Workshops as Boundary Objects for Data Infrastructure Literacy and Design

Firaz Peer
Georgia Institute of Technology
Atlanta, GA, USA
fiazpeer@gatech.edu

Carl DiSalvo
Georgia Institute of Technology
Atlanta, GA, USA
cdisalvo@gatech.edu

ABSTRACT

In this paper, we describe how we used workshops as boundary objects that bridged the dual goals of data infrastructure literacy and design. We organized 11 workshops with community leaders from the Westside neighborhoods in Atlanta. The moments of breakdown that took place at the workshops allowed the participants to critically reflect on the socio-technical complexities of the data infrastructure, which scholars have argued is key to data literacy. Additionally, these moments of breakdown also offered us, as designers, insights we could use to reimagine data infrastructures. We contribute an ethnographic analysis of the workshops we organized, along with a preliminary set of data infrastructure literacy guidelines. In doing so, we invite the DIS community to take up such workshops as a way to continue to design data infrastructures, after design.

Author Keywords

Data Infrastructure Literacy; boundary objects; design after design; infrastructural inversion.

ACM Classification Keywords

• Human-centered computing~Ethnographic studies

INTRODUCTION

Researchers within the DIS community are increasingly paying attention to the socio-political infrastructures within which technologies are developed and implemented [11, 25, 49, 50, 63]. Researchers have also suggested infrastructural inversion [8] as a method to help designers envision design possibilities [64]. We performed a similar infrastructural inversion in our research and found that the data infrastructure literacy workshops we organized served as boundary objects [55] that met the needs of both designers and data literacy advocates.

Data literacy researchers have advocated for expanding the notion of data literacy to *data infrastructure literacy* [35]. Data infrastructure literacy aims "not only to equip people with data skills and data science, but also to cultivate sensibilities for data sociology, data culture and data

politics" [35]. Gray et al. introduce the word "infrastructure" into data literacy in an effort to draw attention to the various human and non-human actors that are involved in the creation, analysis and sharing of data. This includes the individuals and organizations that collect the data using sensors or by combining other datasets, the software and hardware platforms used to clean, analyze and share them, along with the underlying socio, cultural and political contexts within which such data are created. The workshop activities that we selected and the moments of breakdown that transpired while conducting them allowed our participants to critically reflect on these aspects of the data infrastructure.

Additionally, we found that observing how our participants perceived of and unpacked the infrastructural black boxes offered us, as designers, an additional frame of reference from which to reimagine data infrastructures. We therefore argue that such workshops can serve as boundary objects, through which participants learn about the socio-technical infrastructures implicated in the creation of data, while designers can also envision the barriers and alternate user experiences for the infrastructures they are designing.

We used community data available on the Communities Who Know (CWK) Data Dashboard as the infrastructure over which to structure our data infrastructure literacy workshops. The dashboard was built through a multiyear collaboration between Georgia Tech (GT) and community leaders from the Westside neighborhoods in Atlanta. The dashboard was built by GT to satisfy the need for more accessible community data expressed by the community leaders. The hope here was that the community would be empowered and more likely to engage in matters of common concern if they had free and open access to data about their demographics, education, public safety, historic data and other resources.

Building a data dashboard as a tool for community engagement assumes that users know how to use the dashboard and make sense of its data and visuals, a key skill that is unevenly distributed within non-profit organizations working to make a difference in their communities [9, 30]. Parsing through a dashboard's numerical and graphical data and drawing conclusions based on probability, statistics and the relationship between numbers is a non-trivial task that requires training and resources. Since data dashboards are made up of different assemblages [43], scholars have argued that knowledge of how its socio-technical black boxes

influence data need to be included in any data literacy initiative [35]. This is what makes the CWK dashboard ideally suited as an infrastructure over which we build data infrastructure literacy.

Infrastructures are inherently relational: what serves as an infrastructure for one group might merely be a reference for another [57]. Systems become infrastructures under certain conditions and in response to certain organized practices, which is why Star and Ruhleder claim that the question we need to be asking is *when* is something an infrastructure, rather than *what* [57]. Based on this framing, the research question we were seeking to answer through is research was *When can we observe data infrastructure literacy within communities?*

To answer this question, we organized 11 data infrastructure literacy workshops between March 2017 and July 2018 with community leaders from different neighborhoods in the Westside of Atlanta. Observations, notes and audio recordings from these workshops were supplemented with participant interviews to reveal how they understood and used community data. The ethnographic data we collected were analyzed from a grounded theory perspective, which resulted in two key findings.

First, we saw evidence of how these workshop activities served as boundary objects for data infrastructure literacy and design. Our explication of workshops as boundary objects builds on prior work [51, 64] and offers another way the concept can be useful for design researchers. Second, and more in response to our research question, we saw evidence of when and under what conditions we could observe data infrastructure literacy within communities. We present these findings in the form of guidelines that others can follow when trying to build data infrastructure literacy with their communities within workshop settings.

RELATED WORK

The concept of boundary objects was first introduced by Susan Leigh Star and Jim Griesemer in 1989 [55], when they were motivated to understand how groups that belonged to different social worlds worked without consensus. Boundary objects, as they claim (i) have an interpretive flexibility, which means they reside in different social worlds with each group having their own understanding of what these objects do and how they work. (ii) maintain a common identity that both groups share, while also being tailorable to the groups' specific needs (iii) afford a back and forth, so when these groups are not co-operating or working towards specific goals, they switch between both forms of the object.

Rajapakse et al. have used boundary objects to discuss how people with disabilities build personal infrastructures to support their everyday lives [51]. The researchers worked with individuals with disabilities and their families to co-design artifacts like video stories, photo-series, personal profiles and visit logs. These artifacts were treated as boundary objects as they served multiple groups in the project, each of which had their specific needs and goals. For the families involved, these design artifacts helped communicate and clarify the personal infrastructural needs of their disabled children with other student designers, makers and disability service organizations that were involved in the project. The co-design process helped the researchers and designers learn about the capacities, dreams, challenges and limitations of their participants and negotiate what features they would like to include in the prototype. Most importantly, this process of infrastructuring [21] went beyond mere end-user participation as it gave the individuals with the disability more control over how the artifacts and prototypes were developed, while also enhancing their self-determination.

In another study, Wood et al. staged urban walks as a way to perform an infrastructural inversion of the Global Navigation Satellite Systems (GNSS) that all of us, as users, take for granted in our everyday use [64]. Participants were given a brief overview of how GPS (Global Positioning System) and GNSS systems have been developed and were then asked to navigate through a collection of concrete buildings using the *GPS Test* app on an Android phone that was given to them. The app was used to defamiliarize the participants from the GPS apps they were accustomed to, as it revealed the position and signal strength of the different satellites that were used to triangulate the position of the participants. The act of walking around the buildings by looking at a non-traditional GPS interface was a non-trivial task, which was compounded by the moments of breakdown that took place when the phone could not connect to one of more of the satellites. It was through these activities and the resulting moments of breakdown that participants critically reflected on the underlying infrastructure of GNSS and on how their own sociotechnical practices were impacted through this unfamiliar interface. The method of inverting the infrastructure also revealed alternate user experiences and offered the designers a way to critically reflect on some of the hidden issues at play. These staged activities thus served as boundary objects for both the participants and the designers.

We mention these two projects here because our approach to the data infrastructure literacy resonates with both of them. In choosing the activities for the workshops, we tried to strike a balance between offering our participants data they were familiar with versus that which they knew nothing about. It was during moments of breakdown that the data infrastructure lent itself to the most critical reflection from the participants. These moments of breakdown presented us as designers with provocations we could use to reimagine the data infrastructure for the community. We reflect on these moments of breakdown and the insights in the discussion section. For now, we turn our attention to data infrastructure literacy and how we use the term in our research.

From Data Literacy to Data Infrastructure Literacy

When defining data literacy, there is a tendency to highlight the technical skills that allow one to use data as a resource while ignoring the social critique of data that can lead individuals towards emancipatory end goals [61]. Scholars have argued that data literacy includes both the computer and data science skills needed to manipulate data, as well as the capacity to critically analyze them through a social lens [61]. It is more than just the acquisition of knowledge and skills on how to use data but needs to include the ability to read, work with, analyze and argue with data as part of a larger inquiry process [18]. It includes the ability to ask and answer real world questions through an inquiry process that also acknowledges the ethical aspects of data use [62]. Within community settings, Frank et al. argue for considering a variety of data literacies that allow individuals to specialize in either their finding, manipulation or presentation [32]. Extending the definition to focus on inclusion and the capabilities of the community to produce, engage with, communicate and use their own data, Letouzé et al. define data literacy as "the desire and ability to constructively engage in society through and about data" [23].

What these scholars have in common is a belief that all data and data approaches can and must be leveraged to empower citizens. A data literate society, for them, is a more inclusive society; having the required data literacy skills will improve the likelihood of the community's ability to craft data-based narratives that support their civic engagement needs. The aspirational goal here, which is in line with our own is to frame data literacy as a process through which the community can learn to use data to constructively engage with issues they care about.

In addition to the technical skills and the critical social lens, Gray et al. have argued to broaden the definition of data literacy to include the "social, historical, cultural and political settings" in which data are created and used, in order to highlight the different ways such infrastructures influence the data [35]. They call for an infrastructural inversion [6, 8] of our data infrastructures so we can comprehend the socio-technical manner in which our data have been "cooked" [5], which could ultimately lead to an infrastructural imagination [7] of how they might be organized differently.

A consequence of introducing the term infrastructure is that it connects data literacy to previous literature from the field of Science and Technology Studies and scholarship on information infrastructures, which has opened up the black boxes within large socio-technical systems like electric power grids [39], weather systems [27], health informatics [36] and the like. Data infrastructure literacy therefore asks us and our learners to critically reflect on and analyze the different infrastructural black boxes that are implicated in the creation of data.

We used the CWK dashboard as the infrastructure over which to build the Westside community's data infrastructure literacy. We offer an explanation of why we chose to use the CWK dashboard as an infrastructure, before describing our approach to organizing the workshops.

DASHBOARDS AS INFRASTRUCTURES

Community indicator data dashboards are a specific category of data dashboards that are, in most cases, designed by cities or non-profit organizations to empower communities with data about themselves and the cities they live in. This tends to include data about demographics, education, environment, traffic, crime, jobs or other specific domains that the community is interested in. Kitchin et al. urge us to think of such data dashboards as *data assemblages*, which are complex socio-technical systems, infused with their own political, cultural, ethical and philosophical biases that not only reflect our cities, but also shape them [43, 44]. All data go through a janitorial process before they can be fed to applications and interfaces that help us make sense of them. By aiming for intuitive use and pleasurable experience, data dashboards tend to highlight the neutrality and objectivity, while simultaneously underemphasizing the messiness of the underlying data [43] and the communities they represent. From the time data are collected, to when they are in the hands of the analyst drawing conclusions from them, data are mired in a series of complex socio-technical and political decisions regarding their format, range, validity, interoperability and presentation that need to be reflected upon. In appropriating data dashboards as data assemblages Kitchin and Lauriault want to foreground the issues of voice, access and power that need to be considered when studying such dashboards [42].

We acknowledge this view of dashboards as socio-technical assemblages but believe that thinking of them in terms of infrastructures allows us to better appreciate the relational manner in which these dashboards exist. While the term 'assemblage' extends a static and unidimensional outlook for dashboards, an infrastructural lens allows us to foreground the ever-evolving background elements of dashboards from different relational perspectives; to pay attention to the always existing and ever-changing nature of infrastructures. An infrastructure comes to life through the accretion of multiple socio-technical layers over a period of time, where a breakdown in any one of them can bring the entire system to a standstill. Infrastructures are something upon which something else "runs" or "operates," which is taken for granted and becomes invisible as it sinks into the background over time [8, 57].

Community indicator data dashboards are built on a set of always evolving socio-technical assemblages that take on different relational significance based on who is engaging with them. For the developer who is using computer code to program the dashboard, the multiple standards, network protocols, databases, development environments, design patterns, efficiency, redundancy and maintainability of code form the immediate infrastructure with which they are concerned. To a community resident who only uses the dashboard as a reference for numbers and graphs, these

technical details probably matter less than the socio-political issues of where the dashboard gets its funding from and how its existing stakeholders and partners influence the data. This relation quality, where background issues for one group of users are foregrounded for another is a key characteristic of infrastructures. Thus, specific groups of users bring specific values and expectations to the dashboard, which are reflected in the specific socio-technical contexts within which such data infrastructures are developed and used. The job of the designer then, is to envision all possible scenarios of use and their socio-technical impacts when developing data infrastructures.

This is a complex task which cannot be completed without observing how end users interact with the infrastructure. Researchers have therefore argued to continue the design process even during use [29, 38, 40, 60]. Data infrastructure literacy workshops, like the ones we are arguing for, offer an ideal platform for designers to observe how the system is being used, and can yield insights for design. We will have more to say about these insights in the Discussion section. For now, we turn our attention to describing the socio-technical complexities within which the CWK dashboard came to fruition.

CWK Data Dashboard
The Westside communities in Atlanta are home to many landmark institutions and have a rich history associated with the American Civil Rights movement. But desegregation and the economic downturn of the early 2000's riddled the community with problems of foreclosures, abandoned homes, drugs and crime. Multiple resident organizations and individuals are leading the charge to transform the neighborhoods. The first step in this transformation is to change the narrative from one of drugs, crime, homelessness, joblessness and poverty that consistently gets highlighted when talking about the Westside neighborhoods, to one that highlights its positive assets and contributions the communities have made to the city.

These Westside neighborhoods abut the Georgia Institute of Technology. As one might expect, there has been and continues to be occasional tensions between the neighborhoods and the university. In a sincere effort to bridge communities, redress past relations, and foster new commitments, in 2011, the College of Liberal Arts at Georgia Tech (GT) setup a communications network called The Westside Communities Alliance (WCA), whose purpose was to serve as a liaison and facilitate partnerships between the university and the Westside community. The creation of a dashboard—intended as a resource to assist the residents of Westside neighborhoods in changing the narratives told about their neighborhood by providing data and counter-data—was one of the primary initiatives taken up by the WCA. It came together through a multi-year effort in which faculty, staff and students at GT worked with community partners to understand and build a platform that satisfied their data needs. The dashboard aimed to recognize the
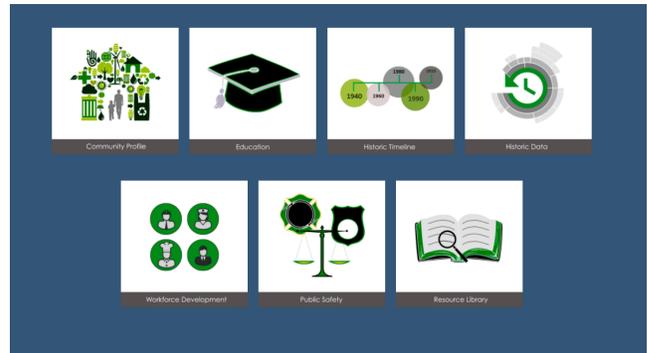

Figure 1: CWK Data Dashboard landing page

historical, geographic and economic significance of the Westside communities to Atlanta and brought together previously inaccessible datasets from multiple city and state departments under a common platform that residents could use from the comfort of their homes.

The dashboard sources its data from the Census, American Community Survey, Georgia Governor's Office of Student Achievement, Atlanta Police Department, Fire Department as well as from other reports and datasets about the city. Currently, the dashboard consists of seven modules - community profile, education, historic data, historic timeline, public safety, workforce development and resource library. The dashboard was built one module at a time over the span of five years using a variety of technology platforms like Tableau, d3, CARTO and others.

Observing how these different modules and their underlying black boxes came together through a series of socio-political, technical, economic and cultural constraints alerted us to the infrastructural properties of the dashboard. Knowledge of these black boxes and the constraints through which they operate is crucial for those who wish to use its data and become a part of its community of practice [56]. Data infrastructure literacy, rather than just data literacy is therefore necessary to make sure these data are engaged with appropriately and the conclusions one draws from them are accurate and verifiable.

METHODS
Literacy has historically been a top down endeavor, where the elites in power set the agenda for what is to be taught and learned by the rest of society, which is counter to its spirit of enlightenment and empowerment (Data-Pop Alliance, 2015). Paulo Freire calls for foregrounding the social injustice perpetuated by existing power structures and the role education can play in resisting it [33]. His concept of Popular Education advocates for establishing a dialog between the teacher and the pupil to contextualize learning to the specific circumstances the pupil is familiar with. Given the history of the community that we are working with, the Freirean inspired critical data literacy approach is best suited to achieving the community's goal of transforming the narrative that is being told about their neighborhoods [61].

Bhargava et al. have used this approach in their effort to build critical data literacy with students at an alternative school in Belo Horizonte in Brazil [4]. We followed a similar participatory bottom up approach that is sensitive to the context and needs of the learner [61] when organizing our data literacy workshops with the Westside community.

Residents of the Westside neighborhoods have been the subject of several disparaging media and research reports, which have made them reluctant to participate in more research studies. It was important that we built our relationship with the community and establish a level of trust [22], so they would be willing to share their time and expertise with us. This process of relationship building helped us contextualize the workshops to the specific needs and circumstances that were relevant to the community.

We organized eleven data literacy workshops between March 2017 and July 2018. The first two workshops in March served an exploratory purpose, to understand the kinds of activities and datasets that would pique the community's interest. These two workshops were organized in partnership with the WCA, who also helped us recruit participants by sending emails to non-profit organizations that used community data in their daily operations. The six participants who attended the workshops came from non-profit organizations who used data about the community's education, demographics, income, jobs etc to track and measure the performance of specific programs in the neighborhoods. They had a broad range of skills, with some being only moderately familiar with Microsoft Excel while others had also used professional software programs like Tableau. After the workshops, the first author interviewed three of the six participants based on an interview guide that he developed. The questions included general ones about the participants' background and skills with respect to data, as well as more specific ones about what they would like to learn at future workshops. Findings from these exploratory sessions and interviews helped tailor the remaining workshops to the needs of the community.

While participants in these exploratory workshops were eager to learn about data, they also expressed the need for an incentive to participate. Researchers have also argued that it is hard to get people excited about data literacy if they do not have an incentive or a reason to learn it [41]. We therefore setup the remaining workshops as a set of four weekly sessions, where each organization could send up to two participants and would be compensated with a $400 stipend for every participant that completed at least three of the four workshops.

This stipend was significant and influenced the kind of participants who signed up—we anticipated this and it was, in fact, part of our planning. We wanted to make an offer of support to participants that was meaningful and that would reflect the significant time investment on their part. We also wanted this stipend to convey they were participating in what was not merely a university study, but also a commitment to the university supporting the work of community organizations and resident advocates. In the first round of workshops for example, we had four participants who admitted that using data was not part of their everyday job, but they were interested in picking up new data literacy skills. One participant even admitted that she was there so she could raise money for her organization. Having expected this, we intentionally structured the workshop activities so they would appeal to participants with a broad range of skills and motivations.

Data Infrastructure Literacy Workshops
The workshops were structured as a series of four that would teach participants the basics of data storytelling with the CWK data dashboard. These workshops took place in February/March and June/July of 2018 at two easily accessible locations; a public library and a community food bank. An additional make-up workshop was organized at one of the participating organizations office for those who missed a session in the second round.

For us, the workshops served two purposes. First, we hoped the workshops would allow participants to perform an infrastructural inversion [8], so they could critically reflect upon and see through the different infrastructural black boxes that make up the CWK Data Dashboard. This follows from our desire to broaden the conceptualization of data literacy to data infrastructure literacy [35]; to include not only the tools and techniques required to make sense of data, but also a critical understanding of the socio-technical, political, historical and cultural factors that impact their collection, organization and use. Second, we hoped that these workshops would result in an infrastructural imagination [6], in that observing how participants reflected upon and opened up the black boxes of the CWK dashboard would offer us insight into how the dashboard infrastructure could be reimagined.

Choosing activities
Many of the activities we chose were based on the worksheets and tools created as part of the Data Culture project [16] by the databasic.io team. The goal of the Data Culture project is to go beyond boring spreadsheet-based trainings and use an arts and crafts based data storytelling approach to build a data culture within organizations. The activities we borrowed included building a data sculpture [17], asking good questions of data [14], sketching a story with word counter [19], trying to convince one another [15] and remixing a visualization for different audiences [3] using a sample dataset. The activities used craft materials, sketching and role-playing activities to build a basic understanding of what counts as data, the kinds of questions one can ask of them and how they can be used to sketch stories and make convincing arguments.

CWK dashboard activities
For the activities that involved the CWK data dashboard, we used an information hunt activity that was put together by the dashboard development team. This was initially developed

as a way to evaluate how many questions users could answer in under ten minutes by using the dashboard as a reference. The activity worksheet included questions corresponding to each of the modules, such as

1. Percentage of the population in Atlanta that is age 5 to 17 years?
2. APS school with the highest 7-12 dropout rate and one with the lowest?
3. Year construction began on MARTA rail system.

4. What other data will help you tell your story better? Does this data exist? Where can we find it?

For our final activity which asked participants to create data narratives with the CWK dashboard, we took inspiration from the Data 101: Data Visualization, Data Literacy and Storytelling workshop [58] format, which introduced participants to the different types of data stories [2] (connection, comparison, change, personal and factoid), and asked them to create one of their choice. The focus here again

Workshop Type	Exploratory Workshops	Round 1	Round 2	Make-up Workshop
Date	March 2017	Feb/March 2018	June 2018	July 2018
Number of Workshops	2	4	4	1
Number of Participants in each workshop	5	7	9	3
Activities	Session 1: Building data sculptures with Westside business data. Session 2: Introduction to visualization types and common pitfalls.	Session 1: Building data sculptures, Asking Good Questions with data Session 2: Sketch a Story with WordCounter and Try to ConvinceMe Session 3: Information hunt with CWK dashboard Session 4: Data 101: Data Visualization, Data Literacy and Storytelling	Session 1: Building data sculptures, Asking Good Questions with data Session 2: Information hunt with CWK dashboard Session 3: Sketch a Story with WordCounter and Remix a Visualization Session 4: Data 101: Data Visualization, Data Literacy and Storytelling	Session 1: Information hunt with CWK dashboard and Data 101: Data Visualization, Data Literacy and Storytelling
Interviews	3	6	0	0

Table 1: Overview of workshops

We used this information hunt activity to generate discussion about the dashboard's usability, its data, and how they both could be improved to suit the work that the community leaders were doing. We did not set a strict time limit and encouraged participants to clarify their doubts and ask us any questions they had. This approach of using the information hunt activity not only as a measure of usability or navigational efficiency, but also as a tool to scaffold critical discussions about the dashboard and its infrastructural black boxes proved to work extremely well.

To structure the conversation about whether and in what way the dashboard met the participants' needs, we offered the following prompts

1. What is the problem/issue you are dealing with?
2. If you are using data, how are you currently using it to solve your problem? Can you list your datasets?
3. Do you have all the data you need?

was to use data available on the CWK dashboard to find and create a story that interested the participants. The data storytelling approach was chosen as it closely matches the way non-profits use data within their own work, either when advocating for change or seeking out grants [10, 30]. Aligning the workshop context with the context of use for the non-profits was our attempt at making the workshops more relevant to our participants.

Participants
A total of seven participants from five different nonprofit organizations attended each of the first four workshops in February/March of 2018. The first author followed up these workshops with interviews of six participants who had agreed to share more details about their data needs and issues but did not have time to do so at the workshops. Each interview lasted for about one hour and was transcribed prior to analysis.

An additional nine participants from six different nonprofit organizations attended the second round of workshops in June/July. There were no interviews here, as we scheduled enough time within the workshop for the participants to talk about their respective data needs. The sequence of activities was also modified, as we alternated between general data literacy activities with databasic.io at one workshop and more context specific ones with the CWK dashboard at the next. This was done because some participants complained about working with data that they couldn't relate to in some of the databasic.io activities. Such modifications are not a deviation from the method and are in line with the conversational approach of refining the workshops to the contextual needs of our participants.

The workshops generated qualitative data in the form of written notes, pictures and audio recordings about how community leaders understand data, the different ways they use data to tell stories, the kinds of data stories they tell/value, and the different barriers they face when using data to tackle issues of community concern. Audio recordings from the interviews and workshops were transcribed and iteratively analyzed from a grounded theory perspective [1]. Observations and feedback from the participants have helped us refine the activities into a series of best practices that can be used within future data infrastructure literacy workshop settings. We reflect on some the results from these workshops in the next section, while also tying them into existing literature within HCI.

RESULTS AND DISCUSSION
Within data infrastructure literacy, evidence of learning comes not from efficient use of tools and accurate analysis of the data, but by performing a critical scrutiny of data that is reflexive, does not take data as given, and utilizes an infrastructural imagination [6] to generate inventive uses of data [35]. At the workshops, this came through in the kinds of questions participants asked and the qualitative nature of the conversations during the feedback sessions. This is different from traditional data literacy metrics that rely on pre and post tests as measures of literacy.

In addition to offering evidence of data infrastructure literacy, the workshop activities also offered us insight to redesign the CWK dashboard. More specifically, it was during key moments of breakdown that the data infrastructure and issues with design came to the fore. This supports Star's thesis that infrastructures become visible only upon breakdown of routine functioning and mal-alignment with the concerns of its publics [54].

While almost anything that is interpreted differently between groups can be a boundary object, we have been cautious in extending this concept to our workshop activities. In addition to maintaining a common identity and offering an interpretive flexibility that benefits data literacy advocates and designers, our workshop activities also revealed the scale and scope of the underlying data infrastructure. Star has clarified that this ability to offer insights at the organizational

level is key when considering what can be classified as a boundary object [47].

Our reason for classifying the workshop activities as boundary objects is because it was during these activities and the resulting moments of breakdown that participants critically reflected on the entire data infrastructure. This included the socio-technical, historical, cultural and political settings within which data we used were collected, cleaned, curated, controlled, combined, contextualized and conveyed. A consequence of focusing on two moments of breakdown is that our narrative is limited to only those participants who actively engaged in that activity. We use the pseudonyms Casey, Hailey, Roy, Janet and Patricia to identify those participants.

Inaccuracies
The erroneous data in question was the number of burnt structures in the Westside neighborhoods, which was far fewer than what the participants knew it to be. Participants who lived these neighborhoods knew the staggering rate at which old and abandoned homes were being burnt down over the past few years. To see these numbers being under reported on the dashboard made them question not only the usefulness of the dashboard as a resource, but also the values of organizations like the Atlanta Police Department (APD) which provided the data. This criticality regarding data provenance where participants not take data as given is a desired quality within the mandate for data infrastructure literacy [35] and resulted from participants being made aware of the errors in the dashboard's data. Some even went as far to claim that the APD had intentionally manipulated the numbers in order to highlight an upward trend in the community's public safety.

While there is no evidence of this data being manipulated by the APD, it is worth dwelling upon the reason behind this error and the participants' reaction to it. Was this an error in the way the data was collected and classified by the APD, or in the way the data analysts had understood it or merely a technical glitch in the interface? Answering these questions would no doubt require further investigation, but the infrastructural inversion [6] that the participants employed helped us stay with these inaccuracies and treat them as local signifiers of data context and provenance [48], as data are always connected to place [13, 59].

The inaccuracy of the data on the dashboard also made Casey question the trustworthiness of the tool itself. Patricia and Roy disagreed and were of the opinion that even such inaccurate data was empowering, as it gave them the ammunition they needed to go to the city department (which was the source for the data) and ask them why the numbers were what they were. Hailey agreed and offered an example where city officials in Atlanta were using an inaccurate Area Median Income (AMI) numbers when calculating the rent and number of affordable housing units in the Westside. The median income for these neighborhoods is in the $400-$500 per month range, which is 25-30% of the AMI. But city

officials were classifying units as affordable if they were within reach of those who made 60% of the AMI. This error was because officials were including incomes from more affluent metropolitan areas of Atlanta, where the average income was much higher. Learning about this discrepancy allowed community leaders in the Westside to approach the city officials and request changes to be made to the manner in which affordable units are stipulated. Thus, Hailey argued, inaccurate data could also be empowering, but this was still not enough for Casey to trust that the dashboard as a useful resource.

As designers, this discussion helped us to think through how we might deal with such inaccuracies going forward. Loukissas reminds us that inaccuracies in data are a result of situated practices in the production of data and are important signifiers of local conditions that should not be erased [48]. Therefore, a more productive strategy to deal with inaccurate data might be to highlight it and disclose why we believe it might be wrong. Such disclosure [20, 26] allows us to stay with the problem, which might lead to further insights about local data practices. Additionally, such a strategy asks the community to be critical of the data and not take it as given. It raises the veil of objectivity that tends to be associated with numerical data.

The participants further emphasized their frustration with the inaccurate data when they asked who at the university was in charge of maintaining the dashboard. The community had come to trust the data on the dashboard thanks mainly to the public engagement efforts of the leadership team that had built it over the years. Now that only one of the four team members was actively involved in overseeing the dashboard, there was uncertainty in terms of who represented the dashboard and who the community could trust to have its issues resolved. As designers, this asks us to consider the different ways in which trust is eroded or embodied within civic technologies and the effect it can have on engagement [12, 37]. We argue that the strategy of disclosure as described above is one way to build trust with the community. We discuss additional strategies to build trust in the following sections.

Classification Errors
The "Remix a Visualization" activity asked the participants to remix a data visualization [65] about funding that different organizations on the Westside had received from The Arthur M. Blank Family Foundation. Since 2013 the foundation has committed a total of $37M towards positive transformative efforts taking place in the Westside neighborhoods [source: Blank Foundation website]. Looking at the numbers in this visual made the participants really upset about how the data was being used to tell a story that was different from the ground reality they had been experiencing for years.

The point of contention was that the visual showed close to a million dollars given to two organizations, (Construction Education Foundation of Georgia (CEFGA) and APD Urban Planning and Management LLC, which were classified as

working on "housing". This number would seem admirable to anyone outside the community but infuriated those in the room who were still helping out homeless teenagers, adults and families on a regular basis. They could not fathom the fact that close to $1M had been spent on housing since 2015, but the problem of homelessness remained unabated. This issue was given a face when one of the participants, who was once a homeowner revealed that she had been homeless for the past week and was relying friends to support herself. Hailey, put it across most succinctly in Figure 2 (left) which showed how all this money had zero impact on the neighborhood. Figure 2 (right) by Janet asks for need, impact and results of all the money that has been invested into these organization between 2015 and 2017.

CEFGA, which received $497,772 is classified under both "housing" and "training". But CEFGA's website states that it is a 501(c)(3) non-profit that specializes in offering construction training to high-school and adult students. The organization offers job-training and placement services, which are better classified under "training" rather than "housing". Participants at the workshop in-fact did not know what CEFGA was. When Hailey asked the group what the acronym stood for, Casey, who was frustrated at what she was seeing in the visualization replied "B.U.L.L.S.H.I.T"!
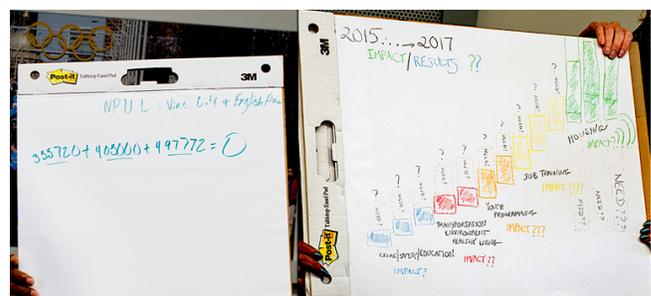

Figure 2: Remixed Visualizations ask about impact of funds given to different organizations.

Classifying CEFGA as "housing" was likely a mistake on the part of the designer. This error in classification led to quite an animated discussion among the participants, with many of them being visibly upset about the alternate reality that this visual was putting forth. The remixed visualizations they put forth asked for evidence of impact these organizations had made in the community. Such an example of mal-alignment with the needs of the publics which results in inventive data practices[35] is another instance of data infrastructure literacy[35].

As designers, we see an opportunity here to build data visualizations that support a plurality of interpretations while also guiding the community towards action [20, 26]. Such interpretations and actions should result from a complete understanding of where data come from. Including a link to CEFGA and stating why the designers had classified it under "housing" rather than "training" would give the user the supporting information they need to interpret the data. While

such additional information might slow down the process of interpretation, scholars have argued that these little *inefficiencies* [24] or *frictions* [34] as they like to call them, need to become more mainstream within our civic infrastructure systems.

Data friction refers to "the costs in time, energy, and attention required simply to collect, check, store, move, receive, and access data" [27]. Since visualizations help turn data into information and knowledge the user can consume, they require, in addition to data friction, a certain computational friction, which accounts for the socio-technical struggle involved in transforming data into information and knowledge [27]. When designing civic technologies, there is a tendency to highlight their technological efficiency, while black boxing their data and computational friction that goes into making them. We argue, as others have before us, that it is precisely through inefficiencies that we can ask the user to pause and reflect on the infrastructures that are bringing this data together.

But how far should the designer go in incorporating such moments of friction in their data infrastructures? How much friction is too much? Specific strategies to address these questions will vary with the context within which such infrastructures are being designed. We refer our readers to [34, 45] for a more detailed discussion on how *meaningful inefficiencies* and *frictions* can be designed into their civic infrastructure systems. For now, we turn our attention back to the workshops to give our readers a sense of the consequences that such moments of breakdown can have on a group of community leaders working within a politically charged environment.

Consequences of Inaccuracies and Classification Errors
While our selected activities and the dashboard did offer a rich context within which to reflect on the data infrastructure, it also made Casey feel personally responsible for not being able to convey her community's story through data. Speaking on behalf of all the participants, Roy painted a picture of how everyone in the room "have been hyper engaged in their community affairs for the last 3-5 years", so narratives of deprivation and saviors like the Blank Foundation promising millions of dollars to uplift the community was something they saw in the mainstream media all the time. It was "seeing the numbers" behind the headlines "made it more real" for Hailey. Casey highlighted the need for them as a community to be able to easily access accurate data about themselves in a usable format, so they can create narratives that highlight their point of view rather than those of outside researchers or media outlets. She was concerned that they were sitting in a room doing "coloring book stuff" when there were issues like homelessness and gentrification out in the real world in which people's lives were at stake.

Hailey was disheartened to see how data could be twisted to tell different stories. At the start of the first workshop, she had stated that she was interested in working with data because "data don't lie". By the end of the fourth workshop, she was disturbed to see how their lack of engagement with data was negatively impacting their neighborhoods.

This sense of responsibility seemed heightened in the fourth and final workshop, when participants were unwilling to engage in the activities for that day and wanted to instead talk about what the first author had learned from the workshops so far, and how that would impact the community or the dashboard going forward. These community leaders had taken time away from their overbooked schedules to participate in the workshop sessions, so it was important for them that their expertise be acknowledged and represented in our next steps. Who would take responsibility for erroneous data on the dashboard? Was there somebody they could talk to in order to report issues, request features or even just understand the data better? Could the dashboard be used to hold organizations and funders responsible for the work they do and the impact they're having on the community?

These questions form the basis for the next phase of our research. We are in the process of redesigning our engagement process and the CWK dashboard, so it can better meet the community's needs. In spite of considering some of these issues when the dashboard was being designed, many of the decisions the team took reflected the socio-technical constraints of the time. The team "muddled through" [31] the development process as they were forced to prioritize features based on the skill level of the students and funding that was available. This process of satisficing [53] resulted in a tradeoff where practical development concerns were sometimes prioritized over the values expressed by the community leaders [52]. The workshops offered a space for us to reconsider these values and continue to design after design [28] by surfacing the different barriers to use, inaccuracies and mal-alignments [54] within the data infrastructure. These results have therefore offered one answer to our research question, which was to identify when we can observe data infrastructure within communities. We offer the following guidelines as a way for other design researchers to emulate such data infrastructure literacy workshops within their communities.

Proposed Guidelines for Data Infrastructure Literacy Workshop Activities
We chose to structure our data infrastructure literacy workshops over the CWK dashboard infrastructure as the dashboard is part of a larger research agenda that studies data dashboards from an infrastructural perspective. Although our choice of data infrastructure was apt for our workshops, we do not believe it is required for data infrastructure literacy workshops to be based on dashboard infrastructures only. This is because even simple data collections result from interactions between a network of infrastructural black boxes that need to be unpacked if one is to truly understand how data are made. We believe that any collection of community data or a data visualization can serve as the basis on which

to build a data infrastructure literacy, as long as we also adhere to the recommendations discussed below.

1. Invite participants for whom the data and the issues it represents are *matters of concern.*

All data are approximations and do not offer a complete picture of the world they represent. Identifying their shortcomings requires that they be analyzed by experts. Our first guideline therefore asks to ensure that the workshop participants are experts in the issues that the data represent. We are not suggesting we need expert data analysts, but in fact need individuals who are familiar with the local contexts from which data are extracted. They need to care enough about the data or the underlying issue that they consider it a matter of concern [21, 46].

2. Take a *critical pedagogical approach* that aims to contextualize the workshop activities with specific matters of concern that the participants identify with.

This requires that we select data and activities that match the context of learning with the context of use. The critical pedagogical approach as advocated by Paulo Freire, calls for establishing a dialog between the teacher and the pupil in order to contextualize the learning to the pupil's needs. Our exploratory workshops allowed us to identify key issues and select datasets, visuals and activities that were relevant to our target audience. We used the data storytelling framework to structure our workshop activities since it is predominantly how non-profit's tend to use data, either when advocating for change or raising funds [10, 30]. We did this so participants could draw parallels between the knowledge and skills they learned at the workshops and the work they did every day.
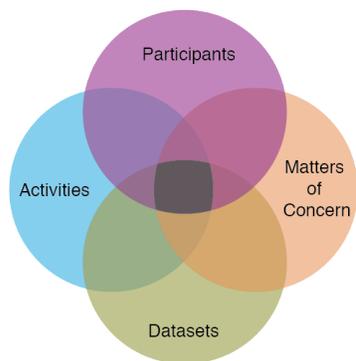

Figure 3: Venn Diagram depicting suitable activities.

One way to visualize the relationship between the participants, datasets, activities and matters of concern is shown in the Venn diagram above. This overlapping area represents the subset of activities and datasets representing specific matters of concern that our participants care about and are apt to be included in a data infrastructure literacy workshop. The other overlapping areas meet two or three of the criteria and might fail to generate enough interest with the participants. The specific matters of concern, participants

and datasets will need to be identified in an organic manner by establishing a dialog with the target community. For data activities, we recommend the NNIP [24], databasic.io or the Data Culture website. The datasets for any of these activities can be easily replaced with ones that the learners are more familiar with.

3. *Be open to an infrastructural imagination,* where participants reimagine the data infrastructure by critically analyzing its black boxes and barriers.

In being *open to an infrastructural imagination* [6], we ask that organizers encourage participants to reflect on the different socio-technical obstacles that need to be overcome in order to use the data. One way we did this was to introduce data and computational friction into our activities, which revealed the specific individuals, organizations, protocols, practices and policies that are implicated in the production of data. This also brought attention to values like trust, disclosure and accountability that were a priority for our participants. The purpose of an infrastructural imagination is to foreground the often ignored background elements within the infrastructure so we can reassemble it from scratch if needed [35].

4. *Focus on moments of breakdown* and be open to discussing inaccuracies and errors in the data infrastructure.

Given that our workshop participants engaged in their most critical discussions when they encountered inaccuracies and classification errors, we contend that the overall goal of data infrastructure literacy workshops should be to offer a platform where these moments of breakdown can come to the fore. These, as we have stated before, are important signifiers of situated data practices and should not be erased or ignored.

CONCLUSION

In this paper, we demonstrated how data infrastructure literacy workshops can serve as boundary objects that satisfy goals for both data infrastructure literacy and design. The moments of breakdown that resulted from our workshop activities allowed participants to critically analyze and respond to the socio-technical, political, economic, cultural issues that are inherent to the development data infrastructures, which is what data infrastructure literacy is all about. Additionally, these moments of breakdown offered designers ways to reimagine the dashboard infrastructure from the community's perspective. We hope that the workshop guidelines will serve both designers and data literacy advocates as they learn, design and build data infrastructures with their communities.

ACKNOWLEDGMENTS

REFERENCES

[1] Bernard, H.R. 2006. *Research methods in anthropology: qualitative and quantitative approaches (4nd edition)*.

[2] Bhargava, R. Finding a Story in Data. https://datatherapy.org/activities/activity-finding-a-story-in-data/.

[3] Bhargava, R. Remix a Visualization. https://databasic.io/en/culture/remix.

[4] Bhargava, R., Kadouaki, R., Bhargava, E., Castro, G. and D'Ignazio, C. 2016. Data Murals: Using the Arts to Build Data Literacy. *The Journal of Community Informatics*. 12, 3 (2016), 197–216.

[5] Bowker, G.C. 2013. Data Flakes: An Afterword to " Raw Data " Is an Oxymoron. *Raw data is an oxymoron*. 167–171.

[6] Bowker, G.C. 1994. *Science on the run : information management and industrial geophysics at Schlumberger, 1920-1940*. MIT Press.

[7] Bowker, G.C. 2014. The infrastructural imagination. *Information Infrastructure(s): Boundaries, Ecologies, Multiplicity*. A. Mongili and G. Pellegrino, eds. Cambridge Scholars Publishing. xii–xiii.

[8] Bowker, G.C. and Star, S.L. 1999. *Sorting Things Out: Classification and its Consequences*. MIT Press.

[9] Carroll, J.M., Beck, J., Dhanorkar, S., Binda, J., Gupta, S. and Zhu, H. 2018. Strengthening community data: towards pervasive participation. *Proceedings of the 19th Annual International Conference on Digital Government Research Governance in the Data Age - dgo '18* (New York, New York, USA, 2018), 1–9.

[10] Clarke, C. 2009. *Storytelling for grantseekers: A guide to creative nonprofit fundraising*. John Wiley & Sons.

[11] Clarke, R., Briggs, J., Light, A. and Wright, P. 2016. Situated Encounters with Socially Engaged Art in Community-based Design. *Proceedings of the 2016 ACM Conference on Designing Interactive Systems - DIS '16* (2016).

[12] Corbett, E. and Dantec, C.A. Le 2018. Going the Distance : Trust Work for Citizen Participation. *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems - CHI '18*. (2018). DOI:https://doi.org/10.1145/3173574.3173886.

[13] Crivellaro, C., Taylor, A., Vlachokyriakos, V., Comber, R., Nissen, B. and Wright, P. 2016. Re-Making Places: HCI , "Community Building" and Change. *CHI'16, May 07-12, 2016, San Jose, CA, USA*. (2016). DOI:https://doi.org/10.1145/2858036.2858332.

[14] D'Ignazio, C. and Bhargava, R. Asking Good Questions with Data. https://databasic.io/en/culture/ask-questions.

[15] D'Ignazio, C. and Bhargava, R. Convince Me. https://databasic.io/en/culture/convince-me.

[16] D'Ignazio, C. and Bhargava, R. Data Culture. https://databasic.io/en/culture/.

[17] D'Ignazio, C. and Bhargava, R. Data Sculpture Activity. https://databasic.io/en/culture/build-a-sculpture.

[18] D'Ignazio, C. and Bhargava, R. 2016. DataBasic: Design Principles, Tools and Activities for Data Literacy Learners. *The Journal of Community Informatics*. 12, 3 (2016).

[19] D'Ignazio, C. and Bhargava, R. Sketch a Story. https://databasic.io/en/culture/sketch-a-story.

[20] D'Ignazio, C. and Klein, L.F. 2016. Feminist Data Visualization. *Workshop on Visualization for the Digital Humanities (VIS4DH), Blati*. (2016).

[21] le Dantec, C.A. and DiSalvo, C. 2013. Infrastructuring and the formation of publics in participatory design. *Social Studies of Science*. (2013). DOI:https://doi.org/10.1177/0306312712471581.

[22] Dantec, C.A. Le and Fox, S. 2015. Strangers at the Gate: Gaining Access, Building Rapport, and Co-Constructing Community-Based Research. *Cscw 2015*. (2015). DOI:https://doi.org/10.1145/2675133.2675147.

[23] Data-Pop Alliance 2015. Beyond data literacy: reinventing community engagement and empowerment in the age of data. *White paper series*. (2015), 42 pages.

[24] Data and Tech Training Catalog: *https://www.neighborhoodindicators.org/data-tech/training*.

[25] Davoli, L. and Redström, J. 2014. Materializing infrastructures for participatory hacking. *Proceedings of the 2014 conference on Designing interactive systems - DIS '14* (2014).

[26] Dörk, M., Feng, P., Collins, C. and Carpendale, S. 2013. Critical InfoVis: Exploring the Politics of Visualization. *CHI '13 Extended Abstracts on Human Factors in Computing Systems on - CHI EA '13*. (2013). DOI:https://doi.org/10.1145/2468356.2468739.

[27] Edwards, P.N. 2010. *A vast machine: Computer models, climate data, and the politics of global warming*. MIT Press.

[28] Ehn, P. 2008. Participation in design things. *Conference on Participatory Design*. (2008), 92–101.

[29] Ehn, P. 2008. Participation in Design Things. (2008), 92–101.

[30] Erete, S.L., Ryou, E., Smith, G., Fassett, K.M. and Duda, S. 2016. Storytelling with Data: Examining the Use of Data by Non-Profit Organizations. *Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing - CSCW '16* (2016), 1271–1281.

[31] Flach, J.M. 2012. Complexity: Learning to muddle through. *Cognition, Technology and Work*. (2012). DOI:https://doi.org/10.1007/s10111-011-0201-8.

[32] Frank, M., Walker, J., Attard, J. and Tygel, A. 2016. Data Literacy-What is it and how can we make it happen? *The Journal of Community Informatics*. 12, 3 (2016).

[33] Freire, P. 2000. *Pedagogy of the oppressed*. Bloomsbury Publishing.

[34] Gordon, E. and Walter, S. 2016. Meaningful inefficiencies: resisting the logic of technological efficiency in the design of civic systems. *Civic Media: Technology, Design, Practice*. 243.

[35] Gray, J., Gerlitz, C. and Bounegru, L. 2018. Data infrastructure literacy. *Big Data & Society*. 5, 2 (Jul. 2018), 205395171878631. DOI:https://doi.org/10.1177/2053951718786316.

[36] Hanseth, O. and Lyytinen, K. 2016. Design theory for dynamic complexity in information infrastructures: The case of building internet. *Enacting Research Methods in Information Systems: Volume 3*.

[37] Harding, M., Knowles, B., Davies, N. and Rouncefield, M. 2015. HCI, Civic Engagement & Trust. *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems - CHI '15* (New York, New York, USA, 2015), 2833–2842.

[38] Henderson, A. and Kyng, M. 1992. There's no place like home: continuing design in use. *Design at work*. J. Greenbaum and M. Kyng, eds. L. Erlbaum Associates Inc. 219–240.

[39] Hughes, T.P. 1984. *Hughes, T. P. (1984). Networks of Power: Electrification in Western Society*.

[40] Jones, J.C. 1983. Continuous design and redesign. *Design Studies*. (1983).

DOI:https://doi.org/10.1016/0142-694X(83)90008-X.

[41] Kayser-Bril, N. 2016. Don't ask too much from data literacy. *The Journal of Community Informatics*. 12, 3 (2016).

[42] Kitchin, R. and Lauriault, T.P. 2014. Towards critical data studies : Charting and unpacking data assemblages and their work. *Geoweb and Big Data*. (2014), 1–19.

[43] Kitchin, R., Lauriault, T.P. and McArdle, G. 2015. Knowing and governing cities through urban indicators, city benchmarking and real-time dashboards. *Regional Studies, Regional Science*. 2, 1 (2015), 6–28. DOI:https://doi.org/10.1080/21681376.2014.983149.

[44] Kitchin, R., Maalsen, S. and McArdle, G. 2015. The Praxis and Politics of Building Urban Dashboards. *SSRN 2608988*. (2015).

[45] Korn, M. and Voida, A. 2015. Creating Friction: Infrastructuring Civic Engagement in Everyday Life. *Aarhus Series on Human Centered Computing*. 1, 1 (2015), 12. DOI:https://doi.org/10.7146/aahcc.v1i1.21198.

[46] Latour, B. 2008. A Cautious Prometheus? A Few Steps Toward a Philosophy of Design (with Special Attention to Peter Sloterdijk). *Design History Society*. (2008), 2.

[47] Leigh Star, S. 2010. This is Not a Boundary Object: Reflections on the Origin of a Concept. *Science, Technology & Human Values*. 35, 5 (Aug. 2010), 601–617. DOI:https://doi.org/10.1177/0162243910377624.

[48] Loukissas, Y.A. 2016. Taking Big Data apart: local readings of composite media collections. *Information, Communication & Society*. 4462, August (2016), 1–14. DOI:https://doi.org/10.1080/1369118X.2016.1211722.

[49] Ludwig, T., Stickel, O., Boden, A. and Pipek, V. 2014. Towards sociable technologies: An Empirical Study on Designing Appropriation Infrastructures for 3D Printing. *Proceedings of the 2014 conference on Designing interactive systems - DIS '14* (2014).

[50] Rajapakse, R., Brereton, M. and Sitbon, L. 2018. Design Artefacts to Support People with a Disability to Build Personal Infrastructures. *Proceedings of the 2018 on Designing Interactive Systems Conference 2018 - DIS '18* (New York, New York, USA, 2018), 277–288.

[51] Rajapakse, R., Brereton, M. and Sitbon, L. 2018. Design Artefacts to Support People with a Disability to Build Personal Infrastructures. *Proceedings of the 2018 on Designing Interactive Systems Conference 2018 - DIS '18* (New York, New York, USA, 2018), 277–288.

[52] Sengers, P. 2018. Diversifying Design Imaginations. *Proceedings of the 2018 on Designing Interactive Systems Conference 2018* (2018).

[53] Simon, H.A. 1969. *The sciences of the artificial*.

[54] Star, S.L. 1999. The ethnography of infrastructure. *American Behavioral Scientist*. (1999). DOI:https://doi.org/10.1177/00027649921955326.

[55] Star, S.L. 1989. The Structure of Ill-Structured Solutions: Boundary Objects and Heterogeneous Distributed Problem Solving. *Distributed Artificial Intelligence*.

[56] Star, S.L. and Bowker, G.C. 2002. How to Infrastructure. *Handbook of New Media: Social Shaping and Consequences of ICTs*. L.A. Lievrouw and S. Livingstone, eds. SAGE Publications, Ltd. 151–162.

[57] Star, S.L. and Ruhleder, K. 1996. Steps Toward an Ecology of Infrastructure: Design and Access for Large Information Spaces. *Information Systems Research*. 7, 1 (1996), 111–134. DOI:https://doi.org/10.1287/isre.7.1.111.

[58] Storytelling with Data: *https://www.neighborhoodindicators.org/data-tech/course-catalog/data-101-data-visualization-data-literacy-and-storytelling*.

[59] Taylor, A.S., Lindley, S., Regan, T. and Sweeney, D. 2015. Data-in-Place: Thinking through the Relations Between Data and Community. *CHI 2015, Crossings*. (2015), 2863–2872. DOI:https://doi.org/10.1145/2702123.2702558.

[60] Tonkinwise, C. 2005. Is Design Finished?: Dematerialisation and Changing Things. *Design Philosophy Papers*. (2005). DOI:https://doi.org/10.2752/144871305X13966254124437.

[61] Tygel, A.F. and Kirsch, R. 2016. Contributions of Paulo Freire for a Critical Data Literacy: a Popular Education Approach. *The Journal of Community Informatics*. 12, 3 (2016).

[62] Wolff, A., Gooch, D., Cavero Montaner, J.J., Rashid, U. and Kortuem, G. 2016. Creating an Understanding of Data Literacy for a Data-driven Society. *The Journal of Community Informatics*. (2016).

[63] Wong-Villacres, M., Kumar, A., Vishwanath, A., Karusala, N., DiSalvo, B. and Kumar, N. 2018. Designing for Intersections. *Proceedings of the 2018 on Designing Interactive Systems Conference 2018 - DIS '18* (2018).

[64] Wood, C., Poslad, S., Kaniadakis, A. and Gabrys, J. 2017. What Lies Above: Alternative User Experiences Produced Through Focussing Attention on GNSS Infrastructure. *Proceedings of the 2017 Conference on Designing Interactive Systems - DIS '17* (New York, New York, USA, 2017), 161–172.

[65] Westside Investment Map. http://westsideinvestmentmap.gatech.edu/infovis.html.