work in the philosophy of science and its connections to the discourse on citizen science and scientific instruments. By *leaving the laboratory,* this thesis branches similar conversations in the philosophy of science on scientific practices as shaped by technologies into the field of citizen science. Drawing on parallels and case examples of data stories, the chapter begins to weave together human-technology relations found in mediation theory as a way to better understand how Dustbox shapes

citizen sensing practices. The concept of *mediated sensing practices* is then argued for as a way to understand and realize the ways in which sensing practices are shaped by the technologies they currently work with, live with and see (a part of) the world through.

From the interactions of the sensor comes the exchanges and findings within the data collected. Chapter 3 starts by recalling the hermeneutics of data collection with the sensor and the software component as the first curator of information. With Emerson's reflection on their overall experience of the Citizen Sense project, the chapter starts to extrapolate on the importance and pervasiveness of hermeneutics in citizen sensing. Emerson's own important experiences and critical thinking finds a place within the data through both their interactions with researchers and through the actual associations with data as well. Leonelli's relational view of data is introduced as a possible framework from which citizen sensing can build onto in order to better understand this phenomenon. Thus, it is argued that we can account for Emerson's experience better of citizen sensing work by reconsidering what we think data is, by acknowledging the complexities of data moving between stakeholders and by the values with which those stakeholders have for using it.

Moreover, chapter 3 takes the relational view of data in citizen sensing a step further into considering the role of technologies. The compelling position of postphenomenology as a framework of technology relations finds its place in this investigation; the mediating relations to data opens up more pathways into both data as a mediated technological artifact and into the relationships we have to that data as shaped by technologies. In order to start considering the role of technology as actively shaping our relation to data and the ways in which we interpret that relationship itself, chapter 3 begins an investigation through the hermeneutic relation.

Final Thoughts

It is rare to find fields of science that have so much potential within so many diverse domains as the work found in citizen science. Part of that rarity stems from the citizens that give time and effort into both trying and learning new fields they are not accustomed to. Another part of the rarity comes from a history and social structure in scientific work of removing oneself from the public; something philosophers are also frequently guilty of.

Projects like Citizen Sense show that not only can we learn something from having unusual strangers in the laboratory, but that we may need them more than we realize in order to start seeing past our usual agendas or lenses. Inviting new people into our workspaces forces us into uncomfortable feelings as researchers, like having to defend our theories with untrained persons, but it also raises the important questions of how conclusions based on values in scientific reasoning are even decided on. One current approach of this in philosophy is bringing citizens into the murky discussions of technology ethics, which ultimately shows how technologies are guided in its roles in society and conversely, how society is guided in its dealings with technology (Verbeek and Tijnink, 2020). Ultimately, these difficult dialogues will never be, and are not supposed to be, stress-free

In this same way, the dynamic assessments of postphenomenology can help with these conversations insofar as the role of technology in shaping values must be considered. From sensing practices, the sensors actively interrogate citizens who live with these seemingly mundane devices. Encouragingly, thinking through this with postphenomenology allows for more freedom to both discuss the lived experiences of citizens with these devices as well as account for the unexpected situations that arise from having such devices in our lives. Through recognizing the non-neutrality of devices, we as humans begin to be more honest with ourselves about our imperfect capacities; like our limited attention to all possible details or the distractions and occasional unawareness to the technologies around us which impress upon us their own restrictions and affordances. Confronting our own inattentiveness and shaped tendencies too, can be an uncomfortable discourse.

The final section of this thesis is a proposal. It is a proposal to create a workshop around mediated sensing practices with both citizens and researchers. The proposal in thesis is built in three parts: a workshop description, the possible outputs of the workshop and the proposed goals of the workshop.

Actualizing Mediated Sensing Practices

Workshop Description

The work in environmental monitoring often takes on the form of ‘leave it and wait’, where sensors are placed in public of private areas and are forgotten. This style of monitoring leaves data inaccessible to many interested parties, including citizens that may be being monitored, and if the data is accessible, it is simply an overview and nothing more. The approach lacks action and substance compared to the practice-based approaches described in the previous chapters. There is a need to not only find a more active role for citizens in environmental sensing, but also to find common ground on which to use the information collected for active participation in a community.

Inspired from current work being done in citizen sensing, this workshop will be based in both sensing practices as well as data interpretation. Thus, this workshop will be targeted at citizens who have worked with sensors in the past or are looking to enter into a citizen sensing project.

The workshop is to be broken up into five parts:

1. Gathering First Context
2. Integrating Sensing Practices
3. Assembling Mediated Context
4. Incentivizing Data Curation
5. Collaborating Through Experimentation

Gathering First Context

The first part of the workshop situates the context of each citizen in the program. Citizens are formally interviewed on their experiences in their community; where they live, what they do for work, what they think about their community, etc. The interviews can gain some traction from the framework of data stories as well; asking about smells in the neighborhoods, possibly pollutants, or evidences of a problem. What value do the citizens think that a sensor will bring to their lives? These interviews will serve as a basis for

‘setting the stage’ when it comes to how citizen experiences of their community can change when sensors enter their lives.

Integrating Sensing Practices

From this, citizens are given sensors to take home in this second step. They are introduced to the devices via a researcher and depending on the device, may have to assemble to the sensor as well. This allows for citizens to build up technological literacy with the sensor, ask questions about how the device works and why it doesn’t do ‘X’. Researchers deploying the workshop work with citizens to insure they can safely and effectively use the sensor but should try to let citizens first build the device and use it by themselves. By allowing citizens to play with and manipulate the device first, they will begin to build more ownership over its successes and future obstacles. To build on ownership of the device more, citizens should name their device, color the casing of the sensor and try to anthropomorphize the characteristics of the sensor. Have citizens try to imagine what it will be like to ‘live with’ the sensor, where they will put it, how ‘happy’ will the sensor be in their homes? The point of this will be to not only try to build ownership over the output of the sensor, but to also start building a sensitivity to the device’s presence. In other words, personalizing the device and asking citizens to recognize its functioning as a functioning thing will help insight more attention later to the device as a new thing in their lives.

Another exercise could inform better communication with researchers. By writing small stories about their sensor ‘living with’ them and then sharing this with the researchers, citizens can communicate how their experiences with the sensor may be impacting their lives. One effect of this may impact the feeling of belonging in a program through the relationship with and care of the device. This leads to longer and more intimate connection to both the workshop, as well as the commitment to the community. In the next section, citizens will have to answer difficult questions about the effect of their new device’s output.

Assembling Mediated Context

Part 3 requires either a visit to a citizen's home or bringing citizens together to discuss how they have been living with the sensors. From mediation theory, we learn that the sensing practices citizens have begun using at home will have formed quickly. Citizens will have started bringing in what values they think are important from the sensors they are using and debate them with others. It is important in this part of the workshop to start asking questions regarding how the perspective of the citizen has changed in regard to their community. If citizens are using air sensors, ask if they think their community's air is 'healthy'? Or 'noisy', regarding noise sensors. Did they know about their air/noise quality before this sensor project? How has the sensor begun to shape their attention to this new information? Has there been an effect on a citizen's feeling of well-being or new outlook on technologies around them?

Citizens should be questioned about how the vision or version of their community they had come in with in part 1 has perhaps changed after seeing the world through the eyes of the sensor. Here too, citizens should be tasked with a small exercise on how they have begun changing their routines around the sensor, noting new feelings around unexpected results like high pollution levels or unsafe water conditions. Part 3 of the workshop seeks to reveal how the role of the sensor in the citizens' lives are not simply there to monitor the particles in the air but are actively shaping the way people understand the world around them. Here, data has not yet been discussed as central to the conversation. Instead, it is saved for the next section in order to allow for citizens to work with the tools they are given and play with the data before they are 'told' what it might mean. This then leads to discussions about data in part 4.

Incentivizing Data Curation

In *Incentivizing Data Curation*, the collaboration between citizens and researchers becomes central. Through an interface, such as Airsift discussed earlier, citizens should be incentivized to critically think about the data they gather. This part opens with a discussion on how to think about data in a relational way. Building on Leonelli's work, citizens are tasked with reconceptualizing how they understand data. If possible, citizens should be able to play with and manipulate charts, graphs, or models of data they gather.

This can be a small lecture or talk with researchers who can share their understanding of the relational view and use it in a way that makes clear to citizens how it impacts their own research. Questions from citizens will arise such as; what is the most visually appealing graph? How can we reinterpret the information from a different date/time/location? Where will this data go when these citizens are done with it? What are relations that most impact my own lens or perspective?

With the help of researchers and those leading the workshop, data as a technological artifact and as something that can be used in different ways becomes shaped. It is shaped by our values in science and is ready to be re-used in new scenarios. So, the data points that citizens gather become an open discussion about methods they used to gather the information and the values deliberated on to make selection comparisons. One example exercise would be to have citizens bring to the table their own sets of data and each participant explain how their data is the 'best' data. By doing this, citizens must justify their methods for obtaining, recording, and storing data and how well those methods serve the purposes for which it was sought for in the first place (Longino, 2020, pg. 398). This will begin to raise objections, justifications, and criticism from other citizens and researchers. Confrontation in this way may begin to show how being informed on the practices of science produce data that must be set in relation to other data; allowing for debate not just about data itself, but also in the practices that generate it. It is in essence, a dialogue about the relevance and trustworthiness of scientific practices in an open forum surrounding the worries and goals of all citizens with similar concerns.

Collaborating Through Experimentation

Finally, part 5 attempts to bring together the many parts of this workshop to a final discourse. The work of citizens in citizen science is too valuable to only have been considered a 'fun occasion to talk'; the experiences of citizens playing with and learning from sensors in their community is valuable in itself to consider. Part 5 brings together all participants to the table for a round of discussion about their experiences.

First, citizens should again be interviewed and describe how their vision or connection to their community has changed, if at all, with the introduction of sensor to

their personal living space. Citizens should be tasked with trying to explain how data may have shaped that understanding as well; what were their experiences with the interface, does the data ‘make sense’, how can it be explained to someone in their community as important to consider? Here too, citizens should be encouraged to reflect on the practices they witness or participate in with researchers, if any. Citizens should be encouraged to reflect and possibly criticize researcher practices they deem insufficient or unconvincing from their own experiences. With the interviews and reflections finished, citizens and researchers should celebrate their work, and if possible, consider if there is evidence of a problem in the neighborhood from the data. Perhaps too, there is an option to follow-up with community members about their continued data practices or neighborhood health.

Outlook

The workshop proposed contains various parts that can be used to leverage two outcomes. One outcome is a created awareness for how sensors impact our lives as co-shaping instruments. It is in one way, an experiment to bring meditated relations to the foreground. Citizens become more adjusted and are given a helping hand to seeing their sensors as not simply gathering data, but also shaping the practice of data collection. With this workshop, citizens also have the challenge of having to interpret for themselves how best to gather data and make sense of it from their own perspective. The support and motivation of professional researchers can help discussions between citizens to navigate these new concepts and ideas, but citizens must begin to build a sensitivity to their own mediated experiences.

From discussions and meetings, citizens then must defend their position, but also acknowledge that they may need help in using their data for more action. Thus, another leveraged outcome from this workshop is the continuation of incentivizing citizen sensing projects in communities. The data gathered from this workshop could help to navigate real-world situations or find evidence of a problem in a neighborhood. Now with tools, data and a more confident stance on the information they themselves obtain, citizens can feel more prepared to take on co-researching opportunities and other projects. Researchers as well should find time to reflect, argue for and create approaches of

working with citizens that informs both the research at hand and recognizes the crucial engagement of citizens within it.

This workshop begins an investigation into not just how experiences of citizens are gathered as crucial data, but how the active role of sensors in peoples' lives are to be accounted for. Sensors like Dustbox provide a useful 'uniqueness' as a sensor; it is rather obvious and requires more interaction than the sensors in our smaller, less manipulatable devices in our pockets. Thus, the hope is that citizens will become more active in their own understanding of the sensor as a functioning tool, as well as begin to understand how their worldview is mediated by the actual technologies that they use every day. The work of scientists and researchers are not perfect disciplines; citizens should be encouraged to understand and see the role technologies play in shaping and co-creating the research methods, data and interpretations they ultimately rely on for their own well-being.

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