Data Visualization as a Social-Relational Approach in Research & Design

by

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B.A., University of Calgary, 2018

Dissertation Submitted in Partial Fulfillment of the
Requirements for the Degree of
Doctor of Philosophy

in the
School of Interactive Arts and Technology
Faculty of Communication, Art and Technology

SIMON FRASER UNIVERSITY
Summer 2025

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Abstract

In my dissertation, I present a social-relational approach to research and design in data visualization. Applying the social-relational concept as a lens, I explore how people's interactions with data visualizations are enmeshed with their distinct social worlds. Thus, data visualizations may enable people to relate to visual information in socially oriented ways that extend beyond the cognitive interpretation of datasets. I explored social-relational qualities through data visualization activities in reflexive c ollaborations w ith a cademic r esearchers a nd d esigners f rom m ultiple disciplines. Then, I co-constructed a data physicalization with members of the general public who were not researchers or designers. My projects' social-relational approach to data visualization practices promoted introspection, self-expression, and rapport-building. Moreover, interactive experiences among members of the public co-constructing a data physicalization with a researcher revealed nuanced social-relational dimensions. Lastly, I characterize social-relational themes in my projects to inform considerations specific to researching and designing for socially oriented engagement with data visualizations.

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DataVis An abbreviation for the academic field of data visualization, or information visualization.

HCI An acronym for the research field of Human-Computer Interaction.

Social Refers to the interactions between people in a cyclic exchange of ideas through mutual encounters such as discussion, sketching, or building a physicalization in the same physical co-located setting or a synchronous online setting. Through this interaction, people are part of a joint activity that depends on each other's actions. Participants' personal states shift due to the interactions, such as learning about another person or thinking or feeling in response to their counterparts in the interaction.

Sociality Participatory or active interactions among groups of two or more people. Sociality is inherent to scientific practices in data visualization and integral to human sense-making experiences. Therefore, sociality is relevant to research and design in data visualizations because making sense of large datasets is a design goal in the field.

Relational A socially-aware approach in research and analysis that considers how people are interconnected with their social networks, physical and digital environments across regional, cultural, and historical contexts and distinct personal lived experiences. I also refer to people's interactions related to their worlds by relational approaches.

Community A group of people with shared beliefs, norms, or goals. A member of a community may participate in group activities, relate to the group members, and feel a sense of belonging, fulfillment, self-identity, or an emotional connection to the group.

Social-Relational A term that encompasses interdependent social networks and connections, with multiple variables such as people, region, history, power, culture, identities, and social constructs like gender or race. Furthermore, the relational approach also includes assumptions that people associate their daily interactions with socially constructed norms and behaviours deeply rooted in their identities and communities.

Researcher-Designers or Academics Individuals who are researchers and/or designers in the academic fields of data visualization, human-computer interaction (HCI), or art and design.

Members of the Public or The Public Individuals who are not academics, researchers, or designers in data visualization or HCI. This distinction helps inform my research questions by identifying the different roles within the interactions I explore. However, the term "public"

encompasses multiple and shifting social roles. For instance, a researcher in data visualization can simultaneously be part of the public community when acting in a different social role or identity, depending on the context.

Data Data are multiple units of information, either numeric, categorical, textual, spoken and heard (dialogical), or image-based, such as personal hand-drawn sketches. I frame data as abstractions of deeply complex interconnected networks. Therefore, data represent aspects of interlinked systems, such as social, geographic or ecological.

Interaction An active participation of two or more people in a mutual activity in which each participant contributes to and responds to others in the group. Communicative activities may include discussions, sketching, listening, responding, writing, peer reviews, reflecting on one's beliefs, reasoning, criticality, and feedback.

Design Design[ing] as a verb means the process of thinking about, conceptualizing and making some item. In this thesis, the items that are being designed are data visualizations or physicalizations. The final design can be a noun, referring to the final concept or creation.

Community-Data Interaction A social-relational approach. Specifically, a research and design orientation I used to explore the nuanced social dimensions between members of the public and data visualizations or physicalizations. The interactions embody people's experiences, attitudes, feelings, and community relationships about data and data visualization.

Reflexivity A cyclic iterative practice of thinking about one's professional praxis and personal context, either alone or in a group with peers. Reflexivity can be acknowledging one's social position as part of gaining deeper personal and social awareness related to the context of one's social setting. For example, reflexive activities include critical conversations, writing, drawing, art construction, and dancing.

Socio-Visual Data A concept characterizing social-relational dimensions of people's interactions with visual or physical data representations.

Chapter 1

Introduction

In my thesis, I explore the *social-relational* properties of data visualization. **Social-relational** is a term I use to describe the details of how people relate to data via visualization in socially oriented ways. I use this term to include such factors as: interpersonally felt connections with a group of people that develop *through* interactions with data via visualizations or physicalizations; the social aspects of the collaborative design processes in the fields of data visualization and physicalization; and emotions arising from these types of interactions. The academic field of data visualization has been my academic home since the COVID-19 pandemic began. While I bring socially oriented perspectives from other fields, such as human-computer interaction (HCI), philosophy, or sociology, my observations and contributions are grounded in the field of data visualization. I focus on the creation process of visualizing data rather than a post-hoc experience with a data visualization.

From the outset of this research, I observed that in the field of data visualization, creating, presenting, and exploring data visualizations involved social and relational aspects that were seldom explicitly considered in data visualization processes. This was particularly true when it came to visualizing information for public engagement, even though public interactions are inherently social. **Sociality** has been used to describe the interaction among two or more people who relate to each other and gain insights or knowledge from each other's responses in reciprocal exchanges such as discussions, or writing and reading [189]. Sociality is central to public engagement with data visualizations. For example, people in the public can interpret visual information in personal ways related to their family and community lives [148, 243]. They may also interpret information in emotional ways [198, 312] and refer to community-oriented histories related to social structures of power, race and gender [70, 102, 146, 294]. Sociality is essential to the academic practices in data visualization. For example, visualization designers are rooted in academic social circles where training, practice, and research happen through professional interactions. Decisions made by designers are anchored in their personal social biases and social positions [244]. Some data visualization designers have considered the social structures of power, gender and race [85], such can be shown when visualizing demographic data [80, 146].

For public engagement with data, I looked to merge the social-relational aspects of people's interactions with visual or physical data representations — a concept I call the **socio-visual**. Then,

I aimed to design and implement socio-visual techniques in data visualization to engage people. However, I did not find established data visualization methods that promote socially oriented or relational interactions. Little has been explored in the realm of social-relational criteria for designing data visualizations. Thus, in my research, I discuss factors that point to the potential of data visualizations and physicalizations as tools for personal reflection [148, 152, 291] and physicalization to support collaboration [56, 239]. Sociality is a fundamental component of data visualization processes in research, design, and implementation [13, 84]. Yet, the social-relational dimensions of human-data interactions have been little discussed, which led me to seek a deeper understanding of these dimensions when people use visual data, both during the creation and interpretation of data visualizations.

Data visualization designs tend to adhere to disciplinary conventions that prioritize cognitive and perceptual interactions with data. Data visualization standards are based on widely accepted data mapping techniques, such as those proposed by Bertin [31], Tufte [297], Munzner [222], and Yau [323], which support cognitive insights through visual information. However, the visual conventions of data mapping do not adequately consider the social-relational properties of people's interactions with visual data. For example, Zhang and colleagues reviewed over 600 data visualizations of COVID-19 data, finding nearly all the visualizations focused on cognitive rational sense-making in user engagement [327]. Yet, sociality is inherent in data visualization creation and reading practices and integral to human sense-making experiences and is not often integrated into how data are visualized.

I posit that a deeper understanding of the social-relational dimensions can enrich how people relate to visual or physical representations of data about themselves and their communities. In my research, I explore the implicit social-relational properties of data visualization processes and interactions, aiming to make them more noticed and explicit. In my thesis, I will present my research ideas and findings to draw attention to the social-relational qualities in processes and interactions among researchers and public participants. I then contextualize these qualities within critical perspectives in data visualization for public engagement. Then, I discuss the potential for leveraging social-relational approaches in data visualization for research and design across multiple disciplines, as well as community engagement in the future.

1.1 Motivation

Given my formative experiences in nursing and my PhD studies at the onset of COVID-19, it is natural for me to first consider medical data, particularly COVID-19 data. Data visualizations supported public health goals that focused on improving informed public consent and evidence-based decision-making. Within the field of visual analytics, information visualization is often referred to as a "visual language" [49]. For example, the flagship conference of data visualization is celebrating "100 Years of Visual Language [69]" to commemorate Otto Neurath's contribution to data visualization. As a visual language, data visualization provides the evidence

(the data) and a communication medium (the visual standards). However, I found that this visual language is limited to a lexicon that incorporates only one dimension of human engagement with information: cognitive, rational engagement. Therefore, standard data visualization is a useful visual language that eases cognitive efforts for rational thinking with data. Rational, data-informed thinking is essential for making informed decisions about public health advice during the COVID-19 pandemic. However, public responses to data visualization messaging showed that people interpreted and experienced health information in not only cognitive, rational ways. In addition, experiences with data included social, relational, and emotional dimensions. Therefore, I was seeking a visual data language that also incorporated social-relational dimensions, but I could not find one at the time.

I sought a data language to support community social life, such as relational and emotional aspects of health data. I wanted to visualize COVID-19 data in a social-relational way, but did not find established approaches to visually represent numeric or categorical data based on social criteria (I refer to the criteria I was looking for as *socio-visual* dimensions). From my nursing experience, I knew that health outcomes were better when individuals felt supported by and were an active part of their communities, which may include their partners, family members, friends, or neighbours. Thus, I wanted to use data visualization to engage users in *feeling part of the community* or *relating with the data* in community-oriented ways. I asked myself rhetorical questions:

- *Could an individual feel supported by the community through interactions with data?*
- *Can data visualizations be designed to promote a feeling of social connection to other people?*
- *What is an alternative data language for my holistic community-based approach to health intervention with data visualization?*
- I*s there a social visual lexicon to promote not only cognitive but social and affective experiences with data visualizations?*

1.2 Background

I position my work within prior research that reports on people's deeply personal and interpersonal experiences interacting with data visualizations. Data visualizations are intended to ease the interpretation of datasets by visually representing them [31, 222, 323]. Numeric and categorical data are visually represented and spatially organized to show patterns, such as graphs or bar charts. The data are abstractions of complex, dynamic social interactions local to distinct communities of people. I began to deconstruct and reframe how data can be visualized as part of an emergent reciprocal social process.

1.2.1 Social Engagement with Data Visualizations

To make sense of data, a data user must be engaged to interact with visualized data. Engagement with data visualization may refer to interactions among people and data visualizations that include experiential dimensions such as perceptual, spatial, or cognitive, ranging from viewing, haptics, proximity to a physical object, or inputting data into a graph or a chart, either on paper or a computer screen or into a physical form of data (data physicalization) like an art installation in a museum.

Though it is widely acknowledged that social worlds are involved in data production and visualization, the social dimensions of *engagement* with data visualizations among the people who use and create them have been little discussed or explored in the processes of visualization and *engaging* with data visualizations. Therefore, I propose that understanding sociality in how data visualizations are perceived, interacted with, and created is essential for designing engaging data visualizations for a broader scope of interactive social experiences.

1.2.2 Data Visualization as a Tool for Personal Emotional Experiences

My work on the social dimensions of visual data builds on scholarship that shows data visualization can promote affective and individual personal experiences [148]. Researchers, designers, and members of the public have used data visualizations for pro-social community-oriented purposes [17, 229, 247]. Data visualizations were used to promote personal social experiences that may make people feel or take action for the greater good of society [32]. However, despite designers' socially motivated aims, they are often limited to established cognitive data mappings and techniques. Data visualization methods prioritize cognitive criteria for rational sense-making of data [89, 231]. Moreover, research on data visualization is conducted in laboratory settings by academics removed from public community life, with a majority of the research participants being graduate students, who serve as proxies for "novices" or "the public" user of data visualization [46]. Based on my reading, affective user experiences often occur when people interact with data visualizations. However, I have found that the social properties of those interactions are frequently reported as secondary outcomes to users' ability to decipher data. These affective social experiences occur despite the standard methods prioritizing visual data for improved cognitive criteria and rational sense-making. For instance, data visualization researchers claim that visualizing data offers statistical insight into data patterns and eases cognitive efforts for users [241]. In addition to improved cognitive rationale, affective, social and relational experiences were reported, such as a process for communication and collaboration [56, 173, 238] self-reflection [291], collaborative fun and playfulness [91, 120, 123, 240], curiosity and serendipity [290], thoughtfulness [145], and expression or feelings about community identities [32, 246, 288] cultural identities and cross-generational stories through data [215]. Therefore, I was interested in further exploring socially connective engagement among people and data interactions with data visualization.

1.2.2.1 COVID-19 Pandemic: An Example Why Social-Relational Dimensions Must be Considered in Information Visualization

To contextualize my work, I discuss the COVID-19 pandemic as a use case and the starting point in my research journey. During the COVID-19 pandemic, hundreds of data visualizations supporting public health messaging to "flatten the curve" [7] flooded public media. COVID-19 data visualizations were intended to *engage* the public by helping people interpret health information more easily to make rational decisions for the collective good. However, a COVID-19 *infodemic* emerged [2], which the World Health Organization (WHO) and the United Nations (UN) described as excessive information that led to public confusion, distrust, and even division within communities [1]. There was a marked gap between designing data visualization for cognitive ease and fair mathematical representation, and the emergent need for people to experience a sense of community with slogans like "we're all in this together" [4, 188], to feel social safety and leverage community strengths and connections in the face of a divisive global crisis. The WHO called for nations to engage and empower local communities with COVID-19 data [1]. However, based on standard practices in data visualization, most COVID-19 visualizations were created with cognitive, rational goals, such as supporting user understanding of death or vaccination rates [327], with limited academic knowledge on how to engage people beyond rational-cognitive approaches and, instead, to design visualizations for social, relational, and community-oriented empowerment.

1.2.3 Social and Community Perspectives are Underexplored in Data Visualization

As a former nurse and public health researcher, I recognized the urgent need to develop a socially oriented approach to representing data. My research questions align with the WHO's [236] urgent call for nations to address the infodemic through community engagement about COVID-19, aiming to build cohesive public trust and protect society's most vulnerable. At that time, COVID-19 visualizations were a primary means of communication. They reproduced the same data visualization design relevant to expert epidemiologists, while public perceptions of data visualization remain mostly unknown [137, 46]. Conversely, the WHO advised implementing socially-oriented activities to explore COVID-19 information directly with the public, such as "listening, promoting understanding, engaging and empowering communities" as follows:

- "Listening to community concerns and questions."
- "Promoting understanding of risk and health expert advice."
- "Building resilience to misinformation."
- "Engaging and empowering communities to take positive action."

[1].

[1] https://www.who.int/health-topics/infodemic#tab=tab$_1$

I wondered how data visualizations could include these social tasks and which criteria would be included in a socio-visual representation of public health data. Thus, I wanted to explore how data visualization can visually engage people in social ways.

In my dissertation, I explore and characterize the concept *socio-visual*, which describes social-relational interactions involving visual or physical data representations. I consider including members of the public, as well as researchers and designers of data visualizations, as active participants in understanding the social-relational properties within their interactive activities. I consider the social-relational dimension of data to be a fundamental step in designing data visualizations that prioritize an individual's ability to relate to data in a socially interconnected way. Through multiple research collaborations in my PhD, I explore *social-relational data visualization*. Then, I contextualize my projects within a practical research and design approach that integrates people's socially oriented interactions with visual data.

1.3 Research Goals

I explore the social dimensions of data visualization through collaborations with people who design, teach, use or think about data visualization. Drawing on critical perspectives proposing data as a dynamic and social process [80, 87, 89, 231], I wanted to uncover some of my assumptions and those of the community of practice I continue to learn alongside in data visualization (DataVis) and Human-Computer Interaction (HCI) in Computer Sciences. Throughout my PhD, I developed a deeper personal awareness and enhanced interpersonal connections, including a better understanding of how data are visualized and perceived. Specifically, I explored data visualization as an approach for reflective interpersonal awareness in bespoke collaborative interactions with academics and with members of the public.

To explore social-relational dimensions in data visualization, I consider how people and data are interconnected within their social worlds, local settings, and histories. I focus on two groups in my projects:

Academics or Researcher-Designers: Individuals who are researchers and/or designers in the academic fields of data visualization, human-computer interaction (HCI), or art and design (shown by green font throughout the thesis).

Members of the public, or the public: Individuals who are not academics, researchers, or designers in data visualization or HCI (shown by violet font throughout the thesis).

The distinction between the two groups — academics, or researcher-designers, and members of the public — is relevant to address my research questions because social roles and identities influence people's interactions [28, 199, 214] and are enmeshed with power dynamics and social interactive dimensions that I aim to examine.

1.3.1 Research Statement

Creating data visualizations for social-relational purposes is an understudied yet essential area if we, as researchers and data visualization designers, want to increase our understanding of making data visualizations more relatable and socially engaging to a broader range of people. Data are not visualized based on social-relational or affective criteria, despite the socially-oriented goals of many designers. The standard methods of representing numeric or categorical data do not account for social worlds. Rather, data are visualized based on cognitive perceptual criteria from laboratory user evaluations. The corpus of data visualization literature lacks a comprehensive understanding of public audiences beyond laboratory settings. Additionally, there are no established data representations specifically for social-relational tasks or a taxonomy based on social interactions with visual data (socio-visual). Moreover, there are socially oriented efforts to increase data literacy for the public. However, a top-down power dynamic exists between data experts and members of the public. For instance, members of the public are seldom invited to give direct input when experts design data visualizations. The experts tend to focus on user "deficits" or "needs" and are remiss in understanding socially nuanced interpretations and community knowledge that can contribute to how information is visualized and shared for non-cognitive, community-related interactions among people and data.

To address this understudied area, I explore how researchers, designers of data visualizations, and members of the public visualize and perceive data visualizations in social-relational ways. Specifically, I examine the creation process. During my PhD, I designed, facilitated, engaged in reflexivity, and observed interactions between people and data visualizations (see Figure 1.1). I analyzed my research collaborations through a social-relational lens. Through my research, I demonstrate that data visualization is an interactive social activity that enables community-oriented exchanges among individuals, thereby deepening the current understanding of the sociocultural and relational dimensions of data visualization research and design processes. I found that data visualization is not only a tool to interpret datasets but also a nuanced and sensitive approach in qualitative research and design for socially oriented inquiry.

1.3.2 Research Questions

My overarching research question is: **How can data visualization and its process activities facilitate and support social interactions among researchers and members of the public?**

As a step toward understanding how the process of data visualization supports social relational interactions among researchers and the public, I addressed the following sub-questions in Section 6.20 and Chapter 8. Then, in Section 8, I compare the social relational themes I identified in my work with academic researcher-designers with those I found in my work with members of the public.

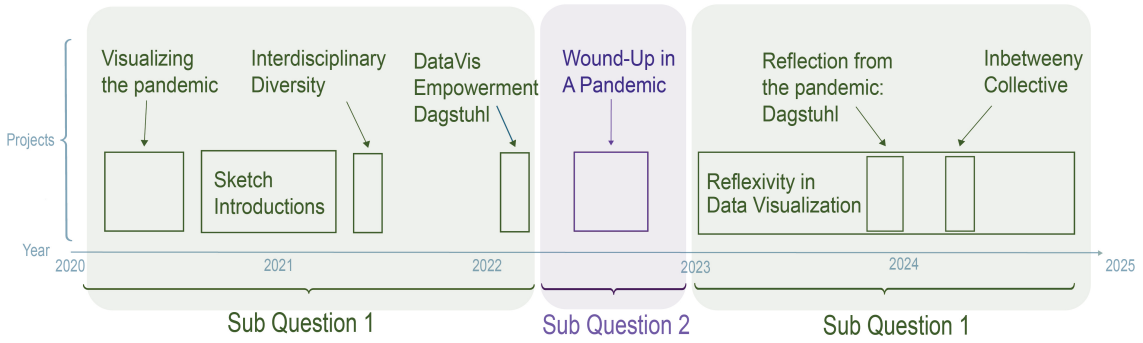


Figure 1.1: Timeline of my PhD projects in which I explored my research question by focusing on two sub-questions divided by participant group. The first question focuses on academics shown in green. The second question focuses on members of the public shown in violet.

Sub-Question 1: How do academic researcher-designers in data visualization or HCI approach social-relational aspects in data visualization?

Sub-Question 2: How might members of the public approach data visualization if introduced to data visualization designed with a social-relational perspective?

1.4 Research Methods: Reflexive Approaches with Academic Colleagues and Members of the Public

I use reflexive research practices in my work, which means that researchers and designers in data visualization – including myself – explore our practices, experiences, assumptions, and epistemic positions through individual and collective activities that promote reflection on our professional practices. These methods benefit my research goals because data visualization in personal analytics and data physicalization have been shown to facilitate self-reflection and self-expression [148]. Through individual and collective reflexivity in my work, my colleagues and I discuss standard practices and innovations in our field and acknowledge differences in power as well as social and epistemic assumptions. We also consider our roles in building and sustaining communities while deepening our understanding of the social contexts of our respective praxes. I employed semi-structured interview protocols and data physicalization as a design-oriented reflective research method in Chapter 7 about a project called "Wound Up in a Pandemic". In Chapter 5, I used sketch-based research methods in my project "Sketching Introductions". In all of my collaborations, I employed autoethnographic methods, including reflexivity, which involves analyzing one's professional practices to improve them [108]. This approach also involves incorporating myself as a reflexive instrument in the research process, as described by Braun and Clarke's reflexive dialogical and thematic analysis [41]. For my final reflexive meta-analysis in Chapter 8, I adapt Longino's

[191, 189] definition of "sociality" to identify the social-relational aspects of my collaborations. The term *sociality* includes the terms "social" and "interactions" as the constructs I used for deductive (closed) coding in reflexive thematic analysis [41] (for a summary of methods, see Appendix B.1).

1.5 Thesis Structure: Wayfinding for the Reader

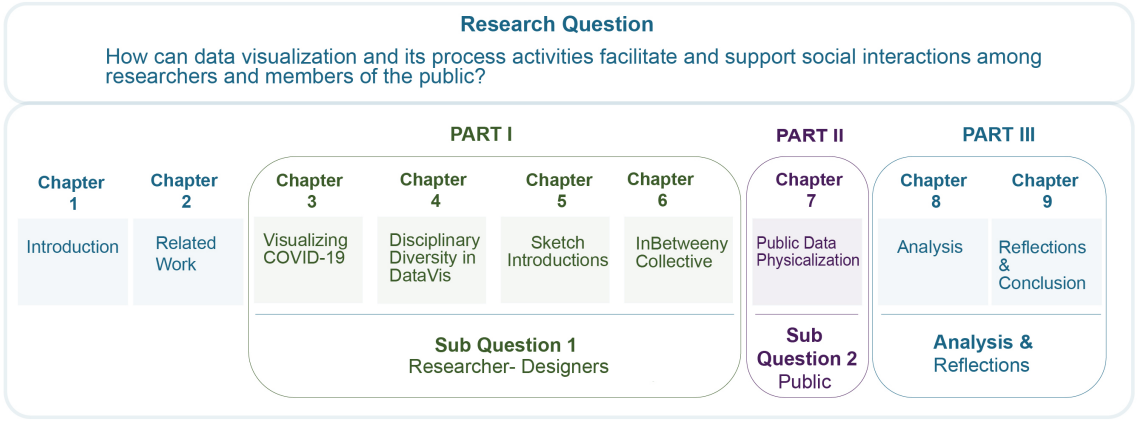


Figure 1.2: Outline of my thesis structure showing chapters nested within research sub-questions. Chapters 3-7 include manuscripts or published papers that describe collaborations with either academic researcher-designers (represented by green font) or with members of the public (represented by violet font).

I organize my dissertation based on the subquestions and the corresponding projects that investigate them, as shown in Figure 1.2. I begin my dissertation by reviewing related work to position my research within the relevant literature. Then, I divide my dissertation into three parts. The first part addresses my first sub-question regarding the social relational dimensions of researchers and designers in data visualization (shown in green font). The second part of my thesis focuses on the second sub-question related to how members of the public approach data visualization in social-relational ways (shown in violet font). In the third part, I analyze the themes I identified throughout my collaborations and contextualize my analysis with reflections and opportunities for future research directions. A list of the projects and their contributions to my research is included in the Appendix C. The following describes the sections in more detail:

PART I: Exploring How Researchers in Data Visualization Approach Data Visualization in Social-Relational Ways

Sub-Question 1: How do academic researcher-designers in data visualization or HCI approach social-relational aspects in data visualization?

In Part 1, I explore the social-relational qualities by participating in reflexive interactions with 36 researchers and designers in data visualization or human-computer interaction (HCI) through 10 projects (list of projects is in Appendix C). In Chapters 4-6, I explore interdisciplinary practices and social power dynamics in data visualization through reflexive academic practices.

PART II: Exploring Social-Relational Dimensions Among members of the public & Data Physicalization

Sub-Question 2: How might members of the public approach data visualization if introduced to data visualization designed with a social relational perspective?

In Part 2, I explore the social-relational dimensions of members of the public and data physicalization by facilitating a public co-construction of data physicalization that represents public trust in COVID-19 information sources, such as government, public health authorities, social media, or family and friends. By employing data physicalization as a participatory research-through-design approach [307], I identified social relational themes of sociability, perceived safety and freedom, slowness, and relational data interaction. In Section 6.20, I contextualize the themes to shed light on how a select group of members of the public perceive data visualization in social relational ways.

PART III: Analysis & Reflections

My overarching research question is: **How can data visualization and its process activities facilitate and support social interactions among researchers and members of the public?**

In Part 3, I describe the social and relational themes I identified by analyzing the 10 manuscripts or papers from my reflexive collaborations with data visualization researcher-designers. These themes likely inform the design of data visualization activities and guide ethical considerations in academic design work. Through my projects, I found a nuanced interplay between themes of sociability, social awareness, time, social norms, and reciprocity, all of which shape how researchers and designers approach their collaborations, research, or teaching in data visualization as discussed in Chapter 8. I present how exchanges among researcher-designers occurred, what their social-relational exchanges were like, and how they refer to the term "engagement" in social-relational terms. Then, I contrast the themes from academics with those of members of the public to investigate my research question through a reflexive conclusion in Chapter 9.

1.5.1 Thesis Structure

I organize the thesis as follows:

Chapter 1: Introduction includes an introduction, an overview of my research questions and explains the organization of my dissertation.

Chapter 2: Related Work includes my review of relevant literature divided into ideas that influenced my exploration of social-relational processes in the research and design of data visualizations. I integrate scholarship from data visualization (DataVis), human-computer interaction (HCI), and Feminist scholarship across HCI, science and technology studies (STS), sociology, philosophy of science, law and governance.

I divide the core of my dissertation into two parts according to my two research sub-questions.

PART I: Exploring Social Relational Dimensions with Researchers & Designers in Data Visualization

Part 1 of my dissertation includes Chapters 3, 4, 5, and 6, in which I explore reflexive collaborations with my colleagues. My projects include reflections on distributed collaboration, designing COVID-19 data visualizations for the public, exploring interdisciplinarity in data visualization, creating sketch-based personal visualization introductions in collaborative academic settings, and examining how researchers' lived experiences and social worlds influence their research approaches.

PART 1: Chapter 3: Exploring Researcher-Designers' Activities in Remote Design Work

- "Distributed Synchronous Visualization Design: Challenges and Strategies". We reflect on our experiences of distributed collaboration in designing COVID-19 data visualizations and trying to preserve the social richness of in-person collaboration online [193].

PART 1: Chapter 4: Exploring Interdisciplinary Approaches & in Data Visualization

- "Embracing Disciplinary Diversity in Visualization". Through reflections with data visualization researcher-designers, we outline the most familiar research approaches in the field of data visualization and draw attention to research approaches that go beyond what is often seen in the data visualization literature [192].

PART 1: Chapter 5: Valuing the social-relational within academic introductions

- "Sketch Introductions: Shifting Introductory Formalities in Collaborative Design Practices". We present an activity of self-sketched introductions as a playful way for new collaborators to introduce themselves via their hand-drawn sketches. We discuss our process of developing and facilitating a sketch-based icebreaker activity, explaining the social and visual considerations we learned through our reflexive, design-oriented process.

PART 1: Chapter 6: Exploring How Researcher-Designers Relate to Their Work in Personal or Social Ways

This chapter includes the following two papers:

- "The Inbetweeny Collective: Reflexive Dialogues on the Liminality of Researchers' Lived Experiences" (Section 6, we reflect on how researchers' lived experiences and social worlds affect their research approaches in the fields of data visualization, human-computer interaction, and health [252].

PART II: Exploring Social Relational Dimensions with Members of the Public

Part II includes Chapter 7, which explores how members of the public interact with a participatory activity involving the co-construction of a data physicalization representing trust in information sources about COVID-19.

PART II: Chapter 7: Investigating Public Perceptions on COVID-19 Data Through Participatory Data Physicalization

- This chapter includes the manuscript "Wound Up in a Pandemic: Community-Data Interaction in the Making", where we designed and implemented a community data physicalization as a way to explore social dimensions of how members of the public interacted with data physicalization and their personal perceptions and local community contexts.

PART III: Analysis & Reflections

In Part III, I include chapters 8 and 9, where I tie the thesis together with an analysis and contextualization of social-relational dimensions throughout my projects.

PART III: Chapter 8: Reflexive Thematic Analysis

- In this chapter, I include a reflexive content analysis of my collaborations using the papers we co-authored to identify *how* social exchanges happened among the co-authors, and *what* the exchanges were like, and the contexts in which the word "engagement" was used. I deductively analyzed 10 papers or manuscripts I co-authored, which are listed in Appendix C, using Longino's theory of the *sociality of interactions* [191]. The analysis protocol is in Appendix B.1. I focus on the following interactions: 1) **exchanges between researcher-designers**, and 2) on **the mutual effects** from their interactions, such as social, emotional, and community-oriented feelings or considerations reported in the papers.

PART III: Chapter 9: Reflections & Conclusion

- In the final chapter, I reflect on my personal and professional growth throughout my PhD projects and contextualize the social-relational themes that I found in my analyses with both academics and members of the public. Then I present future opportunities and questions for research.

Chapter 2

Related Work

Summary

In this chapter, I situate my thesis within critical discussions about research in the field of data visualization and physicalization. The following ideas from the literature are relevant to my thesis:

- **Feminist and social constructivist theories offer a framework** to a) characterize the word and concept of "data" as representing social processes and systemic power dynamics, b) conceptualize social interactions as spaces for knowledge production, and c) explore social-relational dimensions in research applications through reflexive analysis of social interactions and academic collaborations.
- **The social dimensions of visual data remain underexplored.** Researchers, therefore, call for more socially-oriented research with the public because data are embedded in diverse personal, emotional, and community experiences.
- **A limited number of studies have specifically explored sociality between people and data visualization design and research practices.** Yet, sociality is foundational to the scope of practices and experiences in data visualization.

In this chapter, I situate my thesis within critical discussions about research in the field of data visualization and physicalization. My focus is on literature that demonstrates the potential of data visualization or physicalization to support participatory explorations of the social-relational dimensions between people and data. I focus on prior participatory design-oriented research approaches because they include social interactions among people. The findings report on social perspectives relevant to my research goals. I discuss that many researchers and designers in data visualization acknowledge that visual data and people are socially connected, and data are *relational*. However, few studies have specifically explored sociality between people and data visualization design and research practices through participatory reflexive methods. My work builds on theoretical work in feminist data visualization by examining what I call **socio-visual**

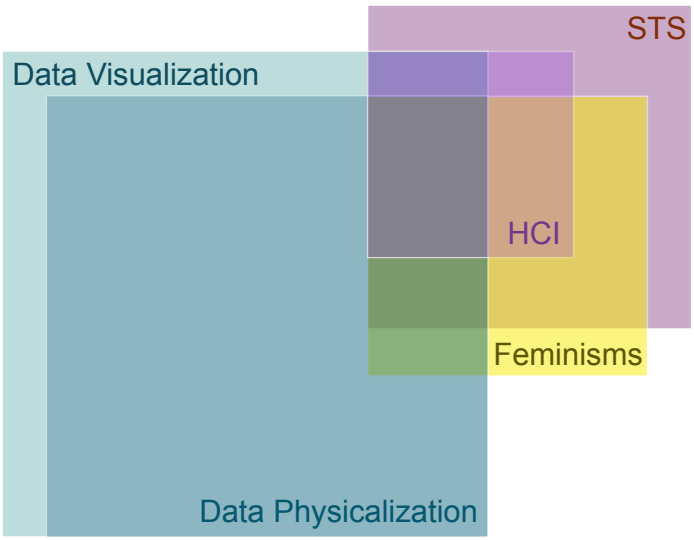


Figure 2.1: The square sizes correspond to the number of papers reviewed within each field. Overlapping areas indicate interdisciplinary intersections. "STS" is science and technology studies and includes sociology, philosophy of science, law and governance.

interactions. This term refers to the social and relational aspects of how people engage with visual or physical representations of data.

My thesis is situated within multiple interdisciplinary perspectives. I refer to literature from data visualization, human-computer interaction (HCI), and feminist theories across science and technology studies (STS), sociology, psychology, philosophy of science, and law and governance. Figure 2.1 shows how these research areas overlap in my work. **I organize the related work by ideas that motivate my explorations and anchor my contributions within the field of data visualization.**

2.1 Motivation: Challenges and Opportunities in Data Visualization

I highlight challenges and opportunities in the field (see Figure 2.2): Limited understanding of how the public engages with visual data, the lack of reflexive research practices among academics, unequal power relations between researchers and the public, and the opportunities of leveraging social interactions in the processes of visualizing or physicalizing data.

2.1.1 Limited Understanding of Public Perceptions and Public Engagement with Visual Data

My research is relevant because researchers and designers of data visualizations in academia have not established the socio-visual dimensions, with little exploration into how members of the public perceive data visualizations in social-relational ways [46, 137]. I am concerned about the lack of social-relational approaches in data visualization, given the increasing socially oriented efforts in the field. For instance, promoting data literacy for the public [52, 57, 97, 164, 214] where

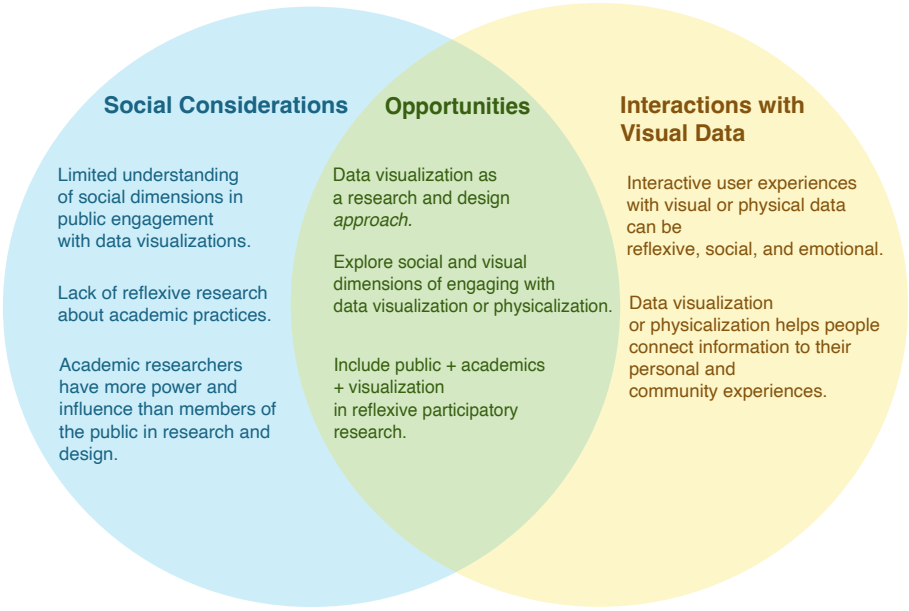


Figure 2.2: I show the opportunities of integrating socially-based findings in data visualization research with the limited scope of social-relational understanding in the field.

community relationships and cultural identities play a critical role in how information is visualized and perceived [32, 288]. Similarly, the World Health Organization (WHO) and the United Nations (UN) have urgently called for community-oriented public engagement with COVID-19 information to address a barrage of global misinformation about the pandemic, referred to as an 'infodemic' [236]. However, the word "engagement" and how to engage people in a social-relational way with data visualization has been little explored. The infodemic encompasses data visualizations and complex social relationships and emotions that influence how people perceive information [1, 236]. However, the social-relational aspects of public communities are little known within the corpus of data visualization literature. Many studies in data visualization have focused on cognitive perceptual user experiences in university laboratory settings [46].

2.1.2 Exclusion of Public Participation in Data Visualization Research

Members of the public are often excluded from research in data visualization. For instance, a recent literature review by Burns et al. found that research participants in data visualization papers about "novice" users or "the public" were mainly university students in their 20s [46]. In the following, I highlight projects outside university laboratories that demonstrate potential to involve the public as active contributors to data physicalizations, which report on emotionally personal, social, or community-based user experiences with data visualizations [137, 243].

2.1.3 Top-Down Power Dynamics Between Academics and the Public

I describe concepts of *data* from the post-positivist worldview and the feminist social constructivist perspective. Drawing on feminist critiques of power, I explain what socially-oriented feminist approaches are like in theory and practice. Therefore, I consider the roles of two contrasting groups involved in data visualization: academic researchers and members of the public, because of their unequal power differences. For example, researchers and designers working in academia, public health, government, and technology often make decisions about how data are visualized for the public with little understanding of public perceptions about data visualization. In contrast, through communications media, members of the public are usually passive recipients of visual information provided by data experts. I contextualize the top-down power dynamic between data experts and the public in data visualization. The public has less influence over academic work or design in data visualization [85]. Therefore, I refer to feminist critiques that urge academics to consider social power differences among scientists and the public [280]. For instance, public community members are seldom research co-leads or participants in research studies related to data visualization. Therefore, researchers in data visualization call for more studies to include members of the public outside university campuses [137, 243, 327]. Inspired by the calls for research with members of the public, I include participatory data physicalization in Part II of my thesis. I discuss the perceived power relationships in my collaborations and characterize perceived power differences between academics and members of the public that I found through my research in Chapter 8.

2.1.4 Limited Research on Social-Relational Academic Collaborations in DataVis

Researchers in data visualization recognize social power differences and personal biases implicit in data visualization design [13, 14, 80, 85, 263]. For example, feminist scholars critique social power structures in human-computer interaction (HCI) [103, 134], and data visualization [85], urging researchers to reflect on their social positions of power with an openess to divergent worldviews and scientific approaches [13, 192, 254]. However, there has been little research about the social-relational properties of academic interactions in data visualization. Particularly, how social-relational dimensions impact their professional praxes [80]. Therefore, I also collaborated with academics in data visualization to examine academic collaborations in Part I of my dissertation 2.3.8, exploring sociality in collaborative academic practices.

2.1.5 Theoretical Tensions and Research Opportunities

Through the related ideas and prior research, I explain how my work fits into contemporary critical discourse about people's social interactions with data visualizations and physicalizations. First, I explain the disciplinary convention of visualizing data to provide users with insights and enhance their cognitive experiences. For example, the disciplinary positivist assumptions that a graph visualizes numbers, and those numbers are deemed neutral at arms-length from social contexts or feelings [199, 299]– that data are a "given" [89].

Below, I begin with theories that conceptualize data to represent aspects of social interactions. I draw upon critical feminist perspectives to explain why positivist assumptions about data are limited. Then, I highlight constructivist perspectives that show the potential of visualization or physicalization to promote personal and social awareness. Lastly, I propose the advantages and limitations of interactive data physicalization as a participatory research approach.

2.2 Theoretical Perspectives: Data Represent Sociocultural Activities and Community Relationships

2.2.1 Data as a Social Process

What do you think of when reading the word "Data?" Data often refers to information gathered, organized, and interpreted by people, usually depicted numerically and categorically. Patterns of numbers and categories can be *visualized*, meaning data can be represented visually by encoding, or *mapping* data [222, 297, 323] onto lines, shapes, colours, icons, or textures. For example, data can be represented by a graph, a bar chart in 2-D formats, or tangible 3-D data installations called data physicalizations [229]. Similar to a cartographic map, data visualizations often include legends or annotated descriptions alongside the visualized data to facilitate navigation of the data mapping. The above notion of data visualization may be more common knowledge, given the familiar COVID-19 graphs published in multiple public media [4].

Alternatively, imagine "data" as numbers and categories related to social relationships [231]. Data visualization as a *relational* process [90, 199] means that data are related to local embodied "knowledges" [132], or to Indigenous ways of being and knowing [216, 253] — a social depiction of "data" positions data visualization amidst social worlds as both representing aspects of social worlds or motivating people to express sociality. I refer to Offenhuber's definition of data as social-relational phenomena to contextualize my epistemic position and my thesis work. Considering data as a social relational approach diverges from the "representational perspective" [231, 233] in the field of data visualization that Offenhuber explains in the following excerpt:

> In the relational model, a datum is not defined as a reference to the world but as a set of relationships among material entities[...] While the representational perspective views data as context-independent and universal, relational data depends on the situation, location, and people involved. The relational perspective accounts for causality and the data collection process. [231]

2.2.2 Dominant Epistemology in Data Visualization: Data Separate from Sociality

The "representational perspective," as mentioned by Offenhuber above, has been a dominant epistemology in data visualization research and design. The cognitive and perceptual advantages of visualizing data have been extensively studied and shown by the corpus of literature. As data visualization researchers and designers, we recognize that visual data representations facilitate the

interpretation of data sets more easily [54, 144, 261, 297]. In addition, critical scholars in DataVis and Human-Computer Interaction (HCI), Humanities and STS urge researchers in data visualization to consider the social worlds that data represent [46, 85, 89, 137, 147, 214, 232, 264]. My thesis contributes to this work by offering a deeper exploration into the social context surrounding data visualization practices.

2.2.3 Theory: Social Interactions in Data Visualization Produce Knowledge

Definition of Social Interactions
Communicative activities between two or more people, which may include discussions, sketching, listening, responding, writing, peer reviews, reflecting on one's beliefs, reasoning, criticality and feedback.

Based on Longino's theory of social epistemology [191], interactions among people create new knowledge. Thus, I consider that the academic field of data visualization generates knowledge through social interactions among its participants. Academics, students, research partners, and data visualization users interact with one another through social exchanges. Longino theorizes that knowledge is a product of ongoing interactions within complex social networks [191]. **Interaction** means "joint action", which "involves doing things together [...] an exchange of some kind" [191, pp. 3], which may include discussions, writing, peer reviews, reflecting on one's beliefs, reasoning, criticality and feedback. Longino explains that over time, the collection of interactions constructs knowledge within a community of people – knowledge is a product of community interactions. Inspired by Longino's social constructivist perspective, I position my thesis work within ideas and projects that support social and personal experiences with individuals and communities of people. Similarly, Haraway's techno-feminist epistemology accounts for the existence of different *knowledges* in local human bodies, which she refers to as "situated knowledges" [132]. People's physical and intellectual positions matter because they contribute different and distinct perspectives on knowledge and experiences. Through the social epistemic lens, data visualization processes and activities can be considered as sites of knowledge production, especially when communities of people are involved.

2.2.4 Communities

Definition of Community
A group of people with shared beliefs, norms, or goals. A member of a community may participate in group activities, relate to the group members, and feel a sense of belonging, fulfillment, self-identity, or an emotional connection to the group.

Communities of people hold collective knowledge about their shared values, beliefs, norms, or goals [28]. Therefore, I examine data visualization through a community-centred lens, aiming to

explore how people in communities interact with data visualizations or physicalizations. However, community relationships are complex. Thus, I look to participatory and community-based research because the approach presents opportunities to engage groups of people in community-oriented ways with sensitivity to social and emotional aspects. When I began my PhD, I wondered if data visualization might bring a sense of community or community-oriented feelings. For example, McCarthy and Wright describe the complexity of how community members may relate to others in "affective-relational" ways in participatory research – such as a sense of belonging or non-belonging, and social differences may surface during participatory research [206, pp. 95]. In psychology, evaluating a felt *sense of community* has been part of theoretical discourse suggesting sets of social-emotional dimensions that are likely to evoke a felt sense of community such as identity in group membership, emotional connection to the group, social participation, personal empowerment, fulfilment of needs, or social influence [248]. Moreover, an interplay between collective group factors and an individual's sense of empowerment and personal feelings should be considered [163]. Throughout my thesis, I describe different communities: Academic researchers and designers in data visualization as a community of practice [315]. Then, I work with members of the public, who are not data visualization researchers or designers, in a community outside the lab, where the community is defined by geographical proximity, as discussed in Chapter 7. Defining social roles in communities is also complex, such as defining "the public" or the technical "data expert." For instance, sociologists argue that the term "public" is a dynamic social role, where an academic researcher or expert can be an expert in one context, and part of the public in another social context [214]. Therefore, in my research, I focus on the specific context of data visualization practices, while also reflecting on the insider and outsider views of researchers and designers in Chapter 6. Both academics and members of the public offer valuable insights into social-relational dimensions, which I aim to explore.

2.2.5 Feminist Frameworks to *See* Social Connections in Data

I integrate intersectional feminism [72, 85, 68] and social constructivist perspectives on knowledge [28, 73, 214]. Both worldviews align with my research goals, as they view knowledge and culture as being embodied and upheld through people's relationships and interactions. Intersectionality is concerned with analyzing power inequities in the European colonial and patriarchal social strata, characterized by deeply entrenched differences in power across categories such as gender, race, and ability [68]. Moreover, researchers and designers are complicit in the inequities of the world they study, implicitly enacting the power structures and roles of the complex system they aim to influence [70, 103, 295]. Hill Collins proposes *relationality* as a conceptual way to relate and connect disparate ideas or data categories to analyze "saturated sites of power" [68]. These principles highlight why it is essential to increase my self-awareness as a researcher and develop a sensitivity to researching complex social relationships between people and data. An awareness of structural social inequities that are implicitly reproduced by academic research and design practices enables me, as a researcher, to begin to explore them. I consider the feminist concept of *relationality*

in the process of visualizing data and promoting social-relational interactions among people and data.

I consider power relationships in research and design in computer sciences based Intersectional Black feminist scholarship in HCI such as Erete et al. [100, 102], O'Leary, [295], Costanza Chock [71], Dickinson [81, 82], Rankin [256], Harrington et al. [134, 135] and their colleagues. Research practices must change to appreciate sociality and the differences among people and communities in light of social critiques about standard research practices in HCI and data visualization. For example, in HCI, researchers have discussed how academic systems have historically disempowered and excluded people in subtle or overt ways such as citing or not citing research [176], or systematically excluding Black women from computer science education [255], or designing the physical world on data from men's experiences [244]. Historically, the Western academic hierarchy has excluded people based on race, gender, nationality, or religion. Therefore, HCI researchers are urging academics and designers to become more aware of different perspectives that are non-universal and distinct. For instance, Sum et al. call for disability justice in research and design practice [285] so researchers consider people's complex identities and lived experiences in HCI research. Winschiers et al. propose ways to incorporate Indigenous perspectives into HCI research [319]. Similarly, Lazsem et al. suggest decolonizing HCI by increasing researchers' awareness of the impact of their work, developing relationships with Indigenous communities, and cultivating sensitivity to local cultures and contexts [179]. I am inspired by intersectional feminist research in HCI because it challenges inequitable and unjust research and design practices, striving to change them. These perspectives are relevant to my research because socially oriented dimensions and feminist perspectives have been less explored in the field of data visualization. In data visualization, Akbaba et al. approach their work through feminist perspectives and alternative ways of framing research problems [13, 14]. D'Ignazio and Klein's book, "Data Feminism" includes Black feminist scholarship from HCI to contextualize and critique data visualization practices [85]. A better understanding of public perspectives in research is relevant to my work. Dörk et al. discuss the potential of data visualizations created by members of the public as a forthcoming critical sociocultural tool capable of contributing to social change [87].

Understanding nuanced or unnoticed social-relational connections in research and design practices is likely to deepen an understanding of social complexity and make power differentials among researchers and members of the public more explicit. As a researcher, I strive to deepen my understanding of power inequities in data visualization. As discussed above, feminist approaches consider diverse worldviews and ways of knowing, encouraging reflexivity as a step towards increasing social awareness.

2.2.6 Reflexivity

Reflexivity means critical self-reflections on individual and collective professional practices in research and design [107, 110]. Reflexivity and design-oriented approaches have the potential to shift power relationships between the academic researcher and the 'non-expert' public in the

creation and design of data visualizations. To surface socially constructed evidence, critique parts of the system, and explore the variables that can change power inequities, feminist researchers suggest practicing reflexivity [85, 100, 198, 214]. In data visualization, Shukla et al. and Satyanarayan et al. urge designers to reflect on their design decisions and their assumptions about people and the data they visualize to avoid misrepresenting and oversimplifying people and data while also getting feedback from different perspectives from public audiences [263, 272]. Recently, Dhawka et al. interviewed data visualization researchers about their personal values and considerations when visualizing data related to race or gender, highlighting the need for further research to explore the social dimensions of researchers and designers in data visualization [80].

Throughout my PhD, I have practiced reflexivity with my colleagues as a foundational research method in my work. Reflexivity is essential to research and design, enabling the sharing of discourse and awareness about one's practice, social positions, power, and disciplinary norms. Reflexivity is an activity that can reveal and challenge social power dynamics where race, class, and gender are profoundly and inseparably linked [255] but also provide solidarity and support [114]. Perin et al. present a case study on how Black women students are marginalized and excluded from computer science programs, as the design of the standard academic system is often unquestioned by those in power. Therefore, they argue that individuals with institutional power must be reflexive to improve practices and create systemic changes that promote social inclusion in academia [245]. Finlay explains the importance of reflexivity by researchers as a way to challenge and improve one's practice by increasing self-awareness either individually or in a group [107, 108]. Self-reflection can be inspired by physical and embodied interactions with media that relay information to a viewer, which is relevant to data visualizations and physicalization. Bolter and Gromala propose that interactions with digital media should be *experiential*, bringing awareness to the medium, whether digital or physical, inspiring reflection, self-awareness, and "mirroring" the user's context through active participation with the information the interface contains [35]. Their notion applies to visualizations and physicalizations of data that are often designed to convey information. Therefore, I highlight the affordances of the materiality of data physicalization. The following sections discuss the applications of data visualization and physicalization in promoting social interactions, which apply to my thesis explorations.

2.3 Background on the Uses of Data Visualization or Physicalization

2.3.1 Human-Data Interactions: From Information Goal to Social-Relational Goal

A central design principle in HDI is that users must be motivated by an "information goal" to initiate interactions with data. Cafaro and Roberts integrate learning theory with embodied cognition and data visualization to study interactions between visitors and interactive gestural displays in "informal" learning settings, such as a museum or science centres [51]. They argue that public visitors have no prior interest or motivation in interacting with data in museum settings, like technical data users. Therefore, museum visitors from the public experience *organic human-data*

interactions that require different kinds of design considerations [51, pp. 14]. Similarly, my research diverges from the common "information goal" in data visualization. In my research, I do not have an informational goal. Instead, I have an experiential goal of community engagement with data — I have a *social-relational* goal. I am interested in data physicalization and data-based art installations that facilitate community interactions. Human-data interaction (HDI) has emerged as a concept discussed by a handful of computer science researchers, who consider the relationship between people and data. HDI emerged from computer science and visual analytics, utilizing data visualization techniques on 2D graphical user interfaces and large-format public displays [65, 66, 144]. HDI is characterized by researchers improving the designs of interactive digital data systems, enabling people to identify patterns in large datasets more easily [51, 220, 221, 305]. Victorelli et al. conducted a systematic literature review of 43 papers using "human-data interaction" to understand the definition and applications of this research area. They found that HDI refers to people trying to understand large datasets in various information-related contexts, including health, personal data, and contexts of embodied interaction [51]. Some authors have discussed human agency and decision-making with data, while others have considered visualization design frameworks for digital interfaces [282]. The research commitments of HDI are similar to those of Human-Computer Interaction (HCI), information visualization, and data visualization, which are focused on the human user when making design choices.

2.3.2 Hands-On Collaborative Inquiry for Emotional or Social Engagement

Collaborative inquiry is my term to describe research practices that incorporate participatory design methods, involving groups of people to explore emotionally or socially contextual phenomena through interaction with design objects, such as research through design [115, 307, 329] or research-creation [53, 139]. Research in personal sketching and creating physical data artifacts has demonstrated their effectiveness as tools for communication and shared meaning-making. For example, I am inspired by feminist design-oriented research in HCI, such as Devendorf et al.'s collective making and sharing of personal artifacts to express emotional experiences and research collective feelings and lived experiences [79]. Similarly, Liu et al. created eco-feminist objects to explore ecological relationships with fungi, bringing new awareness to mushrooms and nature [186]. A project related to my research into collaborative reflexive sketching is Koulidou et al.'s Dialogical Sketching research methodology [175], which utilizes sketching to anchor dialogue in personal experiences. I am also inspired by prior research on data physicalization demonstrated that the hands-on activity of constructing data physicalization prompted self-reflection [291, 289], and personal meaning-making [153, 152]. I merged the insights from design-oriented research in HCI with the making of data physicalization in my thesis.

2.3.2.1 Sketch-based Practice for Personal Meaning-Making

I refer to sketch-based research practice as a general term to describe sketching with a pen on paper or a stylus on a digital tablet, typically used in collaborative design processes, whether in individual

or group settings. In my research, I use sketching specifically for reflexive practice. I am inspired by the work of Greenberg et al.'s book, "Sketching User Experiences" (2012) [125], which presents various simple exercises to sketch ideas during the design process and facilitate collaboration. I appreciate the simple writing and instructional illustrations that show how accessible sketching for collaboration can be. An example of sketching with personal data as a creative way to communicate and learn about oneself and others is Lupi and Posavec's "Dear Data" project, where they sketched out different data in their lives in a postcard exchange [196, 197]. Schön described the cyclicity of sketching for reflection based on a designer interacting with a sketch from their distinct ontology, or way of being and seeing the world: "The process of seeing-drawing-seeing is one kind of example of what is meant by the phrase designing as a reflective conversation with the materials of a situation." [267, pp. 133]. This project has inspired classroom and research learning activities, highlighting the power of sketching with data to communicate effectively. I apply the potential of data-based personal sketching to communicate with collaborators in Chapter 5, "Sketching Introductions." Similarly, Walny's work [309, 310] focuses on the use of sketching practice in data visualization design, suggesting that sketching with people may enhance group engagement and promote critical thinking about data. In my research, I use sketching to prompt critical thinking about one's practice and sociocultural position as a researcher. Sturdee et al. point to the potential of sketching practice as a valuable research object where the process assists in inquiry about a phenomenon and as a boundary object [184] to study social phenomena. Importantly, Sturdee et al. note that the accessibility of sketching for research practice is a crucial consideration when evaluating feminist practices aimed at increasing participation from diverse individuals in the public [283, 284]. In my work, I explored the practice of reflexive sketching within a feminist framework.

2.3.3 Research and Design Goals in Data Physicalization Consider Social Emotional Engagement

The goals of data physicalization extend beyond the ease of interpreting large datasets to also consider social engagement and implicit and unintended visual properties [93, 147, 154, 219]. In data physicalization, data are represented by physical and tangible materials. The data are *physicalized* by their mapping to physical variables and spatially organized, allowing people to more easily decipher the meaning of the data [22, 153, 162]. In addition, the goals of this field are to design embodied experiences with data, spur public conversations and questions [219] to understand data's situated and social context better [264, 318] and to promote self-reflection [152, 153, 289, 291]. Participants can participate using their sight, touch, and movement [219] for an immersive interpretive data experience [147], and to support collaboration [180, 181, 239]. Most examples I refer to use easily found materials such as card stock, paper, yarn, or string. For instance, community members use strings on a wall with nails to connect different data points in Data Strings by Domestic Data Streamers [154, pp. 163–174], or wear a necklace mapping personal data to the colours and order of its beads by Thudt et al. [291]. Physicalizations often resemble familiar bar charts or network graphs [8]. However, sometimes, the scale, quantity, area, and height

of piles of rice in a room represent aggregate counts of death tolls, where each grain represents a person who perished [9]. While most of the literature demonstrated the social or emotional intentions of the designers, I found less emphasis on the social and community-oriented findings from the research participants. Therefore, the related work highlights an opportunity to use data physicalizations to specifically explore social-relational dimensions that can then be designed for and further studied. Thus far, there are no formal terms or methods for designing visual data to promote socially engaging tasks. In my thesis, I refer to these terms as *socio-visual* dimensions.

2.3.3.1 Social Taxonomy for Data Representations Not Yet Established

As mentioned above, many experiences with data physicalizations are emotional or social in nature. However, in the literature, authors tend to focus on describing the design elements of the physicalization. Therefore, finding reported social or relational dimensions required careful reading. There is a consistent acknowledgement in the literature that social settings surrounding data physicalizations or in situ visualizations offer a highly contextual dimension to visual data that cannot be easily rendered in a university lab on a computer monitor. The physical social context offered by data physicalizations is discussed by Sauvé et al.'s framework of *physecology* [264] and the benefits of embedded data representations in natural research settings by Willett et al. [318]. I read a few literature reviews about data physicalization that encompass a large portion of projects in the field of data physicalization (Hornecker [147], Dumicic [93], Bae [22] et al.). The reviews neither referred to data physicalization as a research approach nor to projects that used data physicalization to inquire about social worlds or promote pro-social behaviour change. Data visualization for pro-social community-based purposes was recently presented in Bharghava's book on community data [32]. Moreover, the scoping reviews did not utilize design terms to describe social-relational dimensions in the designs, despite acknowledging that these dimensions play a role in user experiences [147]. I noticed that the reporting convention focuses on system design to foreground perceptual and cognitive sense-making experiences, with lesser formal descriptions on emotional or affective dimensions. Wang et al. proposed emotional dimensions [312], and Lupton explained that the embodied and emotional interactions with data offer more profound insight into human experiences [199]. My contribution is to bring more attention to the social-relational dimensions through participatory data physicalization, which I explore in my analysis in Chapter 7.

2.3.4 Participatory Data Physicalization for Exploring Sociality

Synchronous participatory data physicalization has been shown to enable community members to provide feedback to researchers-designers in a playful, non-confrontational way by collectively defining and broadening the meanings of data labels made by researchers. For instance, Panagiotidou et al. created a board game called Cognito [239] for campus community members to map their narratives and experiences of places on campus. The researcher-designers created data tokens representing the campus and people's experiences with limited knowledge about campus life. During the game, the players expressed what the tokens meant to them, but also redefined

the meanings of the tokens, which contrasted the researchers' assumptions. Through playful data physicalizations, the researchers-designers gained a deeper and broader understanding of the relationships within the community, as well as an appreciation for the sense of identity and the nuanced social aspects of a place. Via a survey, participant players reported that the game enhanced their social awareness of campus places, with storytelling being a vital feature of the experience. This example demonstrates the potential of utilizing data physicalization for collaborative research interactions with academics and non-academics.

2.3.4.1 Co-constructing data physicalization is socially meaningful to participants

Data physicalization enables social processes for interpersonal and social experiences. A data physicalization can become a social *boundary object* [279], a sociological theory proposed by Star to research collaborative spaces where consensus cannot be reached. For example, a personal data badge can be a social boundary object. Panagiotidou et al. describe an icebreaker where 40 participants at a conference created physical badges to introduce themselves to one another. They used craft materials, such as wire and cut-out paper, to represent their professional backgrounds through physicalization. Making accurate cognitive insights from the data was less important because of the social-relational goals of the data physicalization process. The authors noted that participants found the process of creating the badges and interacting with conference attendees about their badges to be both enjoyable and socially meaningful. Similarly, Nissen and Bowers [226] conducted a workshop with crochet practitioners who crocheted their data. They observed cyclic critical thinking demonstrated by the participants making 'data translations' from data to the material through the making of the physicalization. The physical data object became a 'data thing' imbued with social meaning as a "social object" offering an opportunity to blend artisanal making in the research approach. These examples highlight the process of data physicalization as a means to facilitate social experiences and "translate" sociality, revealing how people relate to data in social ways. My thesis builds upon these findings to further explore the social and relational nuances.

2.3.4.2 Community Interactions via Participatory Data Physicalizations and Data Visualizations

Data visualization or physicalization have been shown to be a community-centred participatory process that promotes critical discussions, individual and collective expressions about data and how data are related to local geographic communities and their distinct cultures [32, 56, 216, 247, 238, 276, 288]. Participatory visualizations resonate with Bressa et al., who defined *input visualizations* as visual representations for the task of collecting new data, rather than mapping a dataset, thereby leaving opportunities to engage with data in novel ways. They reviewed 50 input visualizations and reported on their purposes, which include organization, planning, surveying, discussions, and individual and group reflections [42]. I suggest that these goals align with research and design for communities, demonstrating that input visualization is a valuable method for studying sociality. I explored this idea in my thesis in Chapter 7. Thus, in my thesis, I utilize *input physicalization*

to gather public perspectives and explore sociality. My findings inform future input visualization design with a specific purpose for social-relational engagement.

I rely on data visualization techniques to ensure that the data are easily understood. However, I align with the broader contextual and social objectives of collective and community-specific expressions, utilizing data-based activities to gain insight into the social aspects surrounding the data. I refer to projects that consider or report on social dimensions. For example, Perovich et al. [247] describe their community-led and co-created data physicalization project, "Chemicals in the Creek", a two-year initiative involving environmental community leaders who aimed to raise awareness about pollution in the creek. They designed for 'affective, physical, intellectual, and social engagement' following Wang et al.'s proposal to focus on emotional dimensions in data visualization [312]. The public participants expressed that the physicalization was meaningful because it took place in a community setting, prompting action-oriented conversations and raising new questions after the event [247]. Millan et al. co-designed data artifacts with indigenous Masewal community members in Colombia to explore their locally situated perceptions of data and technology. They learned about data-related cross-generational storytelling and collective goals for community knowledge building and communication over time [216].

The work of Taylor et al. [288] aligns most closely with the goals of my thesis, as they specifically examine data through the lens of sociality and sense of community belonging. They collaborated with city residents to gather data on street traffic and gather their opinions on city development plans. The authors included sociality and public perceptions of data. They found that data directly input 'in place' by the residents of the area has 'flows' that enable sociality to emerge, showing different community relations enmeshed with community social lives and power dynamics. They found that the researchers facilitating data collection were perceived as a neutral presence to "allow data to flow." In contrast, locals viewed data collected by city developers, the city council, or a local neighbourhood member as socially polarizing. Themes of privacy, temporality, and location were social-relational dimensions identified through the process of local residents inputting their opinion data or sharing their travel routes. My work contributes to enriching a social-relational understanding by *input* physicalization. I focus on the design affordances of data physicalizations in the following sections.

2.3.4.3 Data physicalization is simple, affordable, and requires no internet or technical know-how

One of the advantages of data physicalization is its ease of transport and use in rural or remote places. Unlike digital public interfaces, physicalizations do not rely on an internet connection or familiarity with digital interfaces. The materials used to physicalize data can be found in households such as string, paper, fabrics, or even natural materials like stones or branches. The interactions can be designed with little to no technical skills required. For example, Jose Duarte's "Let's Play with Data" physical data toolkit features multi-coloured paper, magnets, and tape for cutting out shapes. The familiar materials and simple design can be used in busy, populated cities. Duarte used his

physicalization kit for participatory data collection about local transportation usage by placing a yellow paper dot on a board under the corresponding method of transportation. Passersby placed the paper dot, and community transportation trends, such as biking, bus, or car use, became visible over time. This activity sparked conversations among people across cultures and generations of city dwellers [154, pp. 134–144]. Aragón's RisingEMOTIONS reported that the human-scale and familiar craft materials opened participation by community members in a wide age range [17]. Thudt et al. describe personal data physicalization making, where participants used materials such as beads, clay, strings, corkboard, pegs, or jars to collect and represent their personal data [291]. This feature is particularly relevant to community-based work because it reduces the barrier to participating in data handling and discussions about data and the community. Prior research shows the affordances of data physicalization as a research approach in fieldwork.

2.3.5 Data Physicalization Construction for Self-Reflection

Constructing personal data physicalization was found to promote self-reflection and contemplative interactions about the data at hand.

I look to Thudt et al.'s work in personal data physicalization and construction because I aim to extend this work into public community contexts. Personal analytics [148] and the physicalization of personal data [152, 153] are foundational to my research. Thudt et al. showcase how participants first collected their data, then they *constructed* their data. Most compelling to me is that all the participants surfaced meanings during the construction by reflecting on their relationship to the data in their homes. Thudt et al. report that reflection occurred during the design phase, encompassing reflection on oneself, values, actions, contexts, and the data. Notably, some participants reported changing some of their behaviours after this experience. The ability to embed physicalizations in local physical environments is essential for inquiry that aims to investigate the profoundly interconnected and nuanced identities and relationships, as they are inextricably linked to local settings outside the lab. The most widely reported advantage of in situ interactions and physical manipulation of physical data is its capacity to promote reflection [22, 93, 147, 154, 263]. In my research, I integrated reflection into reflexive research practices, using data physicalization as an approach for research and design, as described in Chapter 7. Additionally, I employed reflexivity as a foundational method for exploring the social dimensions between people and data visualizations.

2.3.6 Data Physicalization Activities Useful Across Domains

Data physicalization has been used in various domains. Such as in medicine researchers use a physicalization of a brain [237] . In social innovation, researchers showed 15 physicalizations of urban bus services to city bus planners and bus passengers to understand service interactions [48]. In social work, Jackson calls physicalization "Participatory Diagramming" to study complex multi-racial experiences [160]. In transformative learning with communities, "collective imagery" was facilitated through co-constructed installation to find "hidden and disparate elements" in

social experiences [62], and Indigenous-led research with Blackfoot cultural practices in Canada to learn about Blackfoot women's community-specific strategies to cope with violence [159], and in education, where data physicalization was integrated into learning strategies for science education [200]. Satyanarayan et al. reviewed the literature on data physicalization and showcased a more extensive list of data physicalization categorized by the level of computer-supported elements that the physicalization includes [263]. These examples demonstrate the capacity to employ data physicalization activities across disciplinary domains and qualitative inquiry.

To summarize, the above examples from contemporary literature on data physicalization suggest that data physicalization promotes the following:

- Reflexivity that enables new meanings among data and local sociocultural and personal contexts
- Increased social awareness
- Rapport building through conversations, making, and group problem-solving
- Opportunities for community members to provide direct feedback to researcher-researchers
- Affordability and accessibility for those with no technical data visualization knowledge
- Sustainability orientation
- Interactions that are easy and familiar to community members
- Construction processes that may seed considerations for change
- Abstract design that enhances interest and commitment to participate in data physicalization

2.3.7 Limitations or Opportunities

Depending on the material, it can be challenging to accurately represent data because of variable characteristics of certain materials, such as the fluffiness of wool fibre or inconsistencies in the physical placement of material in a data physicalization [240, 242]. Data physicalizations are often static, with a limited set of interactions, unless an additional digital control actuates them and utilizes swarm robotics, as seen in LeGoc et al.' physicalization using Zooids [180, 181]. Some scholars claim that personal visualizations are too limited because the data meanings are only known to the maker because they lack standard data encodings [22]. However, encoding personal data visualization promotes privacy and fosters curiosity [93] as well as a sense of ownership and agency [148, 154, 291]. For example, Dumičić et al. conducted a literature review of 163 papers related to data physicalizations. They analyzed them based on the design intentions, including "tangible, haptic, embodied, multimodal, multisensory, ambient, data sculpture, or physical visualizations," and the design's impact on user experience. For instance, the scale of the installation, though captivating, limits the ability to overview the data and comparison; the abstract design enhances

reflective engagement using taste and smell to support storytelling and interest, and physicalization tends to keep participants interested for the short term but not the long term [93]. Hornecker et al. describe a limitation of the unintended "side-effect" of data physicalizations, such as a shadow cast by the sculpture that can be interpreted for unintentional meaning, which is called "consequential properties" that do not represent meaning – they can be difficult to remove and interfere with the design intentions [147].

In community-based participatory projects, researchers often face time and resource constraints, working closely with communities [17, 247, 288]. While building long-term relationships with the members of the public is essential, sustaining them can be challenging. Dickinson [81], Harrington [135], Cooper [70], and their colleagues share a similar consideration that not only a lack of funding, but also different priorities and constrained timelines, determine the sustainability of collaborations. Moreover, academic considerations of reciprocity and providing community leaders with a means to maintain and enhance the technological innovations they have created are essential in community collaborations [83]. Otherwise, the partnership can feel extractive and repeat colonial historical harms. Pierre et al. [251] caution researchers-designers to be aware of inflicting an "epistemic burden" when researching with research partnerships involving marginalized community members because data collection and design probing can further marginalize the participants. The authors explain that data-centred research can be extractive and harmful to community members if researchers ask them to teach about their lived realities, retell or validate their experiences of injustice, and request their time without compensating them [251]. Data visualization experts tend to focus on user "deficits" or "needs", missing public community knowledge that can influence how information could be visualized in novel ways [46]. Therefore, feminist scholars in HCI argue for community assets and strengths to be prioritized in technological design [121, 292, 321, 322].

I summarize the above examples' limitations of data physicalization as a research approach in the following:

- Variability and unpredictability of materials
- Limited interactive capabilities, especially when excluding computer-supported or electronic elements
- Niche encodings in personal visualizations and physicalizations that others cannot readily understand
- Larger scales of data physicalization that inhibit the ability to compare and overview data
- "Consequential properties," or unintended visual elements such as shadows from the physicalization, that are difficult to perceive or remove
- Implicit or metaphorical properties that may be difficult to discern
- Spatially inaccurate data representation

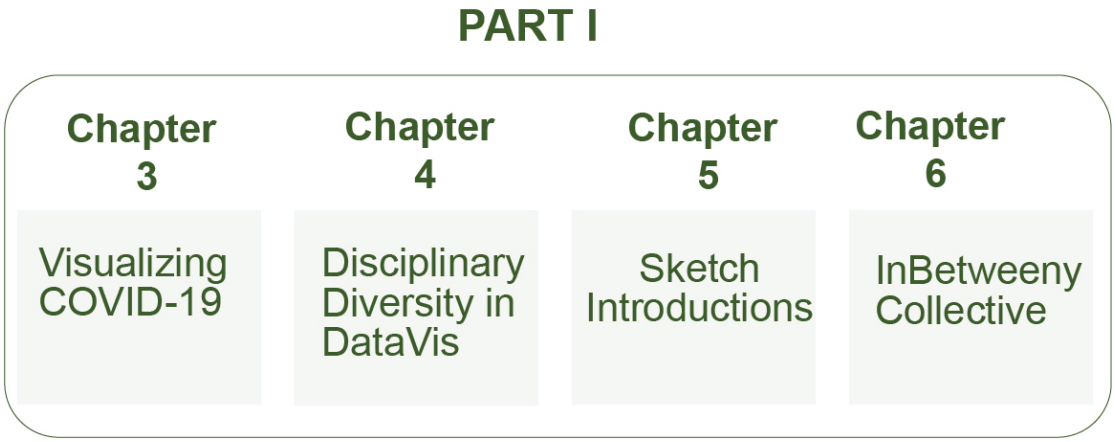
- Limited resources for working with community members
- Risk of extractive community research practices, or placing an "epistemic burden" on participants

2.3.8 Conclusion: Participatory Data Visualization or Physicalization in Design-Oriented Research

Design-oriented research is foundational to my research because it allows me to explore complex personal experiences. For example, I could design an object or an experience to prompt personal interactions. I want to explore interactions among people in their communities and data. Furthermore, a research design object can represent something personal, as mentioned above. In my Wound Up project, presented in Chapter 7, I utilize numeric data represented by a physical installation to evoke self-expression and dialogue between researchers and community members. This practice can facilitate an introspection between people and technology, mediated by a design object, to learn about nuanced experiential and social relationships. Based on the literature, I was motivated to use data physicalizations or sketches to promote curiosity, self-reflection and self-expression. I created research artifacts independently as part of my research in prototyping my data physicalization design. This process involves a designer-researcher approach through the creation of a physical object. Zimmerman et al. named this process of inquiry Research through Design (RtD) as a broad umbrella term that includes design-oriented research in HCI [329, 330]. I refer to Gaver et al.'s Cultural Probes methodology [117] in my work, as well as Wallace et al.'s Design Probes methodology, which describes the potential of using a physical object to *probe* or research interactions amidst a "messy" context to gain personal and contextual insight about socially oriented phenomena [307]. RtD is beneficial to my research because I am interested in exploring the complex contexts of how people interact and perceive data in the background of their daily lives outside the lab. Data physicalization is a portable research design probe that invites tangible, hands-on participation in manipulating yarn that represents data alongside a conversation with someone else about the data at hand (quite literally). Similarly, making-through-thinking is a research process discussed in the Research-Creation methodology by Cambre et al. [53]. In my research, I aim to slow down the process of interacting with data by creating representations of data from one's internal and external worlds, whether through sketching, as in Chapter 5, or constructing a physical, data-informed artifact, as in Chapter 7.

PART I
Exploring Social-Relational Approaches of Researchers-Designers

Part 1 of my dissertation includes Chapters 3, 4, 5, and 6, in which I explore reflexive collaborations with my colleagues. My projects include reflections on distributed collaboration, designing COVID-19 data visualizations for the public, interdisciplinarity in data visualization, sketch-based personal visualization introductions in collaborative academic settings, and exploring how researchers' lived experiences and social worlds influence their research approaches. Part I focuses on sub-question 1:



Sub-Question 1: How do academic researcher-designers in data visualization or HCI approach social-relational aspects in data visualization?

Chapter 3

Exploring Researcher-Designers' Activities in Remote Design Work

Distributed Synchronous Visualization Design: Challenges and Strategies

This chapter includes the majority of the publication I co-authored with Sarah Storteboom, Sheelagh Carpendale and Søren Knudsen [193]. I led the writing of the initial draft and the development of the methodology. Sarah Storteboom was the design lead. Søren Knudsen led project administration. Søren Knudsen and Sheelagh Carpendale led supervision. Everyone contributed equally to conceptualization, review and editing [1].

I include a reflexive collaboration that highlights the critical role of social interactions among researcher-designers, especially since sociality was limited during the civic lockdown in the unfolding public health crisis of the COVID-19 pandemic. Our paper reflects our experiences as designers of COVID-19 data visualizations working in a distributed synchronous design space during the pandemic. This is especially relevant as the pandemic posed new challenges to distributed collaboration amidst civic lockdown measures and an increased dependency on spatially distributed

[1] https://credit.niso.org

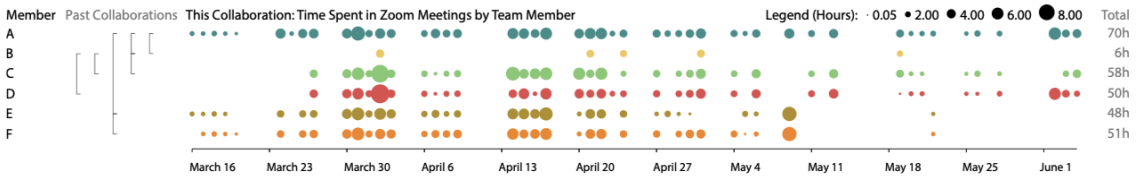


Figure 3.1: Overview of time spent video conferencing from March 16 to June 4 with concentrated synchronous design activities visible from late March to mid May; pivot points in the design process seen on April 2 when members C and D met for a prolonged design session using dual cameras as discussed in Section 3.7. See Table 3.2 for team roles. In this overview, I am team member D.

teamwork across almost all sectors. Working from home being 'the new normal', we explored potential solutions for collaborating and prototyping remotely from our own homes using the existing tools at our disposal. Since members of our cross-disciplinary team had different technical skills, we used a range of synchronous remote design tools and methods. We aimed to preserve the richness of co-located collaboration, such as face-to-face physical presence, body gestures, facial expressions, and the making and sharing of physical artifacts. While meeting over Zoom, we sketched on paper and used digital collaboration tools, such as Miro and Google Docs. Using an auto-ethnographic approach, we articulate our challenges and strategies throughout the process, providing useful insights about synchronous distributed collaboration.

3.1 Introduction

In this paper, we describe and discuss our experiences of forming and working in a distributed visualization design team. While prior work has discussed visualization design processes [270], it tended to focus on how the visualization community works during face-to-face (co-located) design activities and processes for including users or domain experts. Less attention has been paid to how team collaboration works within teams of visualization designers, be they distributed or co-located. We discuss our experiences of the differences between co-located and distributed visualization design work specific to our unique needs and experiences in light of an increased reliance on spatially distributed teamwork across almost all sectors.

Our work was set in motion as part of a provincial response to the COVID-19 pandemic. We were a small team within a broader group of public health researchers who were providing data to government decision-makers during the pandemic. We formed our design team of six members (see Figure 3.1, Members A-F) to support the local health authorities' pandemic response in collaboration with our colleagues at the Centre for Health Informatics at the University of Calgary. As we were a newly acquainted multi-disciplinary team, we found it more beneficial to learn and to discuss the data together in a synchronous environment in the beginning of the project. We worked on the design of visualizations of provincial and national COVID-19 data for a public-facing website showing data visualizations of case and policy data. The intention with this site was to inform city- and province-level leaders to assist them in making sense of the status of the public health crisis and the associated data. While our team had visualization design expertise, our colleagues provided a wider set of skills and knowledge in fields such as public health, epidemiology, and data science. Due to the pandemic, we were unable to meet face-to-face. Instead, against our common work practice, all design team members worked from their home. This situation intensified challenges of distributed collaboration caused by distracting at-home work spaces and a sense of urgency amidst civic lockdown measures.

Through an auto-ethnographic approach [45, 94, 212, 213, 223], we reflect on our experiences of distributed, primarily synchronous ideation and prototyping as a way to identify some challenges in our process of remote visualization design. We contribute descriptions of challenges and

strategies for distributed visualization design. We highlight the potential of doing activities, using technologies, and processes for communicating early and often to reduce friction in visualization design teams.

We relied on remote design tools and methods to actively design in real-time, often for two hours per day. We aimed to preserve the richness and diversity of co-located collaboration; specifically, the facilitation of face-to-face presence with the ability to view responsive body gestures, facial expressions, and the making and sharing of physical and digital artifacts.

3.2 Related Work

This work relates to literature on how to design visualizations; on how to support collaboration through visualizations; and on how to support design in technology-mitigated collaboration.

3.2.1 Designing Visualizations

Making use of design methodology is widely recognized as important for creating useful and usable visualizations [222, 270]. This echoes the broader discussions about design [270], which span a wide array of concerns and advice about concrete design activities. Some examples that focus on co-located activities include the use of sketching [49, 125, 262, 284]; prototyping with a range of media [275], and the use of cards to support ideation [157]. A considerable amount of this design work is collaborative in nature ranging from the sharing of work in progress in design critiques [320], through how people design together such as with co-creating artifacts [24], to ideas about how to involve people that are affected by a design, for example, through human-centered design [227] and participatory design [24]. In addition, there are discussions about how to communicate designs, for example, in creating hand-off documents [204], many of which people colloquially refer to as design (studio) praxis. In visualization, people have considered how to design for the intended audience, such as specific experts or the general public (for example, design study methodology [207, 213, 270]), and how to design with these people (for example, user-centered visualization design [122, 174]). Also, there are suggestions of potentially useful concrete design activities (for example: those based on constructive visualization [151], those conducted as speculative design workshops [44, 173], and the use of pencil-and-paper based sketching of data visualizations [310]). There is also advice on how to structure design processes, for example, how to teach visualization design to computer science students using five design sheet method [262]), and how to more clearly communicate visualization designs (for example, in designers communicating visualization designs to developers as part of a hand-off process [308]). These are all extremely informative when at least some of the activities can happen co-located, however, they are less applicable for synchronous distributed design activities. In synchronous distributed design activities, they serve more as goals than as methods. These ideas will need to be re-interpreted in the context of synchronous distributed design work.

3.2.2 Collaboration and Visualization

There is a rich body of literature on collaboration in related fields such as human-computer interaction (HCI) and computer supported cooperative work (CSCW). The CSCW matrix (see Table 3.1), which separates collaborative work along space time axes is useful for understanding this area [126]. Two main areas of the CSCW matrix have been purposefully considered in visualization: co-located synchronous collaboration (Table 3.1, top-left quadrant) and distributed asynchronous collaboration (Table 3.1, bottom-right quadrant). Although these two modes of collaboration have primarily been studied in isolation — perhaps due to their different technological basis — they share many challenges (see for example Isenberg et al. [158]). Research exploring co-located collaborative visualization includes the use of tabletops for collaborative information access, for example, Scott et al. [268, 269], the consideration of tabletop displays for collaborative browsing of hierarchical layouts of photographs [304], for analysis of scientific data [293], and for exploration of book collections [290]. More recently, people have considered large, high-resolution displays for supporting collaborative visual analytics (for example, Langner et al. [177] and Knudsen & Hornbæk [172]).

Research on visualization for communicating across both space and time (asynchronous distributed) have led to ideas about democratizing visualization by making it accessible to all and to the increasing inclusion of visualizations as a way to communicate data in news media. Sense.us [140] and ManyEyes [306] introduced the collaborative possibilities for visualizations on the web. This type of research situates visualizations in a broader social and societal context. Based on these kinds of systems, Heer & Agrawala [138] provide design considerations for collaborative visualization on the web more broadly. Later work has shown that structuring the processes in collaborative asynchronous visual analysis can lead to increased analysis quality [316, 317], which might provide ideas for subsequent visualization designs [149].

While collaborative visualization-based analysis is distinct from collaborative visualization design, the CSCW matrix helps conceptualizing the space of synchronous distributed collaboration in relation to other collaborative contexts. There are also relevant similarities between collaborative visualization-based analysis and visualization design. For example, being able to point to a visualization or part of one is both important when designing and using visualizations [139]. Supporting collaborative use of visualization is an important research direction. However, supporting visualization design in synchronous distributed settings has not yet been discussed.

3.2.3 Collaborative Design of Visualizations

While the visualization literature includes many discussions about design [29, 33, 122, 174, 207, 210, 209, 213, 222, 270, 308, 130], the focus is on the design processes rather than the collaborative process. The collaborations discussed tend to focus on how visualization researchers collaborate in long-term projects with domain experts. For example, while the term "collaboration" (and related forms) is used 34 times in the design studies paper [270], it is only used a single time in the section

Table 3.1: CSCW matrix for consideration in visualization design.

	Same time (synchronous)	Different time (asynchronous)
Same place (co-located)	same place same time	same place different time
Different place (distributed)	different place same time	different place different time

that discusses the "core phase" of the design study methodology. Discussions about collaborative design thinking seem to be missing.

Similarly, in CSCW literature, while there are discussions about many different types of work, the focus has been on distributed asynchronous and co-located synchronous. We are interested in distributed synchronous design activities.

3.2.4 Collaborative Design Processes

There is CSCW literature about collaborative design processes (for some examples see [287, 109, 143, 228, 324, 18, 39]). However, the focus is still about collaborative design when co-location is part of the design process. For example, some have explored technology mitigated collaborations through tabletop display tools [143, 39], and through investigating the impact of technology based feedback about the group creative design process [287]. One suggestion is to explore the use of the crowd in design processes [324]. Visualization has been used to provide feedback on speaking times and speaking turns during collaboration [30].

There is some exploration of the space we are interested in – the space of how to re-kindle the benefits of co-located collaboration in a technology-supported, synchronous distributed situation. Arias et al. [18] start by acknowledging the complex design problems often require group solutions and articulates needed design support for urban design problems. Both Fischer [109] and Obendorf et al. [228] consider the complexity of team-based design needs where teams must cope with difference in time, space, and knowledge and make a call for deeper exploration of the needs of these types of design teams. Our work, which describes our experiences of the challenges of collaborative synchronous, distributed technology-mediated design, and a range of strategies for dealing with these challenges, contributes to this larger call for research.

3.3 Synchronous Distributed Visualization Design

Amid the COVID-19 lockdown, we were faced with the urgent challenge to design a useful COVID-19 visualization. We were confronted with the reality that our familiar co-located team-based collaboration design approaches could not be directly applied in our enforced distributed but synchronous realm. While this was a challenge in many ways, we managed to reach an effective

design process. Through the use of a reflective auto-ethnographic research approach, we have obtained a deeper understanding of these challenges. We first describe our research approach.

3.3.1 Methodology: Reflective Auto-Ethnography

We conducted a team-based self-study for this project by combining an auto-ethnographic research approach [59] with hermeneutic phenomenology [301]. Auto-ethnographic research is befitting because its evidence base is the direct narrative of the people involved [59]. Hermeneutic phenomenology complements this as it studies the meanings of lived experience through self-reflection, writing, and discussion [301, 178]. Hermeneutic phenomenology combines the use of both the hermeneutic lens, recognizing that any experience is influenced by past lived experiences, with the descriptive, experiential lens of phenomenology. Together, these approaches deepened our understanding of our experience as a team of designers creating visualizations together in a synchronous distributed context. Though more commonly seen in the social sciences, we benefit from these qualitative research approaches. They enable us to focus on our unique experiences of designing visualizations in a synchronous distributed setting through the discovery of themes that occurred in our non-linear collaborative practice.

3.3.2 Demographics: Our Team Members

Our group of designers worked together, as a team, for the first time, though some team members (AB, AEF, ABC, BC, and BD — also shown in Figure 3.1) had worked together previously on separate projects. The team dynamics and the social setting of the lockdown were novel to the whole team. The domain-specific data and the needs of the project had yet to be learned. Thus, the team needed to get acquainted with one another as well as the data. We found that spending more time together in a synchronous setting facilitated immediate peer-to-peer learning, and improved our communication — in our experience, this was the most suitable way for us to connect, to build personal relationships in our group, and to improve group synergy. Initially, team members A, E, and F discussed the project for about two weeks, followed by members A and B discussing possible additional members to balance skills in data visualization, design, public health, and programming (see Table 2). Team member A assembled the team and called the first team meeting. In this description, I am Team Member D.

3.3.3 Our Process, Data, and Analysis

Following an auto-ethnographic approach, the data is both a result of our process and fueled it; therefore, we discuss them as intertwined. We looked closely into the process of our visualization project by analyzing our own experiential data and project artifacts [59, 73, 178]. In auto-ethnography we are both the participants and the researchers — through a self-reflexive process [59, 301], we examine our shared experience as a multi-disciplinary team of designers

Table 3.2: Overview of our team. In this Table, I am Team Member D.

Team member	Role	Expertise in use
A	PI	Visualization, design, programming, management, communication
B	PI	Visualization, design
C	Design lead	Visualization, design
D	Designer	Public health, design
E	Intern	Visualization, programming
F	Intern	Visualization, programming

working towards gaining a deeper understanding of our experience. Doing so, we questioned: *how has distributed collaboration shaped our experience of synchronous design processes?*

Our process was as follows: We continuously collected process data and members of the team kept regular day-by-day written team notes; the team's visualization sketches were collectively stored on a Miro board; our design brief on Google Docs and the Slack history texts were gathered and reviewed; we created a visual timeline from our Slack history; we formulated questions to guide our inquiry and reflection based on our collected data and previous personal experiences relevant to visualization design and health communications; we characterized, analyzed and reflected on our texts, discussed the texts, and generated new texts; we held reflective discussions and documented this in our notes in Google Docs; themes that emerged in our text and from our reflective dialogue were grouped; through our reflections, we interpreted our documented themes and continued to write these reflections on our account; we corroborated collective written experiences with one another through further discussion to validate the findings. Lastly, we wrote this paper by detailing our experiences and findings by repeatedly going through the steps above.

3.3.4 Our Context

March 13, 2020, two days before a local state of emergency was announced, the office of the mayor of Calgary requested help from the Centre for Health Informatics to get a better sense of non-clinical interventions of COVID-19 locally, nationally, and internationally. At that time there was a generalized sense of fear and widespread sensationalism that was broadcast via a multitude of media. A team of 37 members of researchers in health and data sciences from the centre assembled on Slack to create a "COVID-19 Working Group" determined to research COVID-19 data in response to the urgent call for information. The hope was to help by contributing critical information to aid informed decision-making about managing the pandemic. Working under an immense sense of urgency, the team collected cumulative and daily case numbers, researched global COVID-19 policies, and worked on epidemiological disease models that informed the status of the pandemic on a local and national scale. This research was used by municipal and provincial policy-makers. Two team members promptly responded by using open COVID-19 data and a web charting library

to, within a few days, assemble a website that tracked the changing local and provincial COVID-19 data. This website became known within the team as the "COVID-19 Tracker" [58]. During the first 8 weeks, the site garnered 15,000 page views.

While delighted about the speed of this action, the team noted the need for a more carefully designed response and a different team member assembled a smaller design team. It is this smaller group that is our design team and it is our actions in this team that we focus on. Our initial conversations in the design team were via a specifically formed Slack channel. Our design team's dedicated channel decreased the amount of notifications to members of the COVID-19 Working Group and helped focus our discussions. Additionally, our design team started to meet using video conferencing. We discussed COVID-19 design issues to better understand the impact of design on a broader cross-section of people. Our design team delved into the intricacies of the available public COVID-19 data with the goal of designing data visualizations that would support a broad cross-section of the population, which the working group had identified as important: provincial and municipal decision makers, public health officers, as well as the general public. We met frequently — often several hours a day and still met more than once a week with the COVID-19 Working Group to align with the project needs and direction in response to the status of the pandemic.

3.4 Describing Our Design Process Experiences

In this section we describe how we experienced the activities that we engaged in as the design team. In keeping with our auto-ethnographic and phenomenological methodologies, rigor in this report means staying true to the reality of our experiences in our team via detailed descriptions and iterative reflections on our texts and artifacts [178, 73]. In starting our distributed design process, we consulted with the literature. However, we discovered only limited advice on how to organize collaborative synchronous distributed visualization design processes. While we considered our readings about visualization design and distributed design in CSCW, we largely relied on our own, largely face-to-face, experience of prior design processes in visualization design and beyond. Here, we describe how we experienced synchronous distributed visualization design. By articulating challenges and strategies, we discuss the factors that arose in our experiences that may prove useful to consider when doing synchronous distributed visualization design.

3.4.1 Establishing Meetings and Technologies

The design team met to discuss and to sketch together for two hours a day, five days a week and attended half hour meetings with the broader team a few times per week. We mostly used Zoom [2]

[2] https://zoom.com/

for meetings, Slack [3] for short asynchronous communications, Google Docs [4] for written notes and records, and Miro Board [5] for collaborative design.

Daily 2-hour meetings over Zoom brought the team together and allowed for developing an awareness of each other and established a social dynamic and rapport among the team members. The meetings were a time to convene and establish project expectations, sketch, and design together. Most of us had device cameras positioned to show our face during the Zoom meetings. The team also participated in the larger Zoom meetings with the COVID-19 Working Group to gain feedback on our visualization ideas and sketches, and to hear of new developments or requests from senior leadership. A Slack channel was the main hub to set up meeting times, to share reading and video materials about COVID-19 data and visualization design, and to inform each other of online events such as webinars. We also used the Slack channel to post our design ideas. Our visualization design team made use of a collaborative digital whiteboard (Miro). This provided digital space for the group to post sketches, PDF's, and virtual sticky notes during design meetings. Meeting notes and a design brief were created and stored in Google Docs and were used concurrently during our team meetings with one team member taking notes. After five weeks of daily Zoom meetings, our team reduced meeting times over a collective sense that meetings needed to be more directed and convergent — the ideation phase was wrapping up and the team was keen to implement the design.

3.4.2 Defining a Purpose and Setting a Direction

To reach a shared understanding of the project expectations, including timelines and target audiences, we collaboratively authored a design brief. This document directed some of our discussions as we considered the purpose of the site, our audience, and their familiarity with the data. The ideation process began with a distributed face-to-face critique of the COVID-19 visualizations that were already available on our site and across all of the provincial sites in Canada. Screenshots of the various visualizations were compiled on a Miro board along with suggestions for improvements. This in turn led to ideas for improvements to the COVID Tracker website. The activity of critiquing visual elements of other visualizations was a beneficial learning exercise that focused our sketching sessions and informed our design choices. This activity enabled an engaged exploration of the data, of the end-user audience, and the purpose and messaging of the visualizations. Importantly, this activity presented the complexity of the data and enabled us to identify further questions and consultations necessary to validate our findings. While we were interested in helping people understand relationships between otherwise disparate data sets, such as case numbers and policies, we recognized that separating certain aspects of the data was critical so as to not suggest causation

[3] https://slack.com/

[4] https://docs.google.com/

[5] https://miro.com/

where correlations might exist. For example, it became clear that juxtaposing policy data with case numbers could be misconstrued as a causal relationship.

3.4.3 Regular Sketching Sessions

The goal of our synchronous online meetings during the ideation phase was to generate many ideas and sketches, while gaining an understanding of COVID-19 data. We spent a lot of time considering and exploring the data; understanding testing rates, positive case numbers, hospitalization cases, and disease transmission along with policies and correlations. We formed questions through repeated discussions, which, in consultation with members of the COVID-19 Working Group, provided a rich method for developing an in-depth understanding of the data and issues of interest.

Sketching was a valuable activity that helped us to think through concepts, envision a story, and share ideas. Sketching enabled our team to see the data and gain a shared sense of our individual perspectives. During the meetings, and while apart, we sketched on paper and tablets. The sketches were the main artifacts that we each created and showed to each other either through presenting our physical sketch to the device camera or posting it onto our Miro board. The sketches served as the foundation for our discussions.

The design meeting notes and artifacts were stored, categorized by date, and accessible to the team. The cache of sketches along with inspiration clippings and meeting notes proved very useful. We were able to refer to previously posted resources and sketches during design meetings, enhancing our ability to recall our previous work and build on it. However, we found the lag time when posting our paper sketches onto our virtual whiteboard to be challenging. We dealt with this by holding sketches up to the camera, but they were not easily referenced until they were scanned and added to the board.

3.4.4 Software Prototyping

Illustrator versions of our design were produced by the lead designer so we could view a pixel-perfect design, which looks like more polished versions of sketched designs. After several iterations, the Illustrator file was handed off to three team members who implemented the design using D3 [37]. Several iterations of the software prototype were critiqued during collaborative design team sessions and subsequently tweaked. The design phase for the data visualization continued through implementation as updating data sources presents new challenges to be solved. When prototypes were polished and reflected live data sources, they were presented in a Zoom meeting to the COVID-19 Working Group for feedback.

3.5 Emerging Factors in Our Virtual Visualization Design

Our purpose was to think critically about how to communicate the complexity of the pandemic and the data while ensuring that our visualization would not be misinforming. Our process, however, started by identifying the missing factors in our distributed design situation. The familiar lab

environment facilitated serendipity, natural discussion, and a tangible sense of togetherness that allowed for ideas to spontaneously emerge. In order to support the process of ideation and data discovery in our distributed environment, we wished to collaborate via real-time sketching and discussion akin to a co-located design environment such as a lab. We searched for useful tools and materials to enable the team members to communicate ideas about interactions for the design and to share them, as we normally would, "in-person".

We note that being distributed forced us to be upfront about the process. This in turn supported later reflection because our distributed work had been logged through the various tools used in the design process. This design experience was distinct as a result of distributed collaboration under the time sensitive demands of a public health emergency. Furthermore, remoteness posed a perceived risk of misunderstanding and miscommunication, more so given a flux of ever-changing public health data that decision makers were relying upon. This design experience elucidated several factors for re-consideration. Notably, these factors were initially experienced as challenges but sometimes, through working with these challenges, we also noted potential strategies and opportunities.

In the following, we describe eleven factors that emerged from an auto-ethnographic exploration of our distributed visualization design process. While the design factors encompass a wide array of considerations, we recognize that there are more opportunities and strategies possible through re-purposing current software and hardware tools.

3.6 Pandemic Challenges

First and unsurprisingly, the pandemic lockdown led to challenges. These are important to recognise as they heavily influenced our ability to carry out work.

C1. Negotiating Time and Resources *Coordinating time and access to physical space for some team members was a challenge amidst the social lockdown. This challenge is important because the pandemic brought forward some social constraints to distributed work from home such as interruptions in each member's home environment, lack of physical working space, and faulty hardware that played a role in how the team managed to design together remotely.* For example, some collaborators were forced to leave meetings in order to take care of their children and at times their children showed themselves to the camera during design meetings. There were instances when team members had to move their device to a different room during meetings because their small shared living spaces were prioritized based on homeschooling needs of children or for other family members who were working from home. We contended with web cams that did not function, so some team members were not visible during camera-to-camera meetings. Purchasing web cameras at the time was difficult due to a high demand in the market with increased remote work. As a team, we resolved to continue meetings during these circumstances. Audio was muted for a moment when children interrupted our online meetings and we waited until family disruption ended. We persisted with meetings though some members were not visible, interacting only via audio. Additionally, this

work provided an opportunity to "be with" other people and to "contribute" in a way that was a cathartic exercise for several team members in the midst of this pandemic.

3.6.1 Communication Challenges & Opportunities

This group of challenges focus on how our adaptation to distributed collaborations caused several types of communication challenges — some of which we learned how to mitigate.

C2. Establishing Team Cohesion *The sense of uncertainty that arose steeply during the initial COVID-19 lockdown, along with our own perceived challenges of remote collaboration, posed risks of miscommunication and possible difficulties in establishing a spirit of team trust and cohesion.* This was a challenge we were particularly aware of, because, while most of us were in the same geographical region, we designed synchronously from our homes. Our intention was to recreate the familiar "face-to-face" co-located communication flow even though we were working in a distributed virtual setting. We chose frequent synchronous virtual collaboration as a way to 1) align our ideas and learn 2) mitigate a sense of uncertainty during a pandemic with frequent feedback 3) establish team cohesion and rapport. This virtual space was a new reality for many collaborators. Seeing one another brought a sense of togetherness and co-presence that was conducive to successful and natural synchronous teamwork. Notably, it was possible for our virtual interaction to achieve a similar communication workflow with the team's facial expressions and gestures visible through our device cameras. Human communication and connections are an interplay of nuanced cultural mannerisms that may not be visible or as obvious through a webcam. Nonetheless, seeing each other through webcams and computer screens established a collective awareness and a sense of attendance within the team though we were not co-located. However, eye-to-eye contact differed from being co-located. We tended to look at each other's faces on the screen and not directly into our cameras, resulting in it often seeming as though eye contact was averted during conversations. We found that group etiquette naturally developed in our online work space such as muting the microphone during excessive background noise, putting up a hand to speak, and waving goodbye into the camera. A couple of the team members chose to keep their cameras off during all online meetings but remained audible, which created a barrier to gaining an understanding of their affect and their level of engagement because gestures, facial expressions, and eye contact were not visible. We found that members who had their cameras turned on often dominated and contributed more to the discussion and invested more time throughout the project.

C3. Understanding Team Members' Progress *The challenge was to determine the progress of individuals on the team so that we could move forward with project goals. It was important to understand where team members were in their work to ensure that we were completing our goals.* The team was rapidly assembled; some members were volunteers. They were unfamiliar with each other's skills and were unsure if it was okay to ask others given the circumstances. Some work needed to be done asynchronously and, from time to time, team members were not able to follow through with tasks. For example, we decided to assign tasks such as to scope nationwide provincial sites for visualizations of COVID-19 data and compile the findings in an Excel file,

while another member was reviewing other information outside of our team meetings. It was also valuable to prepare some information before our design team meetings to bolster our discussions about visualization design. To ensure that everyone was aware of the status of each task, team member A would check on the progress via Slack, which was visible to the whole team. This method was useful to ensure transparency and clear expectations for individual task completion within our design process. Some members, notably team members C and D often self-assigned tasks while other members relied upon A for task assignment and review.

C4. Diversity of Software and Sketching Expertise *There was considerable variation in levels of skill when sketching ideas or visualizing data, meaning that some of the team members struggled more than others with design activities and required guidance.* As a solution to some of these differences, the lead visualization designer mentored willing team members who were less experienced in designing data visualizations. For example, we held optional group sketching sessions via Zoom as a way to learn and to practice sketching apart from our team meetings. To bypass software knowledge gaps, we photographed physical paper sketches and shared them on the Miro board because everyone was able to use their device cameras comfortably. However, photographing our sketches stifled the natural flow of sketching and sharing during meetings, so we reverted to sketching and presenting our sketches through the camera. This method led to more productive discussions and more sketching to take place during the meetings. We also saw a benefit in the virtual environment because sketches could be easily seen by everyone at the same time provided the camera was set up in such a way that the sketch was well lit and in focus. We would often scan sketches using a phone app or transfer them to the digital whiteboard, where we could continue to review the sketches. After reviewing the sketches and discussing their features we decided on the best sketch to prototype. We also found screen sharing to be a benefit during the polishing stage of a working prototype. While designers might want to adjust some of the positioning and style of elements in a working prototype, they may not have a development space set up or the skills to make those adjustments. The programming team members utilized screen sharing to collaboratively make those adjustments in real time with the designers.

C5. Understanding and Sharing Data *Learning about the project needs and the health data was foundational to our visualization design, so we spent considerable time reviewing and discussing policy data, testing data, health care system capacity, social determinants of health, studying COVID-19 visualizations across Canadian jurisdictions, and in regular consultations with the COVID-19 Working Group in a remote setting.* As COVID-19 data was being visualized broadly across the world, we knew how the data was typically shown, so we considered the clarity and lack of clarity in existing visualizations. Therefore, we looked for new ways to visualize the same data that would not perpetuate the same issues. Information gathering was crucial to our design process because it enabled us to identify relationships and assumptions within the data as we sketched data visualizations in the early design stage. Notably, this process provided a fruitful distributed design environment with a serendipitous sense of data discovery. This collaborative online knowledge seeking provided a generative online learning space. Additionally, this activity

allowed us to deepen our collective understanding of the data and cultivate team rapport. This is an area where we identified a clear benefit to working in a distributed environment. We were able to work independently and then quickly share our findings when identifying something interesting. For example, we considered critical discussions of visualization, such as the understanding that positive cases were indicative of testing capacity. We followed this insight by brainstorming ways to visualize this relationship more clearly as part of a larger visualization product.

C6. Sharing and Acquiring Knowledge *It was challenging to share and introduce knowledge and background skills to other team members. Likewise, it was challenging to acquire new understanding from other team members.* Distributed modes of collaboration introduce more friction in sharing knowledge. It is more difficult to find and share resources and point to specific parts of a resource, as it is prone to error and requires time. This is particularly relevant in a visualization context. In contrast, in co-located situations, pointing, body language, and using artifacts such as laptops to communicate "see this" is easy and affords a low-friction possibility for understanding whether you have caught people's attention. In extension, these situations allow the receiving side to see exactly what is meant and allow for clarifying questions about a specific aspect. For example, we discussed storytelling aspects of our design. However, discovering the depth and subtlety of the data and how it fits with storytelling concepts appeared overwhelming. We intended to deepen a shared understanding of this data through visualizations and storytelling, and further, from an interaction perspective, to use scrollytelling to show the complexity of COVID-19 data. We considered literature on using storytelling elements in visualization [261] to prompt meaningful discussions about the data. For example, we referred to the Martini Glass structure [271] as a potential way to scaffold the complexity of the data and to create cohesion between COVID-19 charts. However, while all team members attempted to grasp these concepts, some team members had a sense of superficial understanding these ideas and found it difficult to use them when thinking about designs. Despite these challenges, working remotely also poses benefits for knowledge exchange. By working in a distributed team, resources will typically be shared through a medium that allows people to return to them, which is particularly beneficial when acquiring new knowledge.

C7. Understanding Design Ideas *Working in a distributed design team adds friction to the process of understanding other collaborators' perspectives throughout the design process [129]. In our case, it took more time to establish understanding when sharing diverse ideas in the process of interpreting domain-specific data and creating data visualizations.* Typically, a co-located physical space that facilitates the sharing of ideas through face-to-face team activities is used during the ideation and iteration phases of the design process. For example, we would compile our sketches on the wall of a meeting room for all members to view and discuss. We adapted this activity to our online synchronous setting by posting sketches to an online collaborative whiteboard in Miro while simultaneously meeting via Zoom. Despite the learning curve of adopting the software, we found this strategy allowed us to share and discuss our ideas productively. Working in the virtual whiteboard environment opened up new opportunities that would not be as feasible when working with the physical counterpart. Endless space offered in the virtual whiteboard allowed

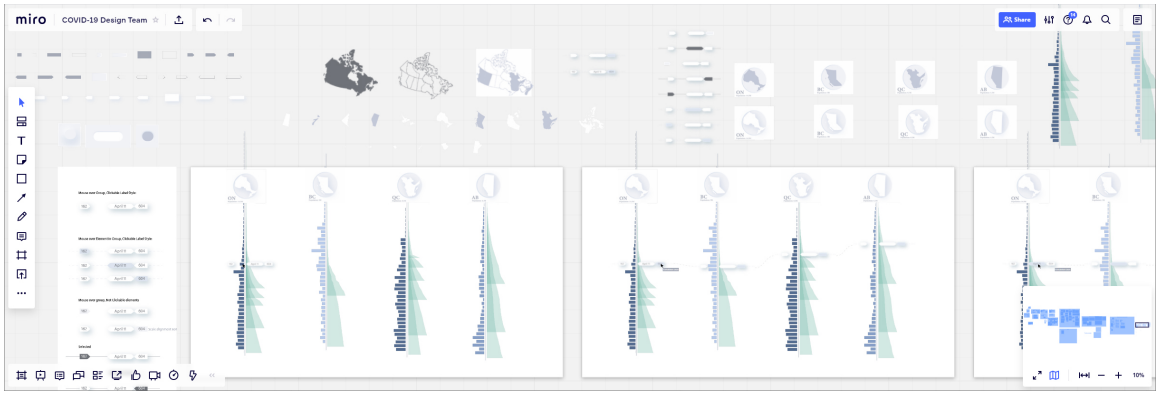


Figure 3.2: An excerpt of our Miro board that captures a design session for lo-fi prototyping of visualization interaction. During the session, all participants were able to duplicate and arrange assets to mimic paper prototyping.

the team a great deal of flexibility in how the content was laid out. Items on the board could be arranged linearly, and grouped and regrouped as the design process unfolded. The team was able to quickly reference previously shared content, which aided in clarifying how assumptions and misunderstandings had arisen. The ability to use virtual pointing and to jump to another's pointing location played a beneficial role in the virtual work space. While pointing is possible in the physical environment, this can at times lack accuracy or require people to physically move closer to the item they are pointing at, which is time-consuming and may occlude it. There is also the limitation that only so many people can be close to a small clipping or sketchbook page. The virtual space permits all collaborators to have an optimal view of where the speaker is pointing and an equal opportunity to point at things. Iteration was an integral part of the design process, and for this, it was often useful to markup existing sketches and design outputs. The digital environment offered the ability to quickly duplicate and markup as many copies of something as needed without compromising the integrity of the original. This was especially enabling when one team member wanted to iterate on another team member's sketch because doing so was immediate and essentially risk-free.

3.7 Strategies for Distributed Design

The intensity of the pandemic situation, coupled with the team's general willingness to experiment, led us to explore alternative uses of hardware and software. Next, we discuss current potential strategies and potential opportunities that lie ahead.

S1. Simulating a Co-located Design Space for Sketching *It is difficult to gain a full view of group sketching in a distributed setting because online meetings are generally limited to one view per participant. In an attempt to create a real-time collaborative sketching experience, two team members tested a setup of two device cameras per person during a Zoom meeting.* The setup included signing into the meeting twice with two separate devices; one device was a PC camera aimed at the face of each participant, and a second device was a phone camera that was directed

on their paper and pen. Though it was awkward to find a suitable angle and stabilize the phone, facial expressions, gestures and gaze were captured along with a view of real-time sketching. This method allowed the conversation to be held concurrently with a view of sketching practice as it was unfolding within the discussion. This remote sketching activity was seamless in a virtual, distributed design setup that simulated a co-located design environment. It supported conversational and visual communication; however, it was cumbersome to recreate this physical setup, and it was not attempted after a single trial. There is considerable potential for developing better and easier ways to set up this type of distributed collaboration. For instance, this approach could bypass knowledge gaps or inaccessibility to using digital sketching tools such as a Wacom tablet. Likewise, we imagine specialised software might provide support for this purpose.

S2. Screen-Sharing to Collaborate in Software Applications *Different team members can use their software fluency and bring different skills to the table. With the goal of including everyone throughout the design process, we used screen-sharing via Zoom to collaborate in specialized environments such as designing in Adobe Illustrator or editing code.* What made this method particularly useful was when there was skill cross-over in the team because meeting participants could control the mouse during a screen-sharing session. For example, a team member shared their design on the screen of an open Adobe Illustrator workspace during the Zoom meeting. Another team member controlled the mouse from a separate location on their shared Adobe Illustrator workspace. This process allowed for real-time manipulation of the visual components of our design and to share skills between multiple team members. Even in cases where collaborators were not manipulating the software remotely, we found sharing specialized environments to be useful as it mimicked casual co-located collaboration. For example, designers might often gather around the work space of the person implementing a design to tweak position, padding, and other style details. We simulated this experience with screen-sharing and being able to grant remote access to the mouse meant that team members could point out these details with accuracy.

S3. Using Hand Gestures for Discussing Interaction *Animating designs using video or animation software is difficult for team members that lack such technical skills. Not everyone in the group knew how to digitally animate a design, which excluded some team members.* We discovered that the most accessible way for each team member to show their ideas was by talking camera-to-camera similar to a face-to-face co-located setting. The software knowledge gap was resolved by relying on hand gestures and moving static design artifacts with our hands while remaining visible in the camera. Everyone in the team with access to a web camera could speak to their ideas and show how they imagined the design would move with intuitive hand motions, facial expressions, sounds, pointing to, or moving their own sketches or cutouts while explaining their idea in front of the camera. This emphasized a fuller presence within a remote collaborative experience similar to that of a lab. We reflected on our choice of communicating about interactions and compared it to our previous visualization design experiences. Based on this process, we think we would have pointed to sketches in a co-located mode of collaboration instead of moving our hands in mid-air in front of the camera. We see the hand gestures as adding an extra barrier to communicating about interactions.

S4. Lo-fi Prototyping for Visualization Interaction *It was challenging to find optimal tools to enable all of us to test interactions in a digital format, given our variable programming expertise. We aimed to re-create the use of paper prototyping in a digital format.* To set this up, we used a digital whiteboard in Miro as a "table top" space and exported assets from Illustrator to use as "paper" clippings. Teleconferencing via Zoom enabled gesturing and speaking into the camera, while all team members could simultaneously copy, resize, and rearrange assets in Miro. Team members were able to collaboratively create UI mock-ups (Figure 3.2) and animate them by clicking and dragging. We found this method to be quick and inclusive to all members, regardless of skill. Additionally, we found the ability to duplicate elements and groups of elements without disrupting the integrity of previous models provided a benefit over traditional paper prototyping.

3.8 Discussion

As a team of information visualization designers we described and studied our experience using an auto-ethnographic approach in order to explore how we experienced visualization design methods in our project. Iterative reflection and thematic organization of our experiences presented us with overarching themes of challenges and strategies. During our pursuit to create a vibrant online collaboration in the early stages of visualization design, we were constantly reminded of situations that needed to be addressed, and that we felt were essential to maintain our co-located design process even though we were no longer able to meet in person. In doing so, we identified challenges and strategies that arose through our process, leading us to try new ways to conduct distributed synchronous collaboration. Our account may offer an example to the members of the visualization community who may identify with similar experiences that they too have had. This may serve to inform future visualization research and methodology in this domain.

We found that tools for designing, creating, and using visualizations such as Adobe Illustrator, RAW graphs [205], Tableau, Data Illustrator [187], and Charticulator [258] did not offer the support we were looking for in our synchronous collaboration. We more frequently relied on external web applications to collaborate both independently and together during our design sessions. We found the combined use of multiple applications such as teleconferencing (in our case, Zoom), virtual whiteboards (in our case, Miro), and collaborative word processors (in our case, Google Docs) provided considerable flexibility. However, constantly switching between applications became cumbersome at times, particularly when coordinating these between several team members during a teleconferencing session. Improved orchestration and integration between these applications, as well as more fine-tuned support for collaborative online sketching would be interesting directions to investigate and welcome improvements in such contexts.

In many design processes there are often activities that require the use of web tools or computing environments and for these we felt the shift to remote work did not hinder our performance of these activities. Research, data understanding, collaborative writing, finessing of high fidelity designs and prototypes are activities that often require the use of a computer. In a co-located scenario, we often

have team members gather in a conference room with personal laptops that they must attach to an external display to properly share with the group, or gather at the shoulder of one team member while they informally demo something on their desktop. These types of in-person collaborative moments can be cumbersome. However, we found they happened more rapidly and comfortably over teleconferencing by utilizing built in tools such as screen sharing, or in combination with external collaborative software.

We struggled more to adapt in the ideation and early iteration phases because our process relied on brainstorming, sketching, and rapid paper prototyping. We tried to mimic real-time collaborative sketching by setting up a dual screen conference, or by holding sketches up to the webcam. To some extent, we were able to sustain spontaneity of brainstorming and idea sharing similar to those of co-located collaboration by continuing to use mostly physical sketching materials like pen and paper. The transfer of physical sketches to the virtual whiteboard was cumbersome and we see this as an area for potential improvement. However, once the sketches are on a digital whiteboard they continue to be accessible for all future discussions and are easily duplicated and iterated on much more easily than their physical counterparts.

While we discussed access to equipment and distraction as being primarily a pandemic related challenge, we also see this as being potentially more widely problematic. Improvements we could make for our sketching sessions might involve high-quality webcams and sketching tablets for all team members. However, the cost and learning curve associated with adopting such technology is high considering that low-fi technology such as pen and paper work very efficiently and with more versatility. Likewise, having dedicated space and time to do one's work is essential for focus, and offloading the responsibility to the individual to carve it out of their domestic space is understandably challenging for remote workers.

Where we saw the largest challenge for remote work was communication and social dynamics. Working in a co-located environment facilitates serendipity, natural discussion, and a tangible sense of togetherness that allows for ideas to emerge spontaneously. We found some team members engaged in prolonged teleconferencing sessions to experience the sense of community and to concurrently share ideas as more of a "hangout" rather than a meeting. However, other team members who neither could nor chose to utilize video and did not engage in the "hangouts" slowly drifted away from the project likely because they felt excluded. In a co-located environment, it is quite clear that an individual is committed to working because they have physically arrived at work, and likewise one can pick up on how busy or idle a co-worker might be when they are co-located. Being disconnected to these physical cues, in conjunction with voluntary roles in our particular project, made assigning tasks or setting expectations challenging. We discovered that social dynamics more frequently and often more seamlessly sort themselves out in a co-located scenario require a lot more facilitation and management effort. We imagine that this may require an additional role or skill set added to a team, or better integration of a person's status ("available", "busy", "away") into the collaborative environments. Messaging applications such as Slack provide status information, but in our experience, they lack nuance and integration with

realistic highly synchronous workflows. There is no shortage of collaborative software that aims to increase productivity and facilitate focus sessions, but few that fulfill the sense of community and spontaneous collaboration that happens in co-located work environments.

Finally, it is worth noting that the ability to reflect on our experience of synchronous distributed design is largely due to the fact that we were distributed. We were forced to put every piece of inspiration and every sketch into Miro. All of our notes and communications are documented on Slack and in Google docs. Having this detailed repository at every stage allowed us to reflect and gain insight into our process and learn from our experience.

3.9 Summary

This chapter contributes to sub-question one, examining how researchers in data visualization approach social-relational aspects in their work. The reflections demonstrate the social-relational nuance in a distributed online setting. In particular, I begin to consider sociality as an integral component of cross-disciplinary collaborative research. The quality of social interactions changed. It was vital for my colleagues and me to have online social interactions for collaborative design. The time and attention they devoted to maintaining social elements in our online collaboration were part of what led me to consider social-relational dimensions, which are seldom discussed in data visualization.

I began to think about the social-relational dimensions in processing data and designing visualizations for epidemiologists and government leaders with varying levels of technical expertise in health or data analysis. The distributed collaboration started my rethinking of collaboration in data visualization, specifically to promote social-relational interactions among people and data. These considerations set the stage for the next chapter, which focuses on reflections with researcher-designers at Northeastern University on interdisciplinarity in data visualization. There, I will discuss the less common research approaches in the data visualization literature. We call on academics to go beyond the disciplinary conventions in the field. The next chapter enriches the context of how researcher-designers approach problems in diverse ways and the disciplinary barriers they may face.

Chapter 4

Exploring Interdisciplinary Approaches in Data Visualization

Embracing Disciplinary Diversity in Visualization

This chapter includes the majority of the publication I co-authored with Justin Raynor, Sheelagh Carpendale and Melanie Tory [192]. I co-led the writing of the initial draft with Justin Raynor. Sheelagh Carpendale and Melanie Tory co-led project administration and supervision. Everyone contributed equally to the conceptualization, review and editing of the paper [1].

Visualization is inherently diverse and is employed in countless domains to enable meaningful interactions with data. There is tremendous opportunity in embracing disciplinary diversity to widen the pool of contributions to visualization design, research, and practice. We describe several examples of diverse approaches, including the scientific method, design studies, tool building, participatory research and co-design with communities, data storytelling, and autographic design. We discuss opening the aperture, pushing back on what we, as a community, deem acceptable and rigorous, and what can be gained through greater inclusivity of approaches. These reflections inform my research question and sub-question one by highlighting social constructivist research approaches that consider sociality and diverse, socially oriented values that are less acknowledged in the field. This acknowledgement relates to my thesis exploration and main research question: how data visualization can support social interactions among people from different worldviews.

4.1 Introduction

Visualization (VIS) is often discussed as both an art and science. A myriad of contrasting approaches accompany the diversity of VIS applications, yet we often limit ourselves to familiar methods. Here we aim to celebrate epistemic, practical, and disciplinary diversity of approaches in VIS, which we collectively refer to as *disciplinary diversity*. We acknowledge differences in research processes,

[1] https://credit.niso.org

share some examples we appreciate in VIS research, and suggest ways we, the VIS community, can strive to be more inclusive. We hope to inspire visualization researchers and designers to explore unfamiliar approaches, celebrate the creativity they bring to our community, expand our mutual respect, and embrace collaboration among disciplines. Our hope is that by opening the aperture of what is possible, the VIS community can partake more richly and more fully unlock the potential of data.

We draw attention to research approaches that go beyond what is often seen in the VIS literature and argue that this diversity of perspectives will spur innovation. We want to emphasize that we are not suggesting these as new paper types, but rather as examples of the many research approaches in active use in VIS and other fields. We then discuss actions the VIS community might take to better encourage, embrace and celebrate diverse contributions. Our work contributes a small step towards the greater goal of broader disciplinary diversity within the VIS community.

4.2 Variations in Research Approaches

To present our viewpoint, we present six examples of research approaches, three familiar and three, perhaps less familiar. Rather than an exhaustive list of approaches, this should be considered a sampling to illustrate the diverse possibilities. We encourage the reader to embrace the unknown and consider what may be possible by looking at problems through different disciplinary lenses. There is validity in approaches that were matured in other disciplines and that can be adopted and borrowed in a visualization design context.

Keep in mind that, though we describe the approaches separately, these processes and their outputs are often not mutually exclusive. Approaches can overlap and merge, mirroring the unique ways in which visualization design unfolds differently in each project.

Each approach is accompanied by a sidebar containing publications that employ the approach or resources for further information. Though these are not intended to be used as templates, the reader can take a deeper look at each approach through these examples.

4.2.0.1 Scientific Method

The scientific method (Fig. 4.1) is a research process common in the computer science oriented visualization communities (e.g. IEEE VIS, EuroVis) because of the natural sciences backgrounds of many of their members. It begins with observing an event, phenomena, or data, which leads to research questions. A scientist then creates hypotheses and designs experiments to prove or disprove the hypotheses. The data is analyzed, a conclusion is formed, and the research is disseminated. Results of one study often drive observations and questions for future studies and the process continues. These types of research studies represent a preponderance of visualization research and are foundational to the visualization community historically.

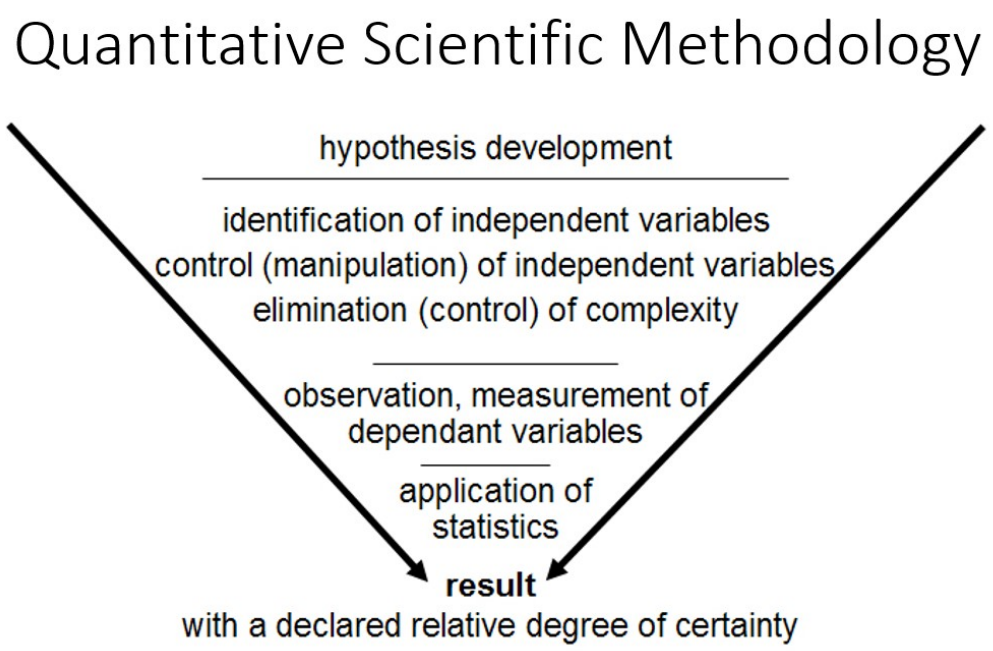


Figure 4.1: Simple outline of the scientific approach (see [55]).

Scientific Method Resources

Jardine, N., Ondov, B., Elmqvist, N., and Franconeri, S. (2019). The Perceptual Proxies of Visual Comparison. IEEE TVCG, 26(1).

Talbot, J., Setlur, V., and Anand, A. (2014). Four experiments on the perception of bar charts. IEEE TVCG, 20(12): 2152-2160.

A key objective of applying the scientific method to visualization research is to build a theoretical foundation for the field and ensure the theory and results are accessible and actionable. The VIS community is a blend from multiple disciplines, which have their own specific criteria, validation, and rules for research outputs. The scientific method offers the possibility of actionable theory, rigor, structure and verifiable results. However, because of the relative age of the visualization discipline with respect to other more foundational sciences, the theory is still forming and as a result can be difficult to apply.

Finally, it is important to understand the gravity of defining theory and best practices in the ways that they are applied. Theory is often created with relatively small studies, but applied in broad foundational ways. It is important to recognize the nuances and applicability when using the scientific method to report on and define visualization theory.

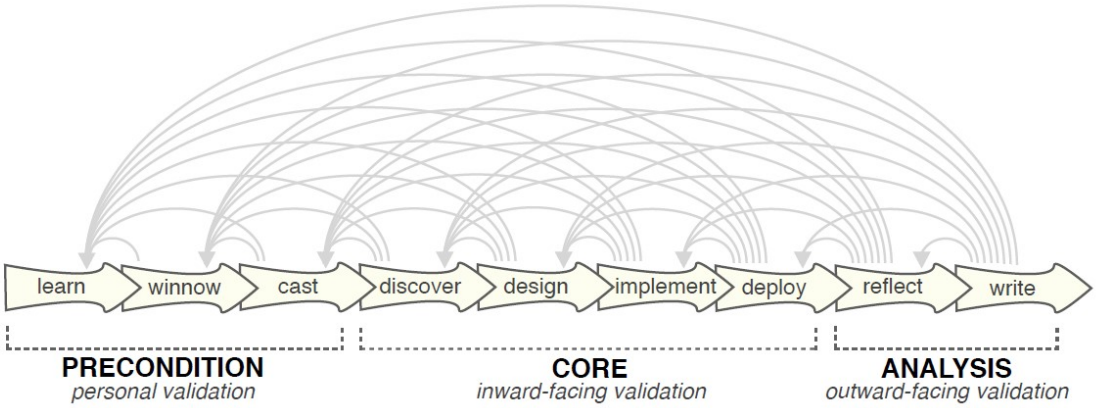


Figure 4.2: Overview of a typical design study process [270] in comparison with he data pipeline (see [55]).

Design Study Resources

Meyer, M., Munzner, T. and Pfister, H. (2009). MizBee: a multiscale synteny browser. IEEE TVCG, 15(6): 897-904.

Pandey, A., Shukla, H., Young, G.S., Qin, L., Zamani, A.A., Hsu, L., Huang, R., Dunne, C., and Borkin, M.A. (2019). CerebroVis: designing an abstract yet spatially contextualized cerebral arteries network visualization. IEEE TVCG, 26(1): 938-948.

4.2.0.2 Design Studies

Design studies are a popular approach in the VIS community to problem-driven research, as described by Sedlmair et al. [270]. Design studies apply existing or new visualization techniques to domain specific problems with domain expert collaboration, to (1) create visualization theory that can later be applied to other problems, and (2) validate efficacy of the techniques. Many different approaches to design studies have been offered starting with Munzner's nested model [222], which takes a waterfall approach to the design and validation of visualizations. The output of each phase (domain problem characterization, data abstraction, encoding and interaction techniques, and algorithm design) drives the next. As shown in Fig. 4.2, Sedlmair's [270] approach is a cycle, showing that researchers often cycle back to previous stages of design ('learn, winnow, cast, discover, design, implement, deploy, reflect, and write') based on the output and what is learned at each stage.

Visualization researchers and practitioners who regularly practice design studies often admit that the process is challenging and that much of the learning occurs in the journey towards an end product [270]. Every design study is unique, often not directly applicable to future research. Although several design study methodologies have been offered, the process is often unique to each study.

4.2.0.3 Tool Building

Popularized by Fred Brooks's concept of "toolsmiths" [168], this approach focuses on building gadgets, software, tools, and techniques that solve specific problems. Tool building (see Fig. 4.3) can often leverage and incorporate findings and theory from previous research, but focuses directly on building tools to solve problems. The approach asks questions such as: "How can we create visualization tools and techniques that are easy for humans to read and use to solve problems?", and "How can we use automation and abstraction to enable designers so that they do not need a deep theoretical understanding before being able to create visualizations?". A few foci that play important roles in tool building include: (1) Understanding user needs, (2) Readability criteria and aesthetic principles, (3) Encoding criteria into algorithms, and (4) Validation.

Understanding user needs helps tool designers define requirements and map them to visualization tasks. Task abstraction centers on the idea that a designer can pull out commonality in domain specific requirements and translate them into more well known tasks. But, getting the domain specifics correct can be challenging when visualization designers are not familiar with the domain. For example, in a design study on diabetes, Zhang *et al.* found that traditional visualization task abstraction methodologies were not sufficient to capture the complex relationships that exist between doctors, patients, log books, instruments, blood tests, backgrounds, and other sources [326]. They created a hierarchical task abstraction technique that allowed visualization experts to see and understand the relationships and interactions that exist between the tasks. *One of the interesting aspects that is often realized in this process is that there is no linear, repeatable, or predictable way to obtain and truly understand user needs and every visualization tool created captures this focus very differently*.

Readability criteria and aesthetic principles represent researchers' attempts to incorporate theoretical findings into their visualization designs. This is often a balance between scientifically derived visualization principles and hard-to-define design theories. This focus can utilize visualization design theory (e.g. [222]) and graph drawing aesthetics (e.g. [313]), but also input from psychology, cognitive science, art, and design. It is often noted that more work needs to be done in this area, particularly with trying to capture hard-to-understand design principles as they relate to connecting human interpretability, memorability, and usability with visualization techniques.

Tool Building Resources

Bostock, M., Ogievetsky, V., and Heer, J. (2011). D^3 data-driven documents. IEEE TVCG, 17(12): 2301-2309.

Satyanarayan, A., Moritz, D., Wongsuphasawat, K., and Heer, J. (2016). Vega-lite: A grammar of interactive graphics. IEEE TVCG, 23(1): 341-350.

Encoding these criteria into algorithms synthesizes the often messy output of design criteria into executable code. This can be challenging and often boils down to the designers' judgement of "Does it look right?" Designers may manually run data through heuristics multiple times in order

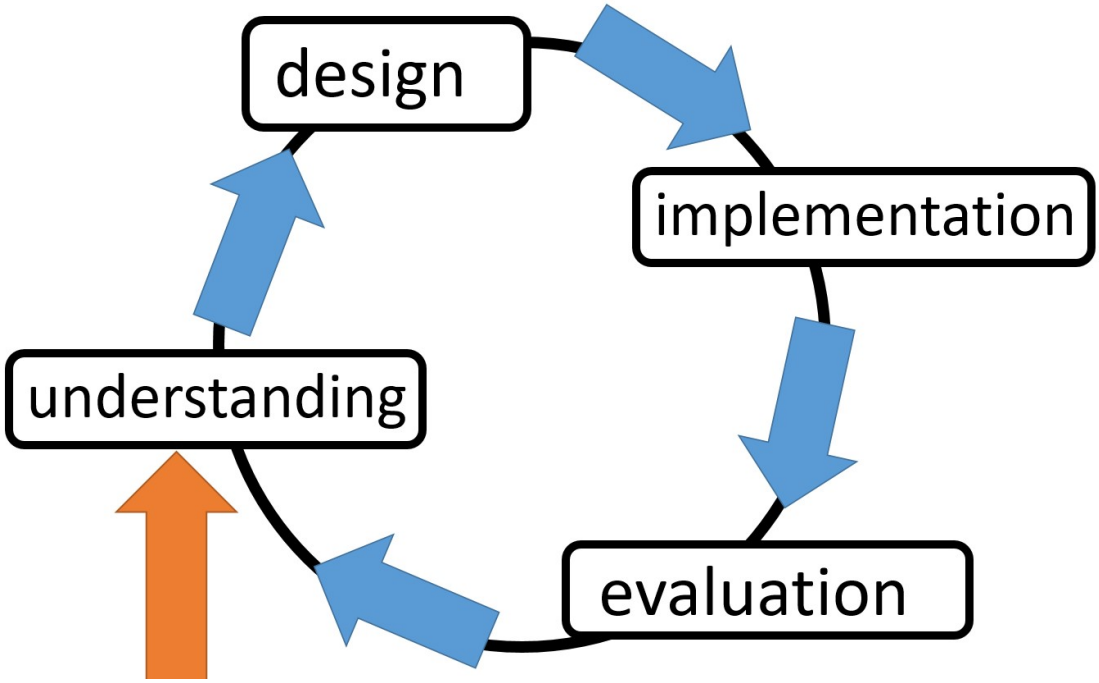


Figure 4.3: Basic steps in iterative tool building. The orange arrow indicates a recommended start point (see [55]).

to get the right look. Studies and tools that open up this option space a bit more modularly do exist. For example, di Bartolomeo *et al.'s* [27] work on networks allows designers to experiment with combinations of readability, crossings, bendiness and groupings to optimize aesthetics and layout. This focus often requires mathematics and an ability to bring together user needs, design criteria, psychology and code.

Validation typically encompasses: (1) quantitative validation of measurable attributes such as speed and computational efficiency, often making use of statistical analysis, and (2) some combination of study design, observational techniques, and qualitative analysis.

4.2.0.4 Participatory Research and Co-Design with Communities

The goals of the first three approaches frequently center on producing a tangible product and evaluating how effective a tool or technique is rather than, for example, learning about how people understand and think about problems or examining how communities function with visualizations in practice.

Although design studies and tool building often look at the journey rather than the end product, *there is still a large opportunity to leverage insights and exploratory outputs from qualitative studies that do not necessarily focus on a deliverable, and to take part in observational and investigatory work rather than the need to be "better" or "right"* [85, 208].

Participatory research, instead, looks at how researchers work with specific communities of people, such as domain expert stakeholders or people who have relevant lived experiences (experience gained through first hand knowledge). These approaches prioritize human relationships,

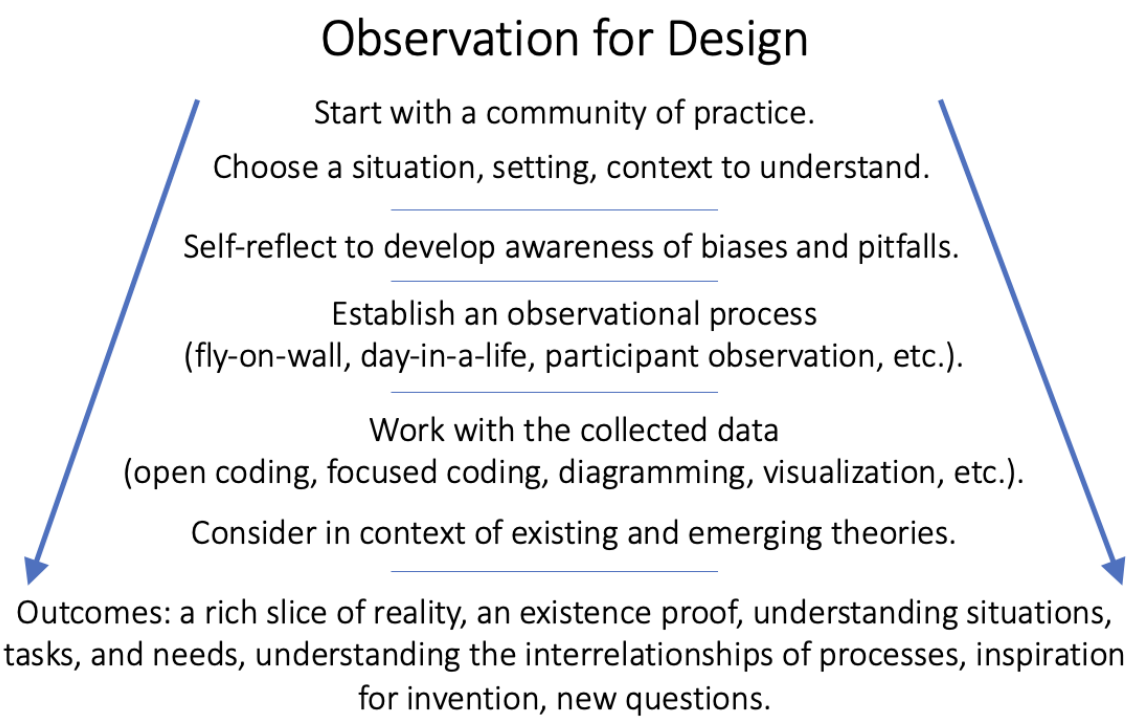


Figure 4.4: Observation for design is a possible approach when working with communities (see [55]).

immersion, and deeply understanding how people want to use visualization in a particular context [130]. For example, in a health application, there are many communities who can have very different needs, such as the clinicians and the patients. Researchers collaborate with communities to better understand a problem and the rich complex contexts before addressing the problem itself. In this way, these studies aim to broaden our understanding of distinct communities and lived experiences, and focus less on building something that promises to be ideal or useful but gain rich insights into a specific reality, offering breadth and depth through the process [208]. Example steps for working with such communities are outlined in Fig. 4.4.

This approach embraces the idea that there is validity and power in the in-depth observation of just one case. Borrowing from the medical and education fields, individual patient or student cases may not fit a known model, but are nonetheless valid and important to understand. An interesting observation from researchers choosing this type of approach is that visualization in context can be completely different than the idealized or optimized visualizations published in the literature. This supports the need to create a place for research that captures unique observations.

We often value seemingly measurable concepts such as generalizability, scalability, and project impact. Yet, participatory research approaches show the importance of other research outcomes as well [208]. For example, qualitative studies and Research through Design (RtD) [330] are research processes that have to do with observation, trying something out, and reporting on what was learned through the process. These approaches may result in “one off" studies, but they are important research findings because they reveal how communities use and interact with visualizations in

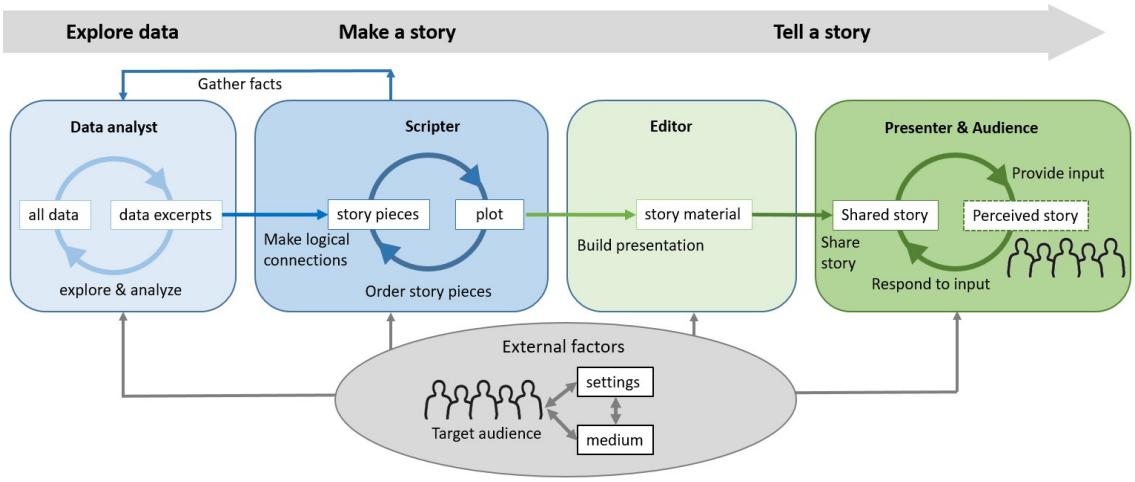


Figure 4.5: Data-Driven story telling. Diagram adapted from [182], (see [55]).

practice. There is tremendous potential for rich contributions using these research approaches and they should be more widely adopted in the VIS community.

Participatory Research and Co-Design with Communities Resources

Hall, K.W., Bradley, A.J., Hinrichs, U., Huron, S., Wood, J., Collins, C., and Carpendale, S. (2019). Design by immersion: A transdisciplinary approach to problem-driven visualizations. IEEE TVCG, 26(1): 109-118.

Hinrichs, U., El-Assady, M., Bradley, A.J., Collins, C., and Forlini, S. (2017). Risk the drift! Stretching disciplinary boundaries through critical collaborations between the humanities and visualization. Proc. Workshop on Visualization for the Digital Humanities.

4.2.0.5 Data Storytelling

Storytelling, visual journalism, and data narratives focus on different research outputs. These approaches recognize the intrinsic value in narratives and voices that can be drawn out from the data itself, and, also importantly, from individuals. The core of storytelling centers two perspectives [182] (Fig. 4.5): (1) The story itself, building a narrative and shaping the way the narrative is presented, and (2) telling the story, the idea that there is an intended audience with whom the story will be shared. Who we tell the stories to, and who gets to tell stories in the first place, make a difference.

Participatory citizen journalism prioritizes the lived experiences of marginalized communities and provides an opportunity for people to tell their own stories rather than having an outside "expert" journalist retell their stories for them. Based on mutual respect, citizen journalism honors the different ways people consume data based on their distinct contexts and needs by showcasing communities that are often excluded. These approaches aim to provide a platform for individuals to tell their own story through writing, spoken word, or photography and include their input throughout the research process. In this way, the role of the storyteller fundamentally changes the role of the researcher — from researcher acting as a conduit or interpreter of people's needs and lived

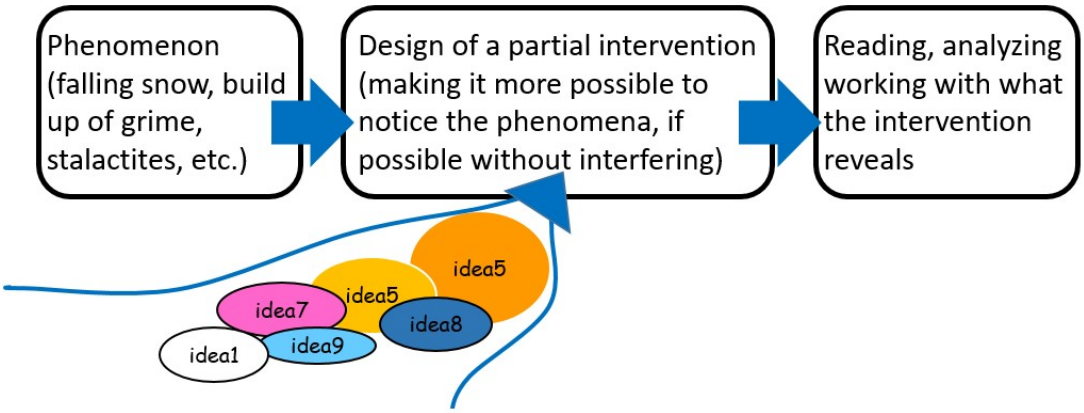


Figure 4.6: This diagram merely emphasizes that the design thinking process is concentrated in making the phenomena noticeable, (see [55]). For autographic design process diagrams see [230].

experiences to a facilitator and a co-designer. The first-hand stories reveal new knowledge to the researcher and the co-designers' ongoing participation provides iterative design feedback wherein new knowledge is cyclically sought and found. For instance, through an online platform designed with members of the disabilities community (`https://disabilityjusticeproject.org/`), people with disabilities can share their stories by using a website with accessible visualization design choices. Participatory research approaches inform the visualization community with contextual knowledge for more equitable research and design. These are not "one-off" cases — they are examples of what researchers learn by working with marginalized communities to better understand distinct community contexts, experiences, problems and needs.

Another approach within storytelling is visualizing data in ways that intrinsically express a narrative. Here, researchers strive to show linear narratives through a combination of viewing time, space and position, so that viewers can see a story through a data set's trajectories over time. This type of work makes an attempt to capture ideologies in politics through visualizing text from speeches or debates, for example, or belief systems, sentiments and theories.

Participatory citizen journalism approaches increasingly straddle disciplines ranging from natural sciences to mathematics, statistics, psychology, political science and journalism, disciplines that differ in their acceptance criteria and measures of rigor. *By focusing on the methods or techniques to visualize data, the VIS community may be discarding valuable insights, inferences, and narratives that are produced from the data.*

Data Storytelling and Autographic Design Resources

Riche, N.H., Hurter, C., Diakopoulos, N., and Carpendale, S., eds. (2018) Data-driven storytelling. CRC Press.

Hanrahan, P. (2004). Self-illustrating phenomena. Proc. IEEE Visualization.

Haroz, S., and Ma, D. K.-L. (2006). Natural visualizations. Proc. Eurographics, 43–50.

4.2.0.6 Autographic Design

Autographic Design [230], which is the act of self-writing or self-inscription, offers a different way of thinking about the problem of representing data. This approach seeks to expose and present physical traces of phenomena to show evidence or reveal something interesting. With Autographic Design, researchers focus on the idea of expressing data through natural units and structures of the world, rather than on mapping or representing data artificially (see Fig. 4.6). The natural world captures reality and offers this in ways that are experience-able. The ways that these experiences occur differ in such areas as climate change, health, air pollution, and ozone pollution. For example, air pollution leaves deposits on the buildings but may need interventions (e.g. a patterned stencil that is removed after a prolonged period) to enable humans to recognize the build up over time.

The directness of this approach stands in contrast to what we traditionally consider visualization, where there is a mapping between an abstract representation and the underlying natural phenomenon it represents. People can use physical traces much like the intentionally designed visualizations and increasingly in place of them altogether. They act as mechanisms for understanding often complex systems in simple and exploratory ways. The importance of this approach is that traces are not representations at all and do not stand for something else. In fact, they stand for themselves and act as a first-hand account of the effects of a system. People make sense of these glimpses of natural data in interesting ways that can, in fact, inform and add to the discourse within the visualization community. However, because visualization is often so focused on data mapping and data representation, this type of approach is often overlooked.

4.3 Discussion

Approaches to visualization are rarely exclusive or independent. There are countless variations of approaches with commonalities in their challenges and contributions; the differences can be nuanced rather than stark. For example, tool building may involve a form of a design study but a design study may not always produce a tool. Understanding these overlaps and differences can strengthen visualization studies and help the community break away from the idea of rigidly evaluating studies based solely on the perceived paper or study type.

For each of us, understanding approaches used in other disciplines opened our eyes to new possibilities. Approaches that we had never before considered struck us as interesting and informative. Yet many of these approaches are uncommon at mainstream visualization conferences. Should these and other approaches be welcomed in VIS? We think so.

Therefore, we envision bringing more voices and expertise to the VIS community. We imagine leaving the office environment to learn and collaborate with the general public who are experts in local knowledge and context. We call on the VIS community to involve a broader set of reviewers and practitioners to represent the multitudes of approaches in VIS and to offer suitable guidance for approaches from different domains. The full scope of what is valued as visualization in the world at large inherently values the differences in approaches. However, only a subset of research approaches

are commonly represented at VIS conferences such as IEEE VIS and EuroVis. We suggest showcasing more research approaches and outputs to expand and strengthen cross-disciplinary diversity at the conference and to enable connections for new ideas and collaborations.

If we look introspectively at the paper review process, are there road blocks or practices that prevent disciplinary diversity? How can we review, categorize and critique research in meaningful and constructive ways while avoiding conformity and allowing new ideas and approaches? How can we accept and understand these new approaches, leverage the diversity that exists in our community, and, at the same time, maintain research rigor? We offer the following recommendations to future reviewers and researchers:

Focus less on paper types. Paper types, which are used in the call for papers (CFP) and in the review process at IEEE VIS and EuroVis, may restrict and structure research in unintended ways that may discourage contributions that have not been previously been considered. Reviewing based on a paper's type may overly focus a reviewer on the wrong outputs of a research contribution that does not cleanly fit into one canonical type. Paper types may have value as training mechanisms for new visualization researchers to understand different ways papers can be structured. One idea that may at first seem like a practical way to rapidly induce change would be to simply add an "other" category. Though easy to implement, this would not achieve the goal as it potentially would treat these authors as intrinsically different from authors submitting defined paper types. In short, people could feel "othered", violating principles of inclusion. Instead, changing language in CFPs and review instructions towards treating paper types as examples in a broader space of possible contributions, rather than stringent review structures, may be a step towards encouraging new and unexpected papers.

Encourage qualitative studies. We see gaps in the visualization literature with understanding intangible aspects of how individuals interpret, understand, and use visualizations, yet the difficulty of getting qualitative studies published is perpetuating this. Qualitative studies add rich context to the community. In many qualitative studies, rigor, objectivity, and validity may emerge through the acknowledgement of researcher bias during the study, and research claims can be validated by researchers who share their qualitative findings with study participants to confirm the researcher's accuracy [85]. Scalability is not usually a goal in qualitative studies.

Allow reporting of research failures as well as successes. Because of the interdisciplinary nature and young age of the visualization community, we encourage papers that include lessons learned and research failures as well as successes. Much can be learned from research failures; such papers can drive debate and inspire new questions.

Consider more research contribution types. Expanding contribution types has been recommended previously [183]. A combination of different visualization problems, approaches, and research outputs can drive many different contributions. For example, qualitative studies may not map to a stringent type of output. Furthermore, we should recognize the potential for new contribution types that have not yet been considered.

Embrace unfamiliar and unusual methodologies. We encourage reviewers and researchers to understand that every piece of research is unique and may require an equally unique approach. If we truly want diversity of thought in the visualization community and if we understand that visualization borrows from so many disciplines, then we must encourage diverse, creative, and novel approaches.

Include reviewers from different disciplines. IEEE VIS, for example, is heavily weighted towards people with a background in computer science. While creating a culture shift in visualization will take time, we suggest additional support and resources for reviewers who may not have an in-depth understanding of research methodologies outside of computer sciences. For example, many VIS reviewers validate research studies based on measurable factors such as sample size, which is important for statistical significance in certain kinds of quantitative analyses. However, in other domains, even one participant may be sufficient to study human phenomena. Evidence of rigor may take many forms, such as in-depth interview methods, thoughtful research through design processes, or co-creation methods that address distinct research questions and values. Reviewers from other disciplines are needed to help validate research methods in the context that they are written within rather than through a specific research lens.

Actively welcome diverse perspectives. The world is increasingly focused on embracing social diversity. Towards this end, we advocate for including as many perspectives as possible, such as people with disabilities, the LGBTQIA2S+, BIPOC communities, feminist perspectives [85], emerging challenges to research methodologies [274] as well as careful consideration in the use of data through the CARE [6] and FAIR [5] principles.

4.4 Summary

This chapter contributes to sub-question one, examining how researchers in data visualization approach social-relational aspects in their work. Our reflections highlight the possibility and rationale for embracing diverse worldviews in data visualization research, particularly social constructivist research approaches that consider sociality and diverse, socially oriented values that are less acknowledged in the field. This project contributed to my (re)conceptualization of data visualization. I was working on using data visualization as an approach for qualitative and design-oriented explorations. This example illustrates a relational approach to data visualization, which considers the nuanced social connections and contributes to the production of socially critical data visualizations, advocating for openness, increased social-relational awareness, and a shift in the scientific culture within the data visualization community of practice.

These reflections are based on a workshop with 25 academics discussing the opportunities of broadening research approaches in the field. I found that the discussions highlight the lack of socially-oriented research approaches, which connects to my thesis exploration of better understanding the social dimensions surrounding data work. I began to consider the subtle social power dynamics in cross-disciplinary collaborations. The subsequent chapter adds a more

nuanced understanding of how data visualization can serve as an icebreaker to bypass subtle, socially constructed academic hierarchies. Additionally, self-sketching or visualizing information about oneself for introductions revealed that visualizing a circle in a collaborative setting carries hierarchical connotations.

Chapter 5

Valuing the Social-Relational Within Academic Introductions

Sketch Introductions: Shifting Introductory Formalities in Collaborative Design Practices

This chapter includes the majority of the manuscript I co-authored with Bhairavi Warke, Will Odom, Diane Gromala, and Sheelagh Carpendale. I led the conceptualization and writing of the original draft. Qualitative analysis led by me and supported by Bhairavi Warke. Will Odom supported the development of the design methodology. All co-authors supported writing the original draft. [1].

We explore data visualization in the form of personal sketching as a creative approach for a group of researchers to become better acquainted, known as Sketch Introductions. This work informs sub-question one and the main research question by providing an example of how data visualization is useful as a social-relational research and design approach. Moreover, the process demonstrated how facilitating visual information encompasses social dimensions, including

[1] https://credit.niso.org

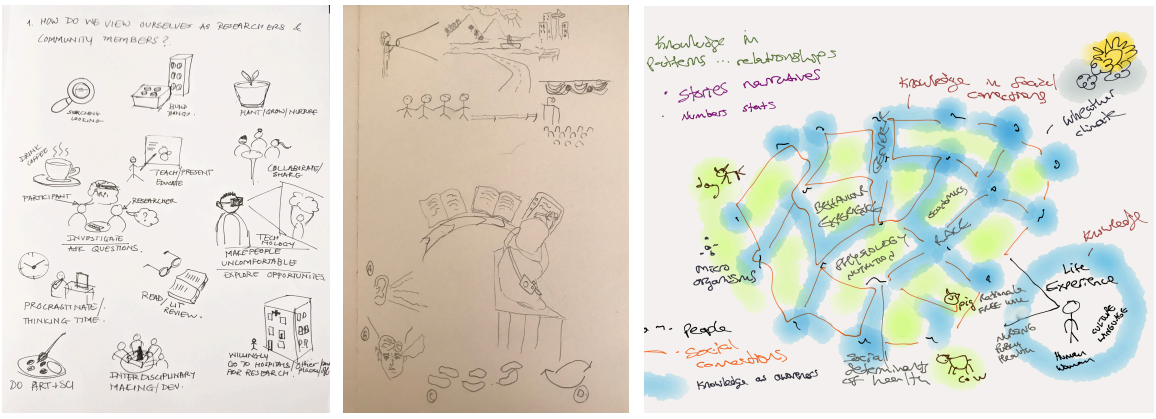


Figure 5.1: Sketches made during the workshop.

personal comfort levels, time, presentation order, and visual sequences that may represent social hierarchy in academic collaborations.

5.1 Introduction

We present Sketch Introductions, an alternative approach for the introductions that commonly occur at the beginning of a meeting. Through Sketch Introductions, collaborators introduce themselves via sketches drawn with a pen or stylus. To start, a colleague who is acting as a facilitator ensures that everyone has usable tools and setup, offers some leading suggestions to prompt sketching, organizes the collection of sketches so that all can view, and ensures each person has a few minutes to state their name and describe their sketch.

We were motivated to adjust and challenge traditional academic rank-based formalities by shifting subtle status markers implicit in typical academic introductions. Collaborative design protocols are steeped in traditional academic life that has existed for hundreds of years, and if we immediately introduce academic ranks, we may privilege subtle power dynamics and interfere with creative input and open intellectual exchanges. This is relevant because there are power inequities in knowledge production [251, 176, 98, 104, 274] while cross-disciplinary collaborations in Human-Computer Interaction (HCI) and data visualization (DataVis) are accelerated by Big Data, AI, and their own cultures characterized by technology. Thus, drawing upon our interdisciplinary research experiences from DataVis, HCI, Industrial Design, Education, and Healthcare, we suggest that re-thinking introductions of collaborators from diverse domains and recognizing differences in knowledge bases through explicit discussion about them may benefit collaborative research. Given that many diverse fields such as medicine, policy-making and journalism have adopted practices and technologies from HCI and DataVis, collaborative work between experts from diverse knowledge domains is not just an ideal but is increasingly necessary.

Knowledge domains implicitly differ in often fundamental ways, ranging from how information is collected and understood, trusted, valued, communicated, displayed and applied by different research communities. These differences in knowledge bases can produce barriers and seemingly insurmountable challenges [296], such as misunderstandings of strengths, goals, requirements and intentions. Furthermore, there are differences among people's lived experiences, histories, and systemic barriers within unjust social power structures. Thus, critical HCI scholars urge researchers and designers to critically reflect on and change status quo institutional procedures that have historically marginalized communities [19, 294, 102, 71, 70]. We argue that even introductions that state a person's name, rank, department, organization, and research expertise implicitly instate the hierarchical institutional power dynamics that the status quo upholds. Being aware of these social dynamics, we took a small step to explore how to shift subtle status markers in introductions among collaborators. We asked, *how can we change traditional academic introductions to support reflexivity through visual design practices?*

Sketching has been commonly used for design in DataVis and HCI. Prior studies suggest that some of the tools used in visualization practices can support self-awareness and self-expression [291, 289, 185, 203]. For two years, we explored sketching as an approach to shifting traditional academic introductions and engaging people through multiple iterations of sketch introductions in different academic contexts. We used design-oriented reflexive research methods and drew upon research in personal visualization. We iterated the activity throughout four different environments — informal pilots among colleagues, online design-oriented workshops, an online introductory academic meeting, and an in-person icebreaker at the beginning of a formal international research seminar. We found that Sketching Introductions was a successful icebreaker because it was an open-ended, free-form approach to conventional academic introductions. We contribute initial steps to leverage sketching personal introductions to centre reflexivity and personal experiences over ranks and titles. To follow, we describe our intention and process of designing this activity and what we learned through our experience. There is more to examine. Thus, we call for further exploration of design processes that aim to interrupt the status quo in conventional research and design practices. Furthermore, we invite our fellow readers and colleagues to try sketch introductions as a playful approach to introducing people to one another in a nuanced visual way.

5.2 Philosophical Framing

Through Sketching Introductions, we change a minor conventional formality as a step to acknowledge and challenge implicit power structures in voiced institutional titles and rank. We draw upon scholarship from intersectional feminism in HCI and DataVis as our philosophical framing that explains why it is important to acknowledge power dynamics and share different perspectives in research practice. For example, Longino, a feminist philosopher of science, in 1989 asserted that science is a social activity and researchers must socialize and share different research perspectives because it is a fundamentally crucial activity to scientific knowledge production to prevent "disciplinary gate keeping" where disciplinary assumptions can be challenged so new insights can emerge; Longino also discusses that power differentials in research must be acknowledged and mitigated to allow more perspectives in science [190]. Feminist epistemology assumes knowledge is non-universal, localized, relational, embodied and context-dependent [132]. By anchoring our work with the perspective that there are many ways of knowing and understanding, we designed Sketching Introductions to foreground different perspectives in knowledge work and bypass some power dynamics. Additionally, feminism has historically challenged normative and systemic power structures, and its proponents continue to call for a critical examination of harmful power systems in research and design practices.

Scholars from Black feminist thought (BFT) and Intersectional feminist perspectives in HCI argue that it is essential to interrogate and change the deep-seated oppressive systems of power present in design and research. We look to the critical scholarship of Erete [100, 102, 101], Rankin [256], Dickinson [81], Harrington [135], Asad [19], and Costanza-Chock [71] who critique standard

research and design practices in HCI because they perpetuate oppressive systems such as racism and sexism that marginalize and oppress people. However, the standard social structures are often unquestioned by the privileged people in power who benefit from the institutional status quo. For example, Rankin et al. studied the experiences of Black women in computer science education who are systematically excluded from "predominantly white institutions (PWI)". Rankin et al. assert that privileged members of universities must commit to questioning their assumptions about standard institutional practices and urge reflexive practices as part of *dismantling* the oppressive status quo of academia [255].

In DataVis, D'Ignazio and Klein draw upon Black intersectional feminist principles and call for populist approaches in the DataVis community to change standard data visualization design processes that look to generalize universalist findings about users [85]. Similarly, Bardzell proposed to integrate "agency, fulfillment, identity and the self, equity, empowerment, diversity, and social justice" practices in interaction design for the HCI community in 2010 [26]. However, Chivukula analyzed 70 papers that cited Bardzell's work in HCI and found most of them did not adapt or enact the feminist goals that it called for [64]. We look to work that adapted feminist principles in their research, such as Key's project, engaging researchers in feminist care in post-humanist research [169], Hancox et al. discuss the potential of increasing "interactional ways of knowing" [131]. Chen et al. envision reflexivity and situated knowledge production in HCI through feminist Research Fictions [61]. In honouring transdisciplinary maker communities, Okerlund et al. use Bardzell's feminist goals to develop an interdisciplinary maker fashion show [234]. Our research is also anchored in feminist principles and informs our practical exploration on how to prompt reflexivity and focus on diverse *knowledges* that sidestep titles and ranks.

5.3 Drawing Upon Reflexivity & Sketching in DataVis and HCI

Reflexivity is a vital activity in qualitative research that applies to our work because it supports introspection about aspects of collaborators' positions and personally held perspectives about knowledge. In a collaborative setting, reflexivity is a collective process that invites individuals to confront and reflect upon themselves. In addition, the process relies on the subtle mutual social exchanges and dialogue that shape relationships between researchers in a collaborative setting [108].

We use Linda Finlay's [2002] definition of reflexivity because through *Sketch Introductions* , we aim to creatively invite reflexivity among researchers and designers:

> As a thoughtful, conscious self-awareness. Reflexive analysis in research encompasses continual evaluation of subjective responses, intersubjective dynamics, and the research process itself. It involves a shift in our understanding of data collection from something objective that is accomplished through detached scrutiny of "what I know and how I know it" to recognizing how we actively construct our knowledge. [108, pp.532])

Reflexivity in practice has been explored in the DataVis community. For instance, Dykes et al. seek to understand better the role of reflection in collaborative research practice [96]. Recently, the Me-Ifesto was created as a reflexive exercise to think about one's teaching and research practice in data visualization [12]. Earlier, I noted the potential of including cross-disciplinary perspectives in knowledge production in the DataVis community [192]. Similarly, Sedlmair et al. acknowledge that collaboration is critical in data visualization design research [270]. In HCI, Zimmerman et al. discuss how the researcher-designer benefits from the iterative nature of design through continuous reflection, reinterpretation and reframing of the situation [329]. Similarly, design probes is an approach that use artifacts in doable activities to gently invite, or "probe", participants to respond to questions about their identity or personal experiences in nuanced ways [307, 117, 115, 307]. In HCI, a vast corpus of work presents research using design probes. In our work, we draw upon Koulidou et al.'s Dialogical Sketching [175], a method that adapts design probe methods specifically to sketching as a visual way for an individual to respond to probes. In Koulidou et al.'s paper, participants sketch in response to a personal experience, sketch together and over each other's sketches, and they found that it was a meaningful way to communicate about personal experiences that are difficult to verbalize in the context of a conversation. Similarly, sketch-based research in personal data visualization has shown to provide a creative way to express and reflect upon personal experiences [289, 291], deepen self-awareness, and support decision-making [185, 257, 203]. Prior research suggests that sketch-based visualization is a practical thinking method and opens up a generative workspace for hands-on learning and communication [311, 310, 309]. Lupi, for instance, describes the usefulness of drawing in thinking and communicating knowledge as an integral part of designing compelling data visualizations [194, 195]. Similarly, Sturdee and Lindley [284] discuss the potential of sketch-based research methods, including sketching, drawing, and 'hand-drawn outputs' for inquiry about human experience and technological design. Sketch Introductions also serve as "hand-drawn outputs" for reflection and communication. We position our research amidst sketch-based research and personal visualization in DataVis and HCI. We extend this work to a distinct, little explored context. To the best of our knowledge, little work has applied a sketch-based approach to interrupt traditional institutional introductions among groups of academic collaborators.

5.4 What is a Sketch Introduction?

We begin by presenting an example of how we developed Sketch Introductions as an icebreaker for a group of academic researchers and explain our process and what we learned through our design process. We addressed the following research question:

How can we change traditional academic introductions to support reflexivity through visual design practices?

Given our philosophical underpinning, we acknowledge the richness in disciplinary and cultural perspectives in knowledge amid enacting power differences in social systems that we are enmeshed with. Therefore, we considered an activity that would introduce people's

interests and experiences instead of their institutional ranks, titles, and seniority. As disciplinary differences can become contentious, we considered sketching a potentially helpful communication method. Because the sketch is visual, we posited that the process of sketching and discussing the resulting sketches might offer a way to keep a group's focus on articulating and sharing their perspective while simultaneously avoiding contentious disagreements about disciplinary differences [296]. Furthermore, we considered the important role of reflexivity among the collaborators to contextualize one's perspective with others in the group. Sketching personal lived experiences and perspectives on knowledge and research, termed "self-sketching" for the purposes of this paper, was designed to offer several advantages — namely, to,

- (1) Develop interpersonal connections through sharing sketches of researchers' perspectives;
- (2) Provide an opportunity for reflexivity through both. In the discussion section, we discuss what we learned from each workshop and propose some of our considerations for future work that portrays experiences and perspectives that they wish to share,
- (3) Have an engaging creative approach for expression and rapport-building accessible to people across all levels of drawing ability.

5.5 A Rough Guide to Try This Out

- Sketch Introductions can be used in a situation where one would use conventional introductions when a group of people begin to work together.
- A newly acquainted group of people from different domains meet — some may be previously acquainted, but others are meeting for the first time;
- A colleague facilitates the Sketch Introductions activity;
- Select sketching tools before the activity: pens, pencils, paper, digital sketching tools, paints, and/or crafting supplies.
- The facilitator explains how to sketch, helping the collaborators feel comfortable by explicitly stating that the sketches are not intended to be works of art - in our case, by preempting possible embarrassment, the facilitator shows samples of their own sketches.
- A reminder that there are no wrong answers and there is no right or wrong way to sketch.
- The facilitator provides a few guiding questions to think about while sketching;
- The group sketches for 10-15 minutes;
- Collaborators place sketches where all can see them - on a whiteboard or table when in person, on a shared digital whiteboard when online;

- Each person introduces themselves by name, indicating their sketch and describing what it represents based on the guiding questions.
- During these sketch introductions, other group members can comment and ask questions

5.6 Learning From Our Design Process: Exploring Sketch Introduction in Practice Through a Design-Oriented Approach

We iterated the activity throughout four different environments — informal pilots among colleagues, online design-oriented workshops, an online introductory academic meeting, and an in-person icebreaker at the beginning of a formal international research seminar. We wanted to learn from each iteration and looked at reflexive research methods across disciplines that study one's practice through reflection, [107, 108] — mainly, as researcher and designers, we learned by designing and implementing Sketch Introductions. Zimmerman and Forlizzi describe the value of using reflexive design-oriented research to generate new knowledge they called research-through design (RtD). Koulidou et al.'s Dialogical Sketching extends RtD to enrich interpersonal dialogue by making sketches to inspire meaningful visual conversations between people. By reflecting on our process of developing and facilitating Sketch Introductions we learned from each iteration and implemented changes to subsequent sessions. To follow, we describe the multiple iterations of Sketch Introductions and what we learned by iterating on our own design practice. We discuss what we learned from each workshop and propose some of our considerations for future work in the discussion section.

5.7 Pilot: Two Strangers Meet through a Mutual Friend Online

Three of the authors participated in a pilot workshop. The facilitator was familiar with the other participants before the meeting; the other two had never met before the workshop and introduced themselves via their self-sketches. The collaborators self-identified as researchers, workshop participants, and women. They were from various backgrounds, including education and leadership, public health, data visualization, industrial design, and healthcare technologies. The workshop was 90 minutes long. Only the facilitator was familiar with Sketch Introductions, and the others did not yet know the details of the activity and experienced it for the first time. The facilitator re-created the environment of an institutional kickoff meeting by introducing a fictitious project brief (see Figure 5.2. To mitigate bias and the power differentials in the discussions, the facilitator mentioned her previous experience and carefully prompted the discussion through open-ended questions.

The facilitation and prior acquaintance with the attendees contributed to the social dynamic both in the sketching activity and the workshops. Although *Sketch Introductions* was carefully devised, it is difficult to separate the impact of the facilitation style and familiarity among attendees from the sketching process and interpersonal dynamics as a whole. Before the workshop, the facilitator emailed the participants a fictitious project brief (see Figure 5.2). The workshop was synchronous

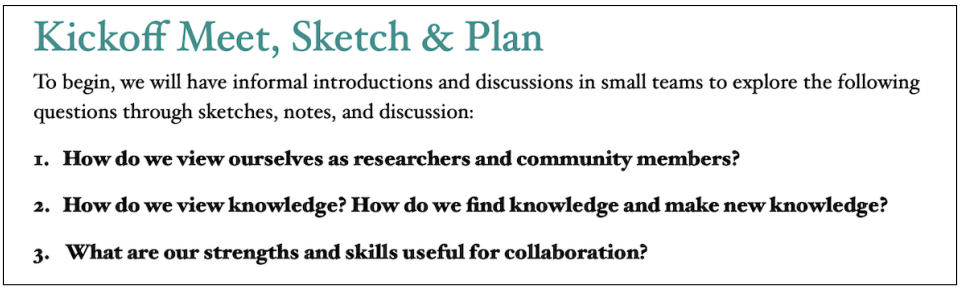


Figure 5.2: This Fictitious Project Brief was presented to collaborators in the first design session in order to set a more concrete research setting for exploring *Sketch Introductions*.

Figure 5.3: In the first session, the facilitator posted questions on the digital whiteboard to guide post-workshop reflections and analysis

and online using Zoom videoconferencing software and a digital whiteboard, Miro. Additionally, the facilitator prepared the digital whiteboard with guiding questions from the brief to guide reflexive self-sketching (see Figure 5.3) and garner feedback after the activity.

During this pilot workshop, the collaborators responded to the question prompts (see Figure 5.2) in a synchronous sketching activity while listening to quiet background music. Each collaborator made a sketch and used the three guiding questions in the brief for self-reflection about themselves as researchers and knowledge producers. Some used all the questions to guide their sketching, while others focused on one or two questions from the brief. Over a 10-min period, they completed their sketch using a pen and paper, or stylus on a tablet. They then uploaded photos of their sketches onto the digital whiteboard for the rest of the group to see. Everyone could refer to the digital whiteboard and see each other's faces through Zoom. The facilitator introduced her self-sketch and invited the group to introduce their sketches (Figure 5.1). Each member introduced their self-sketches for 5-7 minutes and described their visualization in response to the questions about how they view themselves as researchers and public community members. They used the cursor on the digital whiteboard to point to visual elements in their sketch. Others commented and asked questions during each introduction.

The collaborators referred to their self-sketches by describing accounts of personal lived experiences, sociocultural contexts, and professional experiences. Discussion followed during the reflective phase of this process in response to the probing questions (see Figure 5.2).

5.7.0.1 Analysis of the Pilot: Themes & First Impressions

Below, we report on the themes generated from the discussion that followed the *Sketch Introductions* (see Figure5.3) to prompt discussion about participants' initial impressions of using self-sketches for introductions. Notably, the facilitator avoided priming the discussion by not asking about power dynamics or reflection, leaving the questions more general and focused on overall experience (see Figure 5.3). The two other colleagues had not seen these questions beforehand. During the debrief and reflection, participants typed and posted their written feedback, themes, and ideas. The facilitator also took notes during the discussion, which she later analyzed to identify broader themes that informed changes to the next workshop. The themes presented below reflect the experiences of the first two participants from the pilot.

5.7.0.2 Vulnerability of Sketching as a Shared Experience

The fictitious project brief posed the same prompting questions to everyone and instructed that the sketches should be "sketchy", or unpolished, messy, and or incomplete-looking, which helped ease the participants' inhibitions. Regardless of sketching skills, sketching worldviews was challenging to all. The sketches were self-representations of culture, identity, social position, and perspectives on knowledge because the questions primed the participants to think about these specific topics. Sketching felt like a shared experience of vulnerability in an ambiguous social space. It felt vulnerable because introducing oneself via a self-sketch to a group of unfamiliar researchers is uncommon and requires a degree of self-disclosure. Similarly, sketching responses to the prompting questions of the brief felt unsettling for expert sketchers, too, since their regular sketching practices are often limited to ideation and communication of tangible design concepts. However, this experience of vulnerability within the shared group environment was a subtle factor that helped to foster rapport.

5.7.0.3 Lines, Shapes, and Icons to Support Narratives

As a concrete artifact, the sketch rendered each researcher's positionality visually explicit — the sketches represented conceptual facets of the self, such as social and epistemic stances. Interpersonal insights arose via the shared activity. For example, some sketches showed mazes and pathways depicting a journey or a process with blocks, while others presented flow diagrams and open pathways for connections. Participants explained these sketches with narrative examples, facial expressions, gestures, and tone of voice. They explicitly discussed differences in the visualization of perceived barriers, such as *I see that I have more open lines flowing through a network of people without as many barriers.* The sketches showed information as a continuum through drawings of circular imagery, directional arrows between icons to represent relationships among people and actions that emerged in the conversation.

Some initial ideas that emerged from the pilot (without mentioning power dynamics) suggested sketching the self (1) may enable group members to communicate more freely by concealing the

hierarchical structure, as all members experience a sense of vulnerability when presenting their self-sketches to the group; (2) augment oral explanation with visual cues, thus helping members who experience language barriers express themselves better; (3) redirect the visual attention of the group from the individual to the sketch, therefore easing individual performative social pressure that may arise in initial introductions to an unfamiliar group. The imagined potential from the pilot participants require further investigation, which we discuss at the end of this paper.

We continued onto the next workshop.

5.8 Workshop at Northeastern University: Online

Figure 5.4: These are a couple of photos of participant sketches from the online workshop with colleagues at Northeastern University.

After our first design session, as described above, we were invited to trial this idea in a real-world research context with 23 collaborators. We outline the differences in this setting and how we adapted elements from the first design session to the second iteration of *Sketch Introductions*. It was the first opportunity to try the activity in an actual research setting where there were both established and novice researchers with many different disciplinary backgrounds. This practical experience informed the following iteration of *Sketch Introductions*.

During this session, *Sketch Introductions* were used as the introductions for the start of a two-day research workshop. We adapted the steps in the first design session to fill the needs of a 90-minute introductory activity. We used the same sketching instructions and three guiding questions on the digital whiteboard over a video conference. However, there were notable distinctions between the two sessions that show the potential of *Sketch Introductions* as an applicable and doable activity in real-world research teams. For instance, in the first session, we tried *Sketch Introductions* with a mock project brief to contextualize a fictitious research meeting with 3 collaborators. We also allotted time after the *Sketch Introductions* activity to discuss and reflect on our experiences of sharing our self-sketches. In the second session, however, we did not need a fictitious brief because it

was part of a real-world interdisciplinary collaborative meeting, which directly defined the session's context.

In this second session, *Sketch Introductions* focused on supporting 23 people introducing themselves online via self-sketches. Since this session was the introduction to a planned two-day workshop, we did not ask to record personal accounts of the experience, as we did for the first session. This decision was largely due to real-world time constraints, the context and purpose of the group, and the size of the group. Nonetheless, we gained valuable insights about the scalability and feasibility of using *Sketch Introductions* online in a cross-domain collaboration with a sizeable group of academic colleagues.

Following the second iteration, we discussed the experience of facilitating the second session of *Sketch Introductions* among our group and generated takeaways and further opportunities as mentioned below.

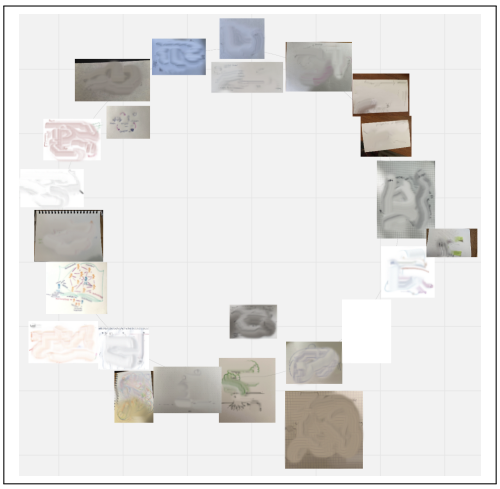


Figure 5.5: During the second session, 23 collaborators used *Sketch Introductions* to introduce themselves to each other at the beginning of a two-day, cross-disciplinary research workshop used a digital whiteboard. They were asked to place their sketches in a circle. This structuring device is an example of the decisions that were made to ensure that implicit hierarchies, such as who goes first in a more linear arrangement, were explicitly avoided.

5.8.0.1 Time Constraints

Considering the relatively short time for each person to sketch and introduce their self-sketch, we reduced the sketching time to 7 minutes, with a 2-minute warning. Each collaborator was given 2 minutes to show and introduce their sketch with a gentle timer sounding at the 2-minute mark. Some went under this timing, and some went slightly over time. However, we acknowledge the possibility that some individuals might feel too pressured to produce a sketch quickly and uncomfortable when introducing their sketch to a large group of people. The fast pacing moved the activity along, giving everyone a turn to show their sketch. The authors and collaborators in this session found the faster pacing more engaging. There is an opportunity to explore how the fast pacing

affected the experiences of the diverse collaborators; for example, whether the quick sketch and the quick introductions were engaging, in-depth, or uncomfortable, and how the pacing impacted self-reflection.

5.8.0.2 Scalability of Self-Reflection

We learned that this activity is scalable to more people than the few in our initial pilot workshop because 23 people used their self-sketches to introduce themselves. We found it compelling to see the many different ways the sketches looked and the diversity of expressions and perspectives they visualized. Additionally, we found that the *Sketch Introductions* brought a sense of levity and light-heartedness, especially when some of the introductions made us laugh and we saw people smiling. In future work, we can study the experiences of this activity with different numbers of collaborators. For instance, we can explore how the number of collaborators affects reflexivity, and if there are benefits and drawbacks to uncover in these different contexts and groups of people.

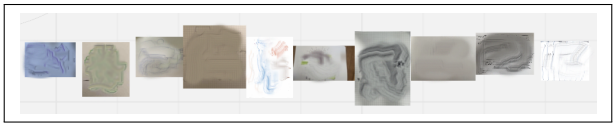


Figure 5.6: This image is an example of linear ordering, included to highlight how order may influence perceptions of importance and create an implicit hierarchy in this context.

5.8.0.3 Visual Hierarchies: Even a Circle Poses Hierarchical Order

In striving to flatten statuses and randomize the order of introductions, we drew a circle on the digital whiteboard and requested that the screenshots of self-sketches be placed randomly around the circle (see Figure 5.5). We did so because circular patterns, such as this one on our digital whiteboard or a round table, may provide a visually equitable space by removing the visual hierarchy of height or the head of a table in a rectangle. Linear sequences more or less suggested by a physical whiteboard (see Figure 5.6 seem to indicate an expected sequence from left to right, where left is prioritized. Nevertheless, we noticed that when the facilitator introduced her sketch, she biased the left side of the circle and prompted introductions to follow a clockwise order around the circle. This insight was realized only after the session was completed. Thus, even with our intention to randomize the order of introductions, the colleagues on the left side of the circle introduced their sketches first because of the facilitator's guidance and unconsciously biasing the left side of the circle. While most of the sketches in Figure 5.5 have been blurred for privacy reasons, to illustrate the variations in sketches, with permission, we include two close-ups of sketches from the second *Sketch Introductions* session Figure 5.4). We would still use the circular shape for future workshops to present the sketches because of its more inviting "round-table" shape. From this workshop, we envision further explorations into cross-cultural perceptions of visual hierarchies and order of presentation in this collaborative setting. Additionally, we see advantages to the seemingly

unlimited space on the digital whiteboard with fewer physical boundaries for the circle of sketches, compared with the potential boundaries and limitations to access and viewing associated with a physical whiteboard or walls in a room. We were interested in facilitating this activity on a tabletop or a wall in an in-person, collocated setting.

5.9 In-person at Schloss Dagstuhl Seminar: Visualization Empowerment

The first author was invited to facilitate Sketch Introductions as the initial ice-breaker activity on the first morning to kick off a 5-day hybrid seminar. This seminar included 26 participants in person and 17 remote participants from Europe, the Middle East, and North America. The seminar context was about teaching and learning in visualization, and the facilitator adapted the activity with the seminar organizers. In this iteration, a single prompting question accommodated the topic: “How do I see myself in relation to the topic Visualization Empowerment: How to Teach and Learn Data Visualization?”

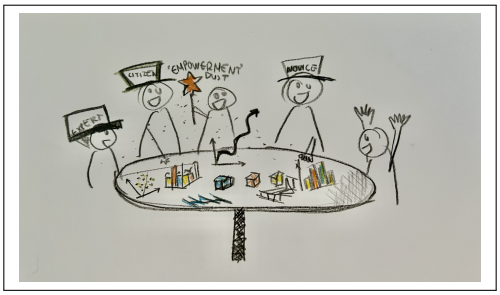


Figure 5.7: In-person sketch on paper responding to the question "How do I see myself in relation to the topic Visualization Empowerment: How to Teach and Learn Data Visualization?"

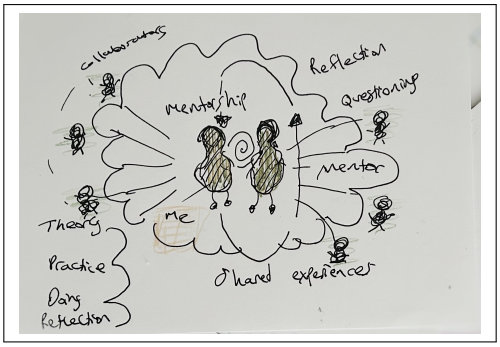


Figure 5.8: In-person sketch on paper responding to the question "How do I see myself in relation to the topic Visualization Empowerment: How to Teach and Learn Data Visualization?"

The spacious seminar room seated 26 participants comfortably with tables, chairs, and 2 large screens. One screen displayed the remote participants, and the second projected in-person laptop presentations or personal sketches. A podium for presentations was equipped with a small camera

pointed at the podium's surface to project sketches drawn on paper. The organizers provided coloured pencils, markers, and card stock paper. Around 10 AM, the facilitator described the activity and showed the instructions with two slides explaining the expectations of sketching in this context, which required the ability to draw stick figures and provided an option to not sketch at all and leave a blank page or come up and introduce oneself as they prefer. The third slide included the question on the screen that was visible while sketching to music. With disparate timezones and varying degrees of jetlag, we began sketching our introductions in response to the question. The facilitator played a 7-minute track of soft piano music [2] while everyone sketched. Some needed more time, and the music restarted and played for another 3 minutes. When everyone in the room was ready, the facilitator invited people to bring their sketches to the podium and project the image on the big screen for everyone to see. A 2-minute timer was set for each speaker to share their sketch. Online participants presented their sketches, and everyone in person and remotely was invited to take a photo of their sketch and post it on the group's digital whiteboard. The digital repository enabled remote and in-person participants to view the sketches. Unfortunately, the 2-minute timer cut some speakers off, and those who presented later managed to keep to the 2-minute mark more often because they had time to think about what they would say.

We learned here that most people managed to sketch and present their sketches. However, the 2-minute time limit may pose excessive pressure to some and be viewed as a barrier to self-expression in such a large group. This iteration marks further exploration, to determine how to balance time constraints and self-reflection in larger groups and the different experiences of online versus in-person Sketch Introductions. The order of presentations mattered as the first presenters had not seen examples of presentations previously. This leaves an interesting consideration for the length of time and considering separating a big group into smaller groups to present their sketches.

5.10 Another Group Tried Sketching Introductions

One of our colleagues participated in one of our sessions and asked permission to facilitate Sketching Introductions with a group of over 20 participants at the start of an in-person research collaboration. This iteration was facilitated independently for the first time and no one from our group of authors was present. Our colleague reported that everybody completed a sketch. However, some people felt "on edge", yet were engaged. Additionally, we were informed that people were so focused on describing their sketches that they forgot to mention their names.

Institutional introductions have subtle reminders of social power hierarchies, and part of our aim was for people to focus on introducing a part of themselves that they choose to share instead of mandated rank or position in the academic system. Colleagues forget to mention their names, but describing their sketch illustrates a relationship between the presenter and their focus on their

[2] Peace Piece by Bill Evans

sketch. However, the factors, feelings, and experiences that led them to forget to mention their names are still unknown. Shifting norms, standards, and systems can feel uncertain and out of one's comfort zone. Perhaps, self-sketching could be a way to facilitate the awkwardness in a relatively safe space. For some collaborators, there may be safety in disclosing their academic status, such as junior researchers or students who may feel protected when others are aware of their developing expertise within the team. However, what feels safe with sketching and sharing differs among people and needs further inquiry.

5.11 Beginning the Discussion

Sketch Introductions is not a typical application of sketching in DataVis and HCI. We were a part of conceptualizing and developing this icebreaker. As developers, facilitators and participants, we have a first-glimpse at what it was like. Thus far, Sketch Introductions has been a valuable approach for us because it was a fun way to facilitate introductions where we met or re-met over 60 colleagues. We have some initial observations as facilitators where we experienced a promising creative approach to getting colleagues acquainted with one another and building rapport. From these iterations, we saw this as a creative, sketch-based approach for group introductions. For example, in the pilot session, the self-sketch supported sharing and discussing personal views and values about knowledge. Design probes are known to promote empathy, trust, and reflection through creative and provocative inquiry methods [307, 116, 117, 175]. We observed that conversations were centred around the self-sketch, and people did not mention their rank or title but tended to mention their city and the name of their institution.

We witnessed sketching as a relational task, inviting self-reflection during sketching and relating to others because we and our colleagues laughed, pointed to the sketches, asked questions and responded with comments. Sturdee et al. share similar experiences with sketching, with a description of the role of sketching as part of a creative cycle: "A sketch is the act of creation, a worked drawing becomes an object of communication, and both outputs are sources of information via analysis and interpretation" [284].

We observed the cycle of creation, introduction, conversation, and interpretation of the self-sketched responses in collaborative conversation, which was an act of collective reflexivity and communication. The sketch was a visual reference that enabled participants to engage with the sketch, which, by proxy, represented a bespoke visual introduction. For example, online participants pointed with the cursor to elements in the sketches and asked questions or explained how their self-sketches demonstrate individual research approaches. Sharing these personal worldviews within the group sparked conversations about values, perspectives, and experiences in all the workshops because they were part of developing collegial rapport and reference points for later discussions. As developers and facilitators of this activity, we better understand how to consider visual-social biases in Sketch Introductions. However, we are left with more questions and wish to

explore the different perceptions of participants and garner feedback from others who might try this in their work.

5.12 Considerations

How these conversations impacted the sense of social trust and rapport building remains to be explored. We learned that in thinking about levelling power dynamics, we foresaw varying levels of comfort in this activity, dependent on familiarity with sketching, English language proficiency or the comfort or ability to articulate what the sketch means. While designing this icebreaker, we discussed that the activity relies on sight, the ability to use a pen or stylus, and access to hardware, software and a stable internet connection for remote participation. Therefore, these requirements exclude certain people from participating. We also anticipated that some might feel overly vulnerable during this activity. For this reason, we explained that the blank page could serve as a canvas for note-taking or that simply showing a blank page could be a way of introducing oneself. Moreover, we expect that disciplinary conventions about art and science might impact how safe and comfortable participants feel during the activity. For instance, those used to sketching may have an easier time adapting to the activity and may feel more comfortable than people who have not previously sketched. However, an artist who does not typically sketch in their practice may feel a performative pressure to produce a well-developed artistic sketch. In addition, we consider that public speaking in front of larger groups of people may depart from our intent to facilitate self-expression, and instead, this dynamic could inhibit some who become uncomfortable presenting their sketches in larger group settings. Conversely, the self-sketch reveals only as much as its creator is willing to share and is a self-selected buffer through which to introduce oneself — this remains a compelling feature to explore. Further inquiry may tell if presenting via a sketched artifact provides a favourable experience.

5.13 Ending with an Invitation to Continue the Discussion

Does Sketching Introductions promote social trust? How do Sketch Introductions affect the sense of interpersonal connection? Though often under-explored, emotional connections and affect play a significant role in the design, engagement and perception of visualizations [299]. A Self-Sketch is likely to bolster this emotional engagement in the visualization design process through the description and interpretation of the sketch. In prior cross-disciplinary collaborative workshops, collaborators used visuals to express their thoughts and emotions that evoked an experience of shared vulnerability among the participants and supported their discussions with the group [314].

We see the potential and limitations of Sketch Introductions and invite our colleagues to try this out, discuss it with us, and imagine how to improve or adapt this icebreaker. Here, we examined an institutional academic norm — the verbal-only introductions — and explored a playful approach to change them and experience what it would be like to facilitate visual self-sketch introductions. We were inspired by critical intersectional feminist scholars and activists who urge everyone to

examine power imbalances in our world and, most importantly, change them — including the HCI and DataVis communities. *Might changing or unsettling standard practices feel uncomfortable and awkward to some, and would discomfort be expected? What are other questions that come up for you when reading this? What would you change about this activity for your setting?* We invite you to think of another institutional convention that can be interrupted and changed by an unexpected design process. In sharing our process, we hope to inspire [re]thinking taken-for-granted standards in your practice and exploring or changing nuanced and invisible power balances that those standards likely uphold.

5.14 Summary

This chapter contributes to answering sub-question one and the overarching research question by reporting on our exploration of facilitating an icebreaker activity called Sketch Introductions, a creative and reflexive way for new collaborators to introduce themselves through their hand-drawn sketches. Traditional academic group introductions often reinforce status-laden interpersonal dynamics, where individuals provide their names, institutional ranks, and titles. However, these formal titles are subtle status markers that may interfere with self-expression and open intellectual discussions. We explored multiple iterations of Sketch Introductions in different academic contexts. Through our reflexive, design-oriented process, we learned to consider factors that facilitate this activity, such as its scalability and how it might impact reflexivity and comfort levels, time, the order of presentations, and visual sequences that may represent social hierarchy. The findings clarify aspects of social power dynamics in collaborative research settings. This chapter adds to a broader discussion of socially constructed and socially upheld disciplinary conventions in the research and design of visual data.

Our pilot studies revealed that sketching individual worldviews facilitated reflexivity and vulnerability, enabling deeper interpersonal sharing and understanding. This project deepened my understanding of the potential of data visualization as an inherently social and relational process. In the following project, I began to explore this notion within the broader culture of scientific practices in the field of data visualization. The next chapter delves into the tensions between social roles and power dynamics, shifting the focus to a more personal exploration. The social roles of academic researchers and designers also include being members of the public, being between academic disciplines, as well as between identities and personal experiences that influence researchers in data visualization and human-computer interaction.

Chapter 6

Exploring How Researchers-Designers Relate to Their Work in Personal or Social Ways

The Inbetweeny Collective: Reflexive Dialogues on the Liminality of Researchers' Lived Experiences

This chapter includes the majority of the publication I co-authored with Denise T. Quesnel, Ekaterina R. Stepanova, Sheelagh Carpendale, and Bernhard E. Riecke [252]. Denise T. Quesnel led the conceptualization, writing, and editing of the original draft, as well as project administration. Reflexive analysis was conducted by all equally, along with writing positionality statements. Katerina Stepanova and I supported the development of the methodology and the writing parts of the draft, as well as the review and editing. Bernhard E. Riecke led project supervision and supported draft review and editing [1]. This chapter contributes to sub-question one by expanding on the concept of an *inbetweeny* researcher and exploring thoughtful approaches to navigating a personally felt liminal space between disciplines and identities to bridge social-relational tensions in research practices.

6.1 Introduction

The integration and embedding of lived experiences from end users and knowledge users is becoming increasingly prominent across various disciplines [112]. This trend extends to the domain of Human-Computer Interaction (HCI), which, through its third wave, has experienced a notable shift towards valuing human experience, emotions, and meaning-making [50]. Humanities-based methodologies [25], first-person work [77], and body-centric design approaches [286, 156] have contributed to this evolution by emphasizing the researcher's positionality and their lived experience

[1] https://credit.niso.org

as central to their analytical perspective. Despite the growing influence of humanities and first-person methods within parts of the HCI community, tensions persist regarding the broader acceptance of lived experience as a legitimate form of knowledge and how this knowledge can be situated within HCI. It is the latter, the 'how', which we aim to explore in this collaborative autoethnography. While the sub-domains and research areas within HCI today have positively influenced diverse approaches and methodologies, they also bring dominating sets of assumptions, perspectives, positions, and practices situated within epistemic and ontological stances that contribute to the field's tensions. There is undoubtedly value in embracing a variety of ontological stances, and the purpose of this paper is not necessarily to argue why one stance has more merit than another. Rather, we posit that **there is a need for design researchers to explore what engaging with their lived experience means, especially when seemingly incompatible ontological stances can and often do co-exist within a researcher.**

6.2 The Ways of Knowing in HCI and Design

We, the authors of this present article, are situated within HCI domains of social computing, information and data visualization, interaction design, and experience design. We observe an ongoing epistemic shift from dominant paradigms within human-centered interaction and informatics, which for qualitative research has arguably been positivism and post-positivism [34] and to a lesser degree constructivist-interpretive; critical (Marxist, emancipatory); and feminist-poststructural paradigms. For example, in thematic analysis, which promotes reflexive researcher subjectivity, Braun and Clarke warn against common tendencies to use positivist assumptions to ensure rigour (e.g., coding reliability) and expectations that researchers maintain neutral and objective [41]. Also, autoethnography and autobiographical design in HCI have held tensions: while recognized as legitimate knowledge in which autobiographical design researchers often inform designs, the processes (the 'how') that facilitate interconnection of the wider social and ecological environment are less commonly reflected on [76].

We often find ourselves mixing methods rooted in diverse ontological stances on the nature of "truth" of post-positivism and social-constructivism. Or, we embrace the situatedness of lived experience yet long for a generalized understanding of a phenomenon, striving to claim contributions beyond the very specific context of a given design and user group.

6.3 Liminality in Lived Experience as a Process Ontology

As researchers, we often navigate a liminal space, balancing roles of 'insider' (having lived experience of the phenomena under study) and 'outsider' (having a scientific or professional interest without lived experience). This liminality rejects the strict dichotomy of 'insider' versus 'outsider', towards embracing a threshold (limen)—a concept introduced by ethnographer van Gennep in *Les rites de passage* [119], expanded by anthropologist Victor Turner [298].

Liminality challenges the notion that ontologies are dichotomous stances by valuing lived experience as *equivalent* to other knowledge [281]. In this sense, liminality in the context of lived experience could be considered a process ontology. Positioned within social-ecological systems, process ontologies emphasize relations and processes and the interconnection of entities, focusing on *becoming* rather than *being* [142]. **In process ontology, the design researcher is not a static entity, but an evolving process.** This perspective emphasizes the fluidity and changeability of the researcher's identity and understanding over time. Their experiences influence the research trajectory and wider social and ecological entities, while these, in turn, continuously reshape the researcher's understanding and perspective. The relationships and interactions between the researcher, participants, and the research context are central to knowledge generation, emphasizing that understanding is continuously constructed through dynamic interactions.

This stands in contrast to substance ontologies, in which substances are fundamental building blocks of reality, 'being' and maintaining their identity even as they gain or lose properties over time [142]. In substance ontology, the design researcher can be viewed as a "substance", whose lived experiences, insights and skills are akin to properties or attributes that define and characterize their approach to research. Just as substances endure through change while maintaining their identity, the researcher's core identity remains consistent even as they are shaped by the research process.

6.4 The Emotional Labor in Lived Experience

It would be bereft not to mention the cost of positioning and leveraging lived experience imbues, in that navigating the liminal space as an "inbetweeny" entails significant emotional labor and reflexive engagement [325]. Balaam et al [23] discuss the emotional labor HCI researchers and designers perform when engaging in experience-centred design (ECD), which requires rapport and closeness to end-user participants. These authors acknowledge that processes, practices, and implications of emotional work are notably absent from core literature, which results in design researchers overlooking their own emotional labor in their research accounts: Consequently, both design researchers and HCI as a field miss opportunities to learn how to explore emotion work, which has downstream effects of the next generation of researchers lacking adequate guidance and supervision [23]. Also, Harrington et al. highlight the emotional labor involved in participatory design with historically marginalized communities and the sense of responsibility felt by HCI researchers and participants to support meaningful change [135]. Researchers uniquely positioned within the community can facilitate such change by accounting for different social positions, power differences, local histories, and intersecting identities via methods that foster equitable and community-led research participation [135, 251, 83]. For example, O'Leary et al. discuss the inherent power differentials in conventional design practices that might perpetuate institutional racism, despite the utilization of participatory design approaches [294], and Erete et al. examine power differences to *dismantle* social systemic oppression and apply asset-and strengths-based narratives over deficit-based narratives [102]. This aligns, for example, with the aims of Action

Research [136] which as a method aims to investigate and solve an issue simultaneously, and narrative inquiry [166], which promotes social justice and inclusion in design.

6.5 Towards Understanding What it Means to be “In-between", and How to Navigate Insider-Outsider Shifts

In these and many other examples, it is clear that despite significant emotional burden, researchers in an ‘in-between’ space are uniquely positioned to facilitate personal and societal transformation and bridge disciplines [273, 111, 124, 105]. Deeper recognition and attention to capacity-building of researchers with rich, relevant lived experience would enhance HCI’s body of knowledge. However, ‘how’ to do this meaningfully can be challenging. We propose that reflexive practices that embrace liminality in lived experience as a process ontology could encourage researchers to embrace uncertainty as a natural part of the research and design process, using it as an opportunity for growth, discovery and systemic transformation. For example, in first-person approaches, the HCI design researcher would be positioned at the center of the design process, and through adopting a liminal process ontology stance would emphasize ’‘becoming” opposed to simply “being”; this would inherently embrace the interconnection of social and ecological entities involved. This approach may help bridge the disciplinary differences in HCI, leading to a wider understanding of how lived experience can be a tool for leveraging the strengths of the research at hand and addressing inherent tensions that emerge.

In the following sections, we reflect on our roles as researchers navigating liminal spaces and the fluctuating identities that drive our research process. We propose that being an ‘inbetweeny’ allows us to transcend the rigid boundaries between lived experience and expert academic knowledge paradigms. To explore this discourse, we have adopted a *collaborative autoethnography* approach. This method enables a continuum of listening, examining assumptions, and integrating diverse perspectives, balancing the varied lived realities of researchers [59]. Our approach embraces a multiplicity of perspectives integral to research practices, rather than privileging a single perspective as the only valid way of knowing.

6.6 Our Positions

We base our positions on our lived experiences of existing in-between spaces or categories as researchers across different areas of inquiry. Our innate positions differ and will be offered within our individual stories. We share identities as scholars, White, cis-gendered individuals who experience privilege in many forms, including education. Our innate positions differ and will be offered within our individual stories, and we acknowledge that privilege can exist alongside marginality [38]. To this, we adopt *Critical Reflexivity*, which demands more than reflection alone but a process of developing and applying practices that emphasize accountability, authenticity, and ethics [20, 11, 265]. We offer a collective reflexive account of research and design practices that are

shaped by, appreciate and leverage the multiple, shifting identities and roles of HCI researchers and practitioners.

6.7 Five Individual Accounts

6.8 Denise's story; Researcher in HCI (experience design; participatory design), and health technology designer

Prior to starting my graduate studies as a mature student, I held a variety of careers inside and outside academia. And as an individual with childhood-onset health conditions, I had accumulated an extensive range and volume of experience within the health care system. In my newly minted PhD journey, I only planned to leverage the experiences gained from my prior careers. I felt it best that my experiences as a person with lifelong health challenges, the volunteer advocate and patient partner in research to remain 'at arms length' from my scholarly research. Looking back, I never did define what this meant beyond a vague degree of objectivity.

During my studies I lived two discrete lives: the 'scientist' who overcompensated for their perceived failings as a person with unique health consequences, and the 'advocate' who tried to improve the health care system from within whilst holding science (as a system of knowing and inquiring about the world) to a high standard. For most of my life, these two worlds never collided—until a month after my first child was born. After I had time to process their life-altering diagnosis, I realized this child would eventually be a member of the very population I was engaged in research with. They shared the same (or similar) diagnoses with these young people, and I was seeing a snapshot into what my child's own future might look like. Simultaneously, I considered whether I could feasibly hold myself at arms length from this research - as it was, my past experiences as a youth with chronic illness is what led me to this research area. Suddenly, it was personal, whether I was ready for it to be or not. I admitted this separately to two people I hold in high esteem: "I think I need to discontinue this research… I can't imagine it's appropriate for me to be doing this anymore." And nearly verbatim, they said: "If you really want to do this research but are questioning whether you should… perhaps consider that you are probably the most suited person to do this, now."

I am happy to say I took their wisdom to heart and that I stuck it out. Upon reflection, I realized my two selves - the scientist and the advocate – were already interwoven within the very fabric of my research, which I hadn't consciously realized until my child's birth and subsequent diagnosis made it obvious. My lived experience with lifelong health challenges was the initial motivation to improve quality of life for youth with their own health challenges, and I subconsciously chose to combine advocacy with scientific rigour. This choice came over 15 years after I had already 'aged out' of the pediatric system into adult care, and the catalyst was the realization that circumstances for young people had barely improved in those years. It seemed that advocacy wasn't enough to move the needle; we needed irrefutable evidence and solutions. At the time, I began this research,

I did not identify as a research 'insider' since I was not currently a young person *per se*, but I also wasn't an 'outsider', either. Yet, I consider now that I always was an 'insider': I have lived experience as a young person with health challenges and I will always carry this with me, for it had shaped me during a formative time in life. Yet, the circumstances I experienced then are very different than those currently experienced by young people, and I humbly acknowledge I am very much an 'outsider' in this regard. I was, and am, an "inbetweeny", appreciating that experience as we come to know it is a continuum. For me, this continuum is likened to the paradoxical qualities of liminal experience as both/and, as well as neither/nor; it gives us permission to be "neither this nor that, but both".

6.9 Katerina's story; Researcher in HCI (social computing; virtual reality; soma-design), and cognitive scientist

Academically raised in a cognitive psychology lab, I experienced resistance when I first encountered autoethnography. It was suggested by a colleague for a project analyzing self-transcendent virtual reality (VR) experiences during COVID-19. I thought: *who are we* to provide a unique compelling perspective that is only valuable because of who we are? As a group of Western, abled, White, predominately male researchers, we are far from being marginalized. I was so adamant about how unsuitable this methodology was that I read a whole handbook [167] about it to argue why it was a poor choice, until I found myself convinced that it wasn't. Recording our experiences felt authentic, humbling, vulnerable, and sometimes insecure—fuelled by an internal tension of positioning oneself, yet never feeling quite at home.

I still experience this tension. While I write positionality statements and root my research in who I am, I feel that am not *enough* of anything in particular. I am a woman, an immigrant, I have minor dyslexia, I am a pretty average recreational dancer and outdoor enthusiast... What other characteristic places me in a (marginalized?) box with a unique position? Yet, I don't *feel* marginalized and don't *want* to victimize myself, or claim that my work makes a representative perspective on a phenomenon from these positions or characteristics, nor want to speak for others who may have a more salient experience. I want my work to be interesting because of *what* I do, not of who I am.

If I am to take the Big Q qualitative research seriously [170, 67], then my unique perspective, my "view from *specifically right here*" is what brings value and validity to the work. It acknowledges that there is no perspective-free knowledge, and also that our unique tapestry of lived experiences is the foundation to our interpretative work. Then I, myself, my identity, underlies the knowledge that informs my work. Identity becomes part of the contribution. How can I know that I am enough of an "X", to offer that as my research contribution?

Though I still experience internal tensions when I lean into my identity as the core of my research position, we can't escape our history of lived experiences implicitly guiding our research path. Its internal pull brings us to curiosities that are relevant to us. I felt that my research career

was largely chaotic and serendipitous, as some doors opened and others closed. After I delivered a seminar once, a student asked me how I planned my career to do the kind of research I do. I didn't have an answer for her; it seemed like it just happened. While I did the recommended reflexivity exercises designed to illuminate my values and passions to help me select an authentic path for my research at the beginning of my career, I didn't follow that envisioned path.

My true eureka moments of researcher reflexivity came when I discovered by looking back how the dots connect along my journey. Writing up the final chapter of my thesis, I realized that my research topic was trying to fill a hole in my own experiences: I grew up in the collectivist culture of Post-Soviet Russia; my move to an individualistic Western society illuminated this cultural mismatch. I've longed to be an inherent part of my community, a part of a larger team with shared goals, resources, failures, and successes that are inseparable from my own. Community identification provided me with a stronger sense of purpose and implicit support, which was lacking in my experiences in Canada. Yearning for that feeling without being aware of it, I kept probing experiences to design that could invite this experience of unity, shaping my meandering research trajectory and bringing me to where I am now.

6.10 Tatiana's Story: Researcher in HCI, experiential learning, public health, and data visualization

The COVID-19 pandemic shaped my Ph.D. experience. As a former nurse and public health researcher, I regarded data visualizations of COVID-19 as end-products intended to be tools for health communication. My colleagues and I created COVID-19 visualizations to inform decision-makers at the onset of the pandemic. At that time, confusion, distrust, and fear flooded the public domain alongside the factual visualizations intended to inform the public with visual facts and patterns of disease spread. Yet, something was missing. I realized that I was part of generating COVID-19 visualizations with a foundational hope and a value that it was important for everyone in society to work together to protect the most vulnerable and that each person has a critical part to play in preventing disease spread. However, it became increasingly evident that the makers of data visualizations lacked a nuanced understanding of who makes up the public and what public experiences were like with the common COVID-19 data visualizations in their communities. We, designers of data visualizations, were missing something crucial – a severed connection between "the expert" and the public was exposed, which inspired my research. It was a time of reckoning for "experts" making and using information visualization based on unquestioned assumptions about the public and supposedly limited data literacy in the public. It was also a difficult time for many public members receiving an overload of information across multiple media.

I wanted to uncover some of my assumptions and those of the community of practice I continue to learn alongside. I was in between being the expert and being a member of the public with my family in lockdown, imagining what it might be like for other families facing the challenges of a global health crisis. Instead of focusing on statistical averages and generalizable universal claims for

a broad user base, I combined my multidisciplinary experiences to think about specific communities. For example, I merged the determinants of health and the holistic care model from nursing, and strategies from communications studies and data visualization design. I also applied my notions of language to conceptualize data visualization for alternative dialogues. For instance, the word "data" means "given". I recognized that numeric data does not visualize or represent the invisible social and relational spaces where numbers and categories overlap with social worlds. As a polyglot with cross-cultural and cross-disciplinary expertise, I considered the invisible spaces between what was "a given" and what data might have taken away. In addition, data visualization is considered a visual language. I thought, what if there were a different data dialect that accounted for the social, emotional, and community facets enmeshed with the data we were visually representing? I am, too, a part of the public, so where do I fit in, and how do I merge all of my disciplinary and personal worlds in learning how to create more socially aware and relatable data visualizations for the next pandemic?

6.11 Sheelagh's Story; Researcher in HCI (information and data visualization; interaction design), artist and computer scientist

I position myself as in between privilege and oppression: privilege as White and increasingly senior (a multiple-edged factor in itself), oppression as woman, mother, and a slew of disabilities, which, even under an alias, I am not quite ready to declare. Both privilege and oppression have had and continue to have oscillating and sometimes simultaneous impact on me. I am also in-between. For the first 20 years of my adult life, I worked as a studio artist and college instructor before shifting to computer science and, within that, data visualization and human-centered design, accruing way too much education along the way (much as a mature student and mother): Art School, Design School, Computer Science (both BSc and PhD) – being (probably annoyingly) fond of saying I do better science because I learnt to observe in Art School and think creatively and critically in Design School. At least when I was studying sciences, while it was openly acknowledged that to be successful, one needed to be able to think creatively and innovatively, there was no instruction around this. Hopefully, that is improved – definitely we incorporate this into our HCI and data Vis courses.

Rather than delineate all the struggles and frustrations, I would like to reflect on my growing awareness that things are changing. The kinds of incidents that I have seen happen and have happened to me in the past are much, much more likely to be called out. The community itself is changing – particularly evident in our students, our young (or even just younger) faculty, and of course a gradually increasing number of us more senior folks. I note it in the reflections and comments of Denise, Katerina, and Tatiana. However, in particular, I note that their attitude is to think thoughtfully about (reflect on) the less-than-ideal challenges by taking it on as a path to self-growth. Whereas in the 'old' days (and something I am consciously working on) it was more likely to manifest as anger and thus often have less favourable outcomes. The goal of

co-liberation [85] seems to be a good direction – opening a path forward for both the privileged and the oppressed to move forward towards co-liberation. I would like to include this famous quote attributed to aboriginal activists in Queensland, Australia circa 1970:

"If you have come here to help me, you are wasting your time. But if you have come because your liberation is bound up with mine, then let us work together.[2] "

6.12 Bernhard's Story; Researcher in HCI (Virtual Reality, transformative experience design), cognitive scientist, and VR designer

I am a professor originally from Germany, now living in Vancouver, Canada since 2008. Although my original degree is in Physics, I never felt fully at home in traditional sciences. Drawn to the creative process, I felt constrained by my discipline's culture and boundaries. This led me to explore various fields and topics, but none felt like a perfect fit. It was only after joining a transdisciplinary department, where diverse backgrounds are the norm, that I began to truly embrace my varied interests. This newfound freedom has been liberating but also brought on the imposter syndrome often felt by "inbetweenies" like myself. This feeling is especially pronounced when coaching students like Denise and Katerina, who dive into exciting research areas that I am fascinated by and enjoy, yet pull me out of my comfort zone and knowledge area. Sometimes I wonder, *who am I* to mentor these amazing individuals pushing boundaries? Occasionally, I wish I could go back and explore these new avenues that didn't exist when I was a student. As an aging white male, I have undoubtedly benefited from privilege, many of which I may not even recognize. However, as a highly sensitive, empathetic, and (not very) self-secure person by upbringing, I have never fit in a traditional masculine box, too. This was most evident during mandatory army service — an environment not suited to sensitive and creative individuals.

My journey towards embracing the "in-between" identity and bridging my diverse interests led me to transformative experience design (TED), a research approach using technology to create meaningful experiences. TED has shaped my research, teaching, and mentorship. I encourage my students to design for impact, and I strive to create a supportive, inclusive environment where they can explore their unique identities and passions. I vividly recall a transformative moment in our lab. At my request, we had all taken the Sparketype assessment [277] to better understand our passions and motivations. The results revealed Denise's primary Sparketype as "Advocate" supported by "Scientist," a realization that resonated deeply with her and helped us all better understand her unique perspective and drive. My primary Sparketype was "Maker" supported by "Scientist", a

[2]Although this quote ended up circulating on the internet as the work of one person—Lilla Watson—Watson herself describes it as the outcome of a collective process, and she desired that it be credited as "Aboriginal activists group, Queensland, 1970s." See Watson, "Attributing Words," Unnecessary Evils, November 3, 2008, http://unnecessaryevils.blogspot.com/2008/11/attributing-words.html. This acknowledgement is word for word from the book 'Data Feminism' [85] - note 52 precisely.

Figure 6.1: A drawing of a researcher on their research path. Thread-like colourful lines represent the researcher's lived experiences and identities interwoven in a liminal space — in the liminal space, the researcher's experiences and identities are neither inside nor outside their research path, but both weave through the researcher and their practice.

revelation challenging traditional assumptions about a professor's role but aligning with my desire to create. This exercise helped us recognize and value qualities often overlooked in academia. It was a powerful reminder that our true passion, drive, and purpose often stem from these hidden qualities.

Witnessing students embrace their authentic selves has been one of the most rewarding experiences of my career. As I increasingly incorporate self-reflection and open discussions into mentorship and teaching, I continue to be amazed when I see students tap into their true authenticity.

6.13 Collective Reflections, Building Bridges, and Navigating Tensions in Knowing

Our process facilitated new questions that prompted discussion. *Must we categorize ourselves to fit into boxes? How do we embrace the multiplicity of our selves within a liminal space? How can we create inclusive environments that value and support unique contributions of "inbetweenies"? How might those in positions of power foster environments where all can thrive? How do we model authenticity and vulnerability, and invite others to bring their whole selves to their endeavours?*

Our dialogues illustrate reflections on liminal in-betweenness of researchers who vary in their stage of career and personal development. We propose **five areas for reflection** detailed within the following section, and summarized in 6.1. In these, we acknowledge Garcia et al., [114], whose feminist collective work underscores the importance of acknowledging power differentials alongside lived experiences in reflexive practices. Though our context differs from Garcia et al., we retain accountability for structural change in our various positions as faculty and graduate students, our privilege amid the colonial legacies of where we live and work, and gendered roles and expectations from the past and present. Central is the insertion of *experiential knowledge traditionally outside academia and design practice*, toward systemic change.

6.14 Reflection 1| What is "lived experience"?

We define lived experience as the personal encounter with a specific phenomenon. According to the enactive theory of cognition, grounded in phenomenological tradition, lived experience and the resulting "knowledge from within" form a continuum of being passively presented with, affected

by, and affecting upon the experience [302, 75]. These are embodied, first-person phenomena that are relational, as the social environment and influences within lived experience are inseparable from the individual.

Among first-person research methods, there is a distinction in what constitutes the "experience". Micro-phenomenology [249], explication interviews [303], and focusing [118] consider "experience" as specific, singular, and in-the-moment, confined to a specific moment in time. Through analyzing several specific moments, one can derive a general structure of a given phenomenon [250] yielding an understanding that generalizes across participants.

In contrast, more social-constructivist methods such as hermeneutic phenomenology [300], autoethnography [167], and narrative research [217] view lived experience as unique to each individual and situated within their sociocultural and autobiographical contexts. Here, there is no ultimately generalizable experience, and lived experience covers a larger timescale, encompassing the full life of the participants. Despite this distinction, both understandings of "experience" produce experiential knowledge, which is tacit, pragmatic, and acquired through direct interaction, not through observation alone [36]. Tatiana's story depicts this continuum: she manifests how the fluidity of identities and roles can be galvanized by seeing crucial, severed connections. In this sense, embracing the fluidity of identity is to recognize that researcher identities are not fixed, but shift and evolve over time and across contexts (Figure 6.1).

To embrace this fluidity, critical reflexivity practices [20, 11, 265], both individual and collaborative, deepen the relationality of knowledge while buffering criticisms that subjective, lived ways of knowing are illegitimate [107]. Sheelagh notes that the community itself is undergoing significant change. She invites reflection with authenticity and mutual respect that extends beyond criticisms of systemic deficiencies, into processes of commendable growth.

6.15 Reflection 2| What does it mean to be 'inside', 'outside', or 'in-between'?

increasing attention is being paid to the "in-betweennes" within the insider-outsider researcher continuum, recognizing how lived experience and professional experiential knowledge shape our commonalities and differences [10, 150, 95, 74, 60, 63, 128] and provide "accountable knowledge" [202]. Experiential knowledge through lived (direct) encounters with a phenomenon can cause researchers to become 'insiders', sharing characteristics and/or experiences with individuals at the center of their study. Conversely, 'outsiders' do not share these commonalities. Insider/outsider researcher positionality is a theoretical concept that can be unnecessarily dichotomous due to the dynamic nature of personal identities and research variables [95, 74, 265]. For instance, Katerina couldn't classify herself as an outsider or insider in the context of designing interactive installations aimed at the general public. However, Denise suggested that Katerina's cultural background could provide "insider" knowledge towards supporting Katerina's intended experience design. This illustrates the sentiment from Yvonne , & Collins:

> Just as there is perhaps no binary insider-outsider relationship, there is perhaps not necessarily a value attributed to one or other side of the continuum. At times, the insider knowledge and perspective are valuable, at other times, there is real value in stepping back and looking in from the outside. Slipping between roles is possible, even within the same research project, but requires advanced and acute reflexivity. Either end of our insider-outsider spectrum could be less helpful, but there is value in the range of insider or outsider perspectives. ([325], p. 4)

The degree of 'in-betweenness' is context and discipline-specific, as are institutional and professional attitudes that can support 'in-betweenness'. On this, Bernhard emphasized that those in positions of power should especially model vulnerability and authenticity, creating a safe space for others to share their experiences and perspectives. Walking the talk is easier with power and privilege- but it is also a responsibility. There is value in both insider and outsider perspectives, and slipping between roles is possible, requiring sustained reflexivity- a challenging skill requiring continuous, deliberate engagement [161]. Collaborative practices deepen reflective engagement and cultivate the relationality of knowledge within a process ontology- which we expand upon next.

6.16 Reflection 3| Knowledge will always, and only be contextual

Our dialogues highlighted the importance of relational and peer involvement in reflecting upon one's own 'in-between' identity. Often, we questioned the relevance of reflexivity on positionality. In these moments, a peer's 'outside' perspective helps to notice influences implicit to the researcher and bridge transformative insights. For example, Denise observed Katerina's cultural influence; Bernhard's request that team members complete a Sparktype assessment. As a mentor, Sheelagh described the importance of authenticity in owning and reflecting on the context of one's experience. She emphasized encouraging and insisting on opportunities for people to follow their bliss, which deeply resonated with Bernhard. These mentorship practices and their related inter-subjective dialogues are key to this paper's existence. To facilitate and sustain practices of collaborative and critical reflexivity, Sheelagh and Bernhard interrogated the traditional competitiveness in academia, and propose creating research environments where trust, collaboration, and mutual accountability are prioritized over individual achievement. This shifts how scholarly outputs are generated and evaluated towards valuing plurality of knowing and experience, e.g., adopting The Declaration on Research Assessment (DORA) [86].

That said, facilitating relational, critical reflection can be very challenging within institutions or disciplines that demonstrate a reluctance to all but their conventional disciplinary approaches. To pragmatically negotiate such tensions, we can structure the contexts of personal subjective and inter-subjectivity of experience. For this, we consider Niglas' integrated multidimensional continuum model [224] as notable: The interaction between philosophy and methodology are indirect, and mediated by the researcher (including their experiences), and the research community. Hence, as with process ontology, research and the knowledge it draws upon can be viewed quite

clearly as **more** than incommensurable paradigms of philosophical orientations, methodological approaches, and positionalities.

6.17 Reflection 4| Who Gets to Claim Positionality?

The notion of 'in-betweenness' helped overcome tensions of positioning personal experiences and identities amidst the experiences of others, as described by Katerina. In methodologies like autoethnography, our identity and voice as expert researchers are intertwined in their epistemological claims. This resulted in Katerina feeling tension for claiming expertise in both her subject-matter knowledge and her lived experiences. This tension emerges in most first-person methods. For instance, soma design [155] is rooted in attuning to the knowledge that one's body carries as a source of design knowledge, developed through mastering a somatic practice (e.g. dance, martial arts, Feldenkrais). It exacts a question of *how much mastery of your body do you need to be able to draw knowledge?* In conversations with graduate students, Katerina witnessed their hesitancy in claiming a history of somatic practice, which impacted their perceived competency in soma design. Do we all need to be somatic connoisseurs [266], or is having a body enough? Yet, 'in-betweenness' can help bridge this gap between somatic connoisseurs, researchers, participants, and end users.

Sheelagh spoke to the challenges of taking on a position of embodied, personal authority because when a person's authority, identity, and lived experiences are invalidated, it can cause significant pain. She clarified that this differs from systematic invalidation or marginalization that stems from dominant traditions in academia, which may not carry the same pain but nonetheless have significant consequences. Bernhard's tensions in navigating his position of privilege and power manifested when stepping 'inside' and being an ally; questioning when 'stepping in' became 'overstepping', and when he should return 'outside'. Sheelagh and Bernhard create conditions for enabling people to be vulnerable and switch perspectives (including 'insider,' 'outsider,' and 'inbetweeny'), and to identify biases. A supportive culture and environment are necessary for such conditions; without them, we risk marginalization and oppression of voices. Support can be nourished through listening, giving all narratives and experiences weight and authority, and not imposing one's own values and thoughts. Creating openness and reciprocity are vital for sustained leadership and social change within transdisciplinary research and beyond. In safe, inclusive spaces, reflecting critically on one's positionality and power [265, 11] may balance collective lived experiences. As a process ontology, this extends beyond allyship into *mutual accountability*.

6.18 Reflection 5| The 'Dance' of Power Balance

Is it necessary to position oneself as an 'insider', 'outsider', or 'inbetweeny' researcher, and why is this even a challenge? To answer this, it is crucial to specify the sources of these epistemologically different ways of knowing because they are subject to power imbalances [225], which lie at the heart

of these tensions. Experiential knowledge has historically been devalued compared to colonialist ways of knowing, resulting in 'epistemic injustice' and lasting, downstream consequences on individuals and societies [113, 235, 92]. For decades, feminist epistemology has acknowledged that truth lies in the plurality of knowledge [132], with the awareness that preconceptions are not the same as bias [201]. Yet, barriers persist for researchers with lived experience [165], including tensions on intersectionality and hegemonic systems of oppression [256, 102]. Imbalances can lead researchers to repress 'insider' qualities out of self-protection, fear, and survivor guilt, making it challenging to view their lived experience as relevant or important, which affects research quality [106].

In Denise's case, repression of her lived experience resulted from intersecting power imbalances in healthcare (where women's illness and pain are systemically invalidated), academia (dominated by positivist traditions), and HCI (once dominated by a homogenous male voice). It wasn't until the birth of her child catalyzed her identity as an advocate-scientist and her acceptance as an 'inbetweeny' researcher that she recognized the systemic power imbalances in her lived experience. Denise acknowledges her inadvertent contribution to upholding hegemonic power imbalances that have historically favoured colonial ways of knowing, and that surrendering to liminality enables her process of growth.

This transformation aligns with the *transformative research paradigm* [16], where individual researcher transformation is essential for institutional and societal change by understanding knowledge through diverse perspectives and power inequities [211]. One field we can learn from that has undertaken extensive reflection and transformation is mental health as a service industry, which is increasingly leveraging lived experience researchers [260, 128, 15, 78], many who hold marginalized identities [74, 225].

6.19 A summary of what we learned for future considerations

We propose learnings aligned with each of the five areas of reflection, aiming to establish sustained practices for ourselves as researchers and our readers presented in Table 6.1. We recommend proceeding in order (e.g., creating a safe environment and culture should precede inviting peers to be vulnerable and open) and revisiting specific areas and learnings as needed. We have reported on how these practices have been impactful to our endeavours, and invite readers and our colleagues to build and grow safe spaces for dialogues that embody distinct contexts.

6.20 Summary

This chapter contributes to sub-question one by personal reflections on the discomfort of relating to research in social or personal ways. Through a collective autoethnography, we, researchers in data visualization and HCI, held iterative dialogues and written reflections that surfaced our individual experiences of being "an in-betweeny," a term I use to describe myself and, importantly, how to

Table 6.1: Proposed learnings to apply for sustained, transformative practices at any stage of development

Area of Reflection	**Learning Application**
1| Defining "experience"	Recognize how the origins of 'experience' shapes the researcher and their community; Carry this into a practice of authenticity and mutual respect.
2| Clarifying 'inside,' 'outside,' 'in-between'	Create a safe culture and environment free of dichotomous positions; Model, and embrace vulnerability and uncertainty in dynamic liminal spaces; Learn to switch between different views and roles as a process ontology.
3| Balancing context in knowledge	Recognize the importance of relational and inter-subjective experiences; Consider multi-dimensional continuums of knowing instead of incommensurable paradigms; Apply this by facilitating collaborative and critical reflexivity.
4| Claiming positionality	Recognize experiential and embodied qualities of lived experience; Gain sensitivities to know when to step back, and when to step in; Co-develop mutual accountability to balance voices and lived experiences.
5| Balancing Power	Discuss power inequities openly, considering roles, colonialism, identity, and intersectionality; Practice compassion towards oneself and others; Learn, and apply insights from domains undergoing transformation.

action social structural change in my community of practice. We did so through initial dialogues about our positionality and the complexity of working through power differences, as well as the challenges of undefined liminal categories or spaces.

Building on the reflections presented here, the next chapter, located in Part 2 of my thesis, will explore the social-relational dimensions in working with members of the public on a data physicalization. The co-construction of a data physicalization with members of the public further developed my understanding of how data physicalization process activities can facilitate and support research on data and sociality. Specifically, the project offers a deeper social-relational context for understanding public perceptions of data visualization work and the subtle perceptions of power, agency, and safety associated with data work.

PART II
Exploring Social-Relational Approaches with Members of the Public

Part II includes chapter 7 with a manuscript reporting on our participatory data physicalization called "Wound Up in a Pandemic" showing trust in information sources about COVID-19 to explore my second research sub question.

Sub-Question 2: How might members of the public approach data visualization if introduced to data visualization designed with a social relational perspective?

Chapter 7

Investigating Public Perceptions on COVID-19 Data Through Participatory Data Physicalization

Wound Up in a Pandemic: Community-Data Interaction in the Making

This chapter includes the majority of the manuscript I co-authored with Foroozan Daneshzand, Diane Gromala, Bon Adriel Aseniero, and Sheelagh Carpendale. I led the conceptualization, sketches, writing and editing of the original draft. Foroozan Daneshzand and Bon Adriel Aseniero supported writing the original draft. Foroozan created some of the visualizations. Diane Gromala and Sheelagh Carpendale supported the review and editing of the manuscript for submission and revisions. Sheelagh Carpendale supported the conceptualization and led project administration, supervision, and funding for the TOSH exhibition, which resulted in research and a manuscript. [1]

This chapter contributes to sub-question two by presenting the social dimensions of how members of the public interacted with data physicalization and the researcher-designer's presentation. This work informs my broad research question by demonstrating how data physicalization is a generative participatory research approach to examine social-relational interactions between members of the public and data physicalization.

To explore how data visualization can be designed to support socially oriented community engagement, we co-constructed a hands-on data physicalization, named Wound Up in a Pandemic, with people who visited a community arts centre. Our exploration was motivated by the potential of studying under-explored public perceptions of and interactions with data visualizations. Through a participatory approach, we built a physical Likert questionnaire about people's trust in information sources about COVID-19. We mapped six information sources to wooden posts, and 25 participants wove their answers into the structure by winding 1 to 5 loops of yarn around each post; the number of loops indicated the level of trust. The researcher was in a facilitator role, who observed interactions

[1] https://credit.niso.org

and interviewed 13 participants. We found our approach supported public engagement with the data and triggered critical, data-relevant discussions. Designing for and exploring such community-data interactions revealed complex and nuanced phenomena among members of the public, informing future considerations for socially oriented data visualizations.

7.1 Introduction

We used data visualization as an approach for conducting research and design for social community engagement. To explore how data visualization may be designed to support socially-oriented interactions with data, we co-constructed a data physicalization named *Wound Up in a Pandemic* (see Fig. 7.2) with people who visited a community arts centre. Our onsite observations and conversations focused on participants' experiences of visualizing data in physical form. Our analysis diverges from most research in data visualization which primarily focuses on perceptual properties of data visualizations and how the public uses multiples senses to interpret the data represented. We analyzed how public participants experienced social and affective interactions with data that characterize interactive social properties of data physicalization.

Designing for community or public engagement is relevant because scientific communication relies on data visualizations for a public that increasingly distrusts data. Public trust is particularly important for researchers and designers who create data visualizations, as was made clear during the early years of COVID-19. Although visualization experts represent complex data to simplify how end-users make sense of it, a gap remains in understanding public end-users and differences in how they accept, trust [99, 46, 171], and perceive data visualizations [328]. Often, public end-users are assumed to be "non-experts" or "novices" [46], and their differences and community contexts are not considered [137, 46]. However, because our research is grounded in constructivist assumptions that data represents dynamic social systems [28], we understand data visualization as a relational process. Therefore, we prioritize socially-oriented interactions with data, as these may embody a community's historical, sociocultural, and geographic factors that may influence perceptions and understanding of data.

Throughout this paper, *a community member* is broadly defined as an individual living in a specific geographic location and working in non-academic settings. *Community* refers to geographic settings outside of university laboratories. *Socially-oriented community engagement* acknowledges a community member's socially connective and relational experiences with their community that may inform their contributions as they construct physical data in the presence of a researcher-designer. *Socially-oriented* refers to social properties that interactions with the physical data have been designed to promote or social properties that unexpectedly emerge. These social properties may be feelings of social connection with community members, where a participant may identify themselves and their community as part of the data or excluded from it; or personal relevance to the data, such as feeling connected to where the data's physicalized form is situated.

We bring designer-researchers to work directly with community members as research *facilitators* to observe and receive feedback.

Building upon research that demonstrates diverse ways to include the public in data, we contribute an example of relational data physicalization for community engagement. We present a conceptual and practical design orientation — *community-data interaction* — to contextualize a critical discussion of publicly-inclusive data physicalization. This is a step towards expanding the scope of data visualization research and design that considers social worlds. In the following, we discuss why data physicalization is a promising approach to generate interest in data visualization among the public and enable participation in community-oriented research with locals outside of research labs.

7.2 Related Work

In data physicalization, data are *physicalized*, or mapped onto tangible (material) variables and spatially organized to more easily decipher the data's meaning [162, 88, 229]. Data physicalizations have been shown to enable a better understanding of the data's situated and social context [264, 219, 141, 288], to promote self-reflection for deeper personal meanings and understanding [291, 289, 152, 153], and to support collaboration [239, 180, 181, 123, 240, 56, 276, 226]. The deeply personal and social experiences using data physicalization are well-known and often include socially-oriented intentions articulated by the designers [22, 42, 99, 147]. Surprisingly, little research has explored and reported relational representations of data that engage the affective senses of social connection. For example, a user may gain a sense of belonging to or relating to a broader community through data interactions and relational data representations.

Studies of public perceptions of data visualizations are lacking [46, 137], with few studies that explore data visualization for social community engagement [127, 216]. Researchers suggested expanding definitions of affective social engagement [312] and motivation [278], encouraged more research and understanding of public perceptions and experiences of data visualizations [327, 328, 137, 17], and more direct contribution and feedback from the public [272, 47]. The social and physical contexts surrounding data physicalization, the *physecology*, are as important as the physical materials and components used [264]. We focus on physicalization's *implicit properties* [147] to be dynamic, socio-relational locations where knowledge can be 'constructed' through interaction. Constructivist scholars theorize that people's interactions embody social relationships and local knowledge [28, 184]. People interpreted data easily by physically manipulating material data representaions [153, 152, 219], and used it as a generative approach to make sense of social worlds [288, 199, 127] and community feedback [247, 239, 123, 17]. Therefore, we look to the interactions between people and physical data as sites where people can express socially-oriented knowledge about community relationships to data and how people might relate to a community through the data.

7.3 Designing the Physicalization: *Wound Up in the Pandemic*

We approached this project via Research through Design (RtD). RtD is an iterative enquiry for generating new knowledge by 1) making artifacts or design objects intended to explore a specific design or a phenomenon and/or 2) interacting with design artifacts that prompt or "probe" human expression and reflection of the phenomenon being studied [307, 117, 115, 330, 329]. Through RtD, it is possible to use a design object as a "probe" to evoke and explore people's perceptions and experiences in complex and "messy" problem spaces [115]. People's experiences of trust in information sources of COVID-19 are such a space: deeply complex, nuanced, and local to distinct experiences in people's lives and perceptions. The physicalization *Wound Up in the Pandemic* served as a design probe in this exploratory research.

There is a need to consider data visualization for community engagement using alternative approaches to "data" and "engagement" that promote data interpretation and a sense of social connection. Public engagement in data visualization is largely passive viewing, except for a small subset of "input visualizations" [42] such as discussions on social media platforms, which serve as a primary outlet for public critique of data visualization design [327, 272, 43]. By facilitating social and multi-sensorial interactions with our data physicalization and the facilitator, we aimed to gain insight of the social meanings and people's relationships to the data. For example, to address public distrust of COVID information, the World Health Organization (WHO) implored nations to facilitate local community engagement activities to enable "listening to community concerns, promoting understanding, building resilience to misinformation and engaging and empowering communities" [2]. When all public health restrictions were lifted, and people could comfortably touch surfaces, we incorporated the WHO's four community engagement guidelines [236, 1] into an interactive data physicalization about trust in COVID-19 information sources, which we call *Wound Up in a Pandemic*.

7.3.1 Designing for Interactions Between Community Members and Data

Our activities for public engagement were: *self-reflection, critical thinking, self-expression, critique and the ability to relate to the data in the context of their community and daily life*.

Choosing the Data Given the COVID-19 infodemic, we used an open data source and questionnaire from Statistics Canada (StatCan) called "Trust in Others" [3] because COVID-19 was relatable to most people.

Ideation We chose this design to facilitate a bottom-up input of "winding" one's perceived trust of a cumulative dataset. We created an adult human scale mock-up (Fig 7.9, where a person could walk through the physicalization, but the bottom and top loops could be awkward to reach. We opted for a tabletop scale with 2 sides and hand-width spacing between bars because it enabled greater accessibility for the interactions, whether seated or standing.

Building the Initial Structure Before the opening day of the public exhibit, the research team built and stationed the frame for the physicalization using wood dowels, 2x4 boards, and yarn

(see Fig. 7.8). Tabular open-data [3] prints were displayed on the wall as a reference to what the physicalization represented. Instructions were printed on card stock and displayed on the wall and the table.

7.3.2 Data Mapping

We choose a simple data mapping, where the numbers (1-to-5) on the Likert scale correspond directly to the number of times the wool is wound around bars in the frame. This simplicity aimed to minimize the learning curve and make the interaction more approachable Fig. 7.4 (right). Two alternating colours differentiated participants' inputs (Figures 7.4 and 7.5). Figure 7.6 (left) shows the StatCan data in the background. Figure 7.6 (right), columns were labelled according to the information sources. Figure 7.7 shows the question and the six information sources.

7.4 Co-construction of the Physicalization

The initial wooden frame was first constructed and then assembled in the gallery (Figure 7.8). The onsite researcher (facilitator) did not interrupt the attendees walking about. Instead, a sign informed that research was underway and hands-on participation was welcome. We invited public viewings – of the visualization as it was emerging – and hands-on manipulation of data represented by yarn.

7.4.1 Choice of Community Space: The Setting

We were invited to co-create this installation in a community arts centre in a popular seaside beach tourist town in rural BC with 29,000 visitors the previous summer. Part of a larger exhibit of data in art called *Data Reflections*, *Wound Up in a Pandemic* was situated in a sunlit room, with space to circumnavigate comfortably. This was a suitable research location because artists were expected to work in the studio during open hours and talk to visitors about their work. This informal dynamic benefited our project because we also wanted to speak with and observe the visitors (see Figure 7.9).

7.4.2 Participants

The participants were 18 years old and older. As this exploratory research is anonymous and no demographic data or self-identified gender data were collected, we do not report on demographic details here. All participants were fluent English speakers.

7.4.3 Process

The first author was on-site for four days, winding the StatCan data into one side of the frame (See Figure 7.4). She discreetly observed the space for 4 days onsite (20 hours), wrote field notes, and conversed with participants. She greeted visitors as they entered the studio, continued working on physicalizing data, and conversed with people only if approached with questions and conversations. For example, visitors walked around the space observing and asking the researcher questions about

the work. Out of the visitors who passed through the space, 25 input their data by winding their responses to the Likert questions on the wooden frame (see Fig. 7.7), and 13 were interviewed. Interviews were audio-recorded with permission and lasted between 10 and 40 minutes (on average, 25 minutes).

7.4.4 Co-exploration Set-up and Questions

We were interested in studying people's experiences as they worked with data in the local community and how working with a physicalization might enable interpersonal community engagement by inputting their data. The first interview question primed participants to connect the concept of *data* to their daily lives, to understand their distinct definitions and uses of data and to ensure we do not apply our concept of data in the analysis. Moreover, we wanted to understand which elements of the physicalization were most compelling beyond what was explicitly stated. Some people may not be inclined to fully articulate the subtle relationships between the physicalization and their perceptions, which is what we wanted to explore. This led to the inclusion of question 9: *Can you imagine where else this kind of activity might be useful?* and *What do you see in the structure?* Through these questions, we probed the social imaginations of the participants to elicit the subtleties and sensitivities that stood out most without needing to articulate them explicitly. For instance, some participants imagined this physicalization could be useful for children, in classrooms, or they saw a playpen or game, which contributed to a more nuanced interpretation detailed in the discussion to follow.

7.5 Using Reflexive Thematic Analysis

Reflexive Thematic Analysis (TA) [40] was the most appropriate analytical approach because of the active and participatory role of the researcher in engaging with research data. Thus, themes do not *emerge* from the data but are "generated by the researcher" through a series of iterative methods [40]. Including reflexive researchers alongside active participants in data, physicalization is essential for our goal to explore experiences of community engagement via participatory data physicalization. We especially envisioned physicalization as a way for researchers and visitors to probe the data's complexity through reflection and dialogue.The onsite facilitator (first author) was the primary coder and transcribed the recordings. Her self-reflection and memos are part of qualitative reliability [73, 40]. For example, she coded the interview data first and then her field notes. Then, she compared her memos from data analysis to the field notes to contextualize the scope of the analysis further. The notes from the different interpretative phases enabled comparison between the onsite observations and reflections after she analyzed the interview data. The transcripts and codes were discussed throughout group analysis sessions to ensure critical and diverse perspectives. We constructed codes around a "central organizing concept": *experiences of interacting with data physicalization about trust in a community setting* and developed five themes as shown in Table 1.

7.6 Findings

The themes are interconnected snapshots of the dynamic interactions among the people in their local context, with the physicalized data they created and the facilitator. It is important to note that these interactions are inseparable and dynamic, and are simply ordered linearly for this paper.

Themes				
Physicality Mediates Interpretation	**Slowness**	**Sociability**	**Relational Data Interaction**	**Perceived Safety & Freedom**
The uses and references to tangible materials	Experiences of time and pacing during the interaction	Experiences of sociable interactions	Awareness of oneself and group of people in represented data	Experiences of social safety, approachability, and self-expression

Table 1: The five main themes in our findings.

7.6.1 Theme 1: Physicality Mediates Interpretation

Participants touched and moved the yarn with their hands and looped it around the posts while conversing with the facilitator or other visitors in the room. The task of winding the answers was easily completed (frequently noted by participants) in about a minute or less from the first to the sixth post.

Impressions of Physical Data: Pointing to the Data, Relating to Familiar Objects, and People

Over half the people (n=7) pointed to parts of the physicalization that showed trends in the data and described what they saw. For instance, P12 pointed to the post representing non-government websites, stating: “But also this is this is very clear to me... but I didn’t feel that until down here [pointed to post]. But then, like I said, what do I really read?” As expected, manipulating and using physical material to answer Likert questions was novel and enjoyable. The string material was reported as “playful” (P2) and beneficial for thinking because it was “flexible and fluid” (P10), “simple” (P6, P12), “easy and quick” (P4) and “clear” (P2). Some remarked on the familiarity of yarn (P3, P6), and likened the process to answering “multiple-choice surveys” (P3, P4, P6), “like ...using yarn instead of a pen” (P6). While it presumably took more time than answering a survey, P6 described “freedom” (P13) in winding their responses to the structure. Another (P4) found the physical winding task helpful because it enabled a greater focus on each question category. P12 noticed the Canada-wide sample pattern and compared to themselves: “I can see the definite pattern right where the levels of distrust are... because I generally tend to think that the majority of Canadians think like I do. Yeah, and are fairly moderate and trusting. So this (stated lack of trust?) actually... surprises me a bit.”

Physicalizing responses: thought-provoking in ways distinct from writing or reading, while also being easier to interpret

Participants expressed the advantages of physically responding to questions rather than using words or numbers. One (P13) illustrates this: “It was very interesting because I had to think about it.

It's one thing to kind of think in your head about how you feel about something ... and another thing to show it and it be a physical thing to look at. And so I found that really interesting — so "putting it" [responding by winding] without putting it in writing." Another participant (p10) found the physicalization clearer than 2-D data visualizations with legends.

Applying the Community Data Interaction (CDI) Lens to Theme 1: The choices of the materials, as well as the physicality of responding to a question and speaking with the facilitator had implicit meanings in participants" lives. For example, based on participants' reports, the physicalized data reminded them of an abacus, art, cage, dreadlocks, jail, a kid's game, a playpen, weaving and knitting. The familiarity of yarn to the participants – knitters, weavers, and fishers – seemed "non-threatening" or "childish," likely because the interaction was considered "game-like," and the physical task of winding was easy. These meanings surfaced through dialogue, body movements and the spatial representation of data in loops of yarn. Participants explained that handling physical data benefited thinking about the data and understanding the mapping. Moreover, they used the process of physicalization to spatially locate, identify and discuss a category to support their thinking and talking. Additionally, participants pointed to or observed the physicalization while they personally related to the data (the topic of trust).

7.6.2 Theme 2: Slowness

The slower pace of interaction facilitated reflection on the data, sometimes in ways that may persist beyond the study. For example, as (P5) was learning how to wind their responses, they simultaneously focused on aspects of physicalizing their data, which appeared to evoke reflection. P5 said: "I think this takes a little bit more time, which is kind of interesting. You know, to kind of physically process it instead of just, like, really quickly process it on a computer. And I just enjoy doing something different." The slower pacing of the interactive experience and its novelty also tended to evoke or facilitate personal connections with the data, which left an impression on some participants. As described by (P13), "I think if anybody did it [the physicalization activity] it's not going to leave their mind. I think they'll start to relate more to these categories on a more personal level."

Applying the CDI Lens to Theme 2: Perception of time is a social dimension of participatory data physicalization. Considering time as a social aspect that may facilitate diverse interactions arising from different personal and community contexts has been little explored in data physicalization research. However, in our work, data physicalization is conceived of as part of a relational community-oriented research and design process, where the researcher is an intended part of the interactions, akin to ethnographers. Given that we consider such interactions to be social, cognitive, perceptual, and dialogical, our studies acknowledge these aspects by supporting more open-ended interactions, not only in terms of how participants engage with data but by directly interacting with the researcher-designer as well.

7.6.3 Theme 3: Sociability

This theme concerns how participants see themselves within the local community relative to the country. Our data physicalization mediated a relational interaction among people, data and physical material in a specific place. The *Relational Interaction* enabled participants to become aware of the way they considered themselves and the data as they worked with it. The facilitator heard participants compare themselves to the data and the local community in conversations. We found the following comparisons associated with expressions of relational community-oriented awarenesses:

- between the individual and their own looped responses,
- between an individual's looped response and the prior responses,
- from column to column (between information sources),
- from the community side of the physicalization to the random sample,
- from the data physicalization to more familiar multiple choice surveys.

Seeing Oneself in the "Bigger Picture":
Throughout the interviews, participants described the meanings they constructed about the data in relation to themselves or their local community. The facilitator did not ask them to view themselves relative to the community. However, this was a consistently observed phenomenon. This comparative tendency was either mentioned unprompted or appeared to be provoked by the simple question: *"What do you see in the installation?"* The onsite facilitator refrained from teaching or explaining data mapping. Rather, she answered questions and left the participants to explore the physicalization in their own time. For example, (P6) and (P9) articulated their responses relative to the community input (P6) or compared the trend of their community to the StatCan data sub-set (P9). "Well, I'm looking at the graphs because I know that's what's important...you can see immediately that what people [in their local community] are doing doesn't match that [random sub-set]... Maybe it's just that there aren't enough people on it, but I do see a general trend: if it comes down to social media, everybody is pretty suspect of that"(P6). Another talked aloud about their opinion of the data and compared their levels of trust to the trend: "Well, it seems pretty consistent; it's what I see. I don't trust social media, or few people do. I agree with that. Not a lot of people trust their family — that's just about right (P9)."
Comparison in Conversation: Speaking from the "I" and comparing with a "We" Some participants were in the process of answering the interview questions by looping. They spoke about themselves from the first-person "I" to describe how much they trusted a given information source. However, after they compared data trends in the physicalization, they referred to "we" when referring to their community side of the data. This was a noteworthy contrast to how participants referred to the anonymous StatCan data. P4 illustrated this shift from describing oneself (as "I") to referring to their self as part of a collective "we." There was also a shifting perception of one's self visible in the data physicalization: "But I didn't do that [compare trends] 'til the end. So I was

finished and I looked over, and then I looked here [StatCan side] ... it's the same flow [data trend] we've got happening [on the community side], which tells me that as people living in the community, WE often think in similar ways, not totally different, which I think helps US to be –hopefully– more respectful when WE do vary — I would hope" (P4).

Physicalized data in discussions became more people-centred over time

Some referred to the yarn data as "opinions" (P2, P7, P13) or discussed "community" in relation to the data (P1, P4), and every participant mentioned 'people' in the interviews. For example, (P7) explained how the data relate to people: "Well, what I'm seeing is a physical graph in the sense that it's 3-dimensional. It's not, you know, any piece of paper isn't like that. It is a very tactile way of representing a graph. So, I guess why it's interesting too is because each person has contributed a layer . . . you're not looking at a single result, you're looking at the net results of all the people that have contributed so far." When asked what they saw in the structure, (P13) replied, "I see all of the different pieces of yarn as opinions...It's like, "oh, look at all these opinions and look how many people have the same opinion about the same things.'" Participants shared personal views on how challenging, divisive opinions were among friends and family when they viewed the lower trust levels in the "family and friends' category (P9, P10). From these responses, participants appeared to identify with the data easily and understood that data went beyond a faceless abstraction to have direct relevance to people they know.

Applying the CDI Lens to Theme 3. Given the marked social orientation of the discussions with participants, our analysis suggests that they were socially engaged with physicalizing data. By applying CDI to our design for socially engaging with data, we aimed to implicitly support sociocultural connections to the data without biasing the results. The increasing aggregate response trends, visible as the number of participants grew, could potentially be considered a source of anchoring effect bias [42]. However, our goal was to facilitate socially-oriented activities. Visualizing aggregate responses surfaced an implicit social property that promoted dialogue and reflection. Through dialogue, participants used different comparisons to learn about the data, think about their responses, input their own data, and discuss their views about the data and people.

7.6.4 Theme 4: Relational Data Interaction

Under theme 4, we describe the sociocultural and affective experiences participants discussed with each other and the facilitator. The relational and social affordances of familiar craft material and physicality were integral to personal relationship building, shared conversations and critique of the data and its visualization. The facilitator observed social interactions around the data physicalization. Though participants were not asked to talk aloud, some chose to do so. While handling the yarn or looking at the installation, some referred to their experiences with COVID-19 information, talked about their families and friends, justified their perceptions about information sources or talked about the confusing question, "how much do you trust the following information sources...?" Spontaneous conversations about the data physicalization occurred among participants; people pointed to the physicalization, asked questions, shared personal stories related to the data

in the physicalization and critiqued the design. Some participants mentioned that they enjoyed the discussion and human interaction and found the experience "interactive" (P7, P10), while another participant (p10) said, "It's a way to "connect" and a form of cross-cultural expression". One (P7) said they enjoyed the social interaction with the facilitator and pointed out that handwriting a response on a computer does not allow the same degree of social interaction as the physicalization.

Social role of the data facilitator: The facilitator was part of the experience with data and allowed for conversations about the data in the physicalization from the personal stories and comments from the visitors. Some visitors did not speak, while others were gregarious. (P7) shared that the interaction was notable because the facilitator was present: "Well, this is more fun. Yeah, and we're interacting with you too. I mean, I suppose in a way we can do that if you were standing here and you asked us to do this with a pen and paper, we could still interact with you. But because those [installation posts] are the questions and the explanation, I think it just lends itself more to the interaction with you" (P7).

Public Critique – participants critiqued the designs of the physicalization: Some participants disliked the colours of the materials (P10), and others wondered how colours might affect responses (P7, P8). One questioned why the physicalization had four rather than two sides, and proposed that it was not as accurate as a written questionnaire because of the yarn's variable thickness (P8). However, this physical way benefits the ability to visualize a group's data in the same physical space relatively quickly. In the field notes, three participants mentioned working with data professionally. Imagining using the installation as a tool for accurate data collection, they questioned the truth and validity (P6, P7, P8) of the physicalized data. P8 considered the results to be "not publishable". Similarly, a fisher (P3) used their knowledge of knots to loop the yarn in a specific way. Tighter around the post than others, these loops visibly stood apart. Self-critiquing this difference, (P3) said: "The fluffy ones. . . have more weight in the data than my tight little half-hitch — which is — oh, I missed my ... I was diminishing my influence in your data." (P3) also questioned the aspect of winding yarn: "No, I just wondered about the social conventions — the conventions of looping clockwise or anticlockwise, resulting in the transfer string being on the front or the back of the structure or the inside or the outside, or transitioning from outside to inside. And again, I just thought I would mess it up, mess up the system by switching it up and doing both." Similarly, (P7) questioned our awareness of how the variations of the materials and how they were used might "make a difference to people." However, (P7) also wondered how differences among people could become so easily visible.

Applying the CDI Lens to Theme 4. The social and relational dimensions are important in developing relationships among researchers and the diverse communities they aim to reach through communicating data visualization. The way that participants used their diverse skills in contributing to the transformation of data into physical form, and how the affordances of specific materials and contexts were informative to the onsite researcher, particularly because they were also registered by participants. Further, most participants demonstrated critical thinking and offered critiques about the data, the question, and how discrepancies in data representation might matter. Nevertheless,

these important findings underscored participants' concern about data validity, implicitly raising the assumption that precision and accuracy equal trust. Finally, the facilitator learned about nuanced social perceptions of the material and how its use can be perceived in terms of the social value of individualism while also considering different knot patterns after learning about fishing knots – these findings are related to the local community and surface through the social interactions with the physicalization.

7.6.5 Theme 5: Perceived Safety & Freedom

Safety in Physical Over Textual Presentation: Participants associated physicalizing their answers with not being recorded in writing (P7, P13), tracked online (P9), traced or tracked through a computer (P6). Participant 13 noted the advantage of "seeing" people's comments represented by yarn because it felt safer than text and the implied authority of text: "I found that really interesting — so 'putting it' [responding by winding] without putting it in writing... people should feel pretty safe being able to say exactly how they feel when they're not really going to be held accountable because their name is [not] on a paper and it's not put in writing."

Safety for Civic Participation: The tangible metaphor of "feeling the data in one's hands" while also feeling personal emotions seemed perceived as less controversial. According to (P13): "...there is no controversy when you can speak your mind by doing this [hands-on response], and it's quiet and silent, and you're not going to be confronted."

Approachable Data as an Alternative to Numbers: Some participants expressed that the tabular StatCan data on the wall was "overwhelming" (P2) or "intimidating" (P7), and described the physicalization as more approachable. One participant, for instance, said they imagined physicalization would be useful to reveal people's yet unknown capabilities in thinking with data and numbers: "In Western culture's dichotomy between art and science...I think it [data physicalization] could be a bridge, you know, for people who have data phobia because they don't know what they don't know...this could help to give people confidence to be involved in data collection – involved in science" (P10).

Safety for Survivors of Violence: P7 imagined using physicalization as a conversational prompt to gather testimonials from children and use its data as possible "evidence' of experiences (P7): "safety in anonymity beyond not being named – that there is a subtler safety in its interactive capabilities perceived useful for children and victims of sexual violence." Similarly, P12 shared her experience of domestic violence and imagined using physicalization as an approachable way to anonymously contribute to communicating experiences of sexual assault in a community because the interaction enables "nuance" with the data.

Uncertainty about the "right" way: Physical manipulation of data components was a novel way to respond to a question. The facilitator observed some participants initially feeling challenged by the uncertainty, novelty and ambiguity of transforming data into physical form. Therefore, she was prepared to say that we had no expectation of doing the activity "right." When first asked, *"what did you find challenging about this activity?"* Most participants found that the question from StatCan

was difficult to answer, primarily because they thought that the attributes in the physicalization over-simplified complex categories. Participants demonstrated critical thinking when talking aloud about how the categories were too broad or that everyone was answering the same question but referring to different information sources and disparate social contexts.

Applying the CDI Lens to Theme 4: Experiences of perceived safety (P7, P13), feeling a sense of freedom in winding anonymous responses (P6, P10, P13) and perceived tactile challenges depict a balance between freedom of inputting data and uncertainty. For example, which direction to begin the winding, how much to press down on a stack of loops, or how tightly to wind the loops. We analyzed the tactile challenges and noticed they were not challenging in and of themselves. Rather, participants were concerned with "doing it right," knowing what to do if a category was an NA or how they could "skip" a question (P10).

7.7 Discussion: Community-Data Interaction as a Research Lens

We present data physicalization as an approach for social inquiry into people and data, offering an enriching complement to lab-based user studies. Data physicalization emerged from the corpus of computer-supported perceptual studies in information visualization. While lab contexts afford a controllable environment, they forgo the richness of social worlds in natural, "in the wild" settings and recognition of how a setting may affect people's behaviour in them [208]. Data physicalization in a community setting opens a view into complex social worlds, potentially expanding the narrow perspective on the public in data visualization research [46], and can challenge the assumption of a "monolithic public" [137]. Thus far, these differences in public *receptivity* to data [137], *neutrality* [288], *personal and collective identity, awareness, social learning and development* [56], or themes that emerged in our study such as *seeing oneself in community*, *freedom* or *perceived social safety* are not on the roster of tasks that data visualization designs for. However, socially-oriented design "tasks" are design intentions that rely on perceptual user tasks. Individual and community perceptions are crucial to public willingness to interact with data visualizations and must be further studied and implemented in design. This is specifically relevant when data visualizations are designed for community engagement in public emergencies, such as communicating public health advice in an evolving COVID-19 pandemic. The pandemic was a use case that demonstrated why curated bespoke communication strategies for the smallest communities matter in the context of disease transmission. We propose exploring socially-oriented data visualization for public engagement as a relevant topic not only for the next pandemic but also for communicating contentious issues, such as climate change, that would benefit from greater public trust in scientific communication and collective action.

We discuss some of our main design considerations based on our findings from our exploratory study, shown in Figure 7.10 below.

Data physicalization has been consistently shown to be a meaningful medium for relational social interactions among people and data. However, in reviewing literature about exemplary

projects using public data physicalizations, we found few descriptions of participants' experiences or perceptions relative to their community. We found robust descriptions of design elements used to justify design decisions. Engagement with a physicalization included design intentions, materials and their cultural metaphors, descriptions of tangible or spatial characteristics [147, 22, 93] or a viewer's proximity to a physicalization that may affect how data are interpreted [219]. However, the intentions of many designers of data visualizations are not primarily concerned with the perceptual interpretability of data but rather intend to engage users in thought-provoking, social or personal aspects of the data through visualization [147]. Through our small study, we learned about sociocultural dimensions of data physicalizations. We can leverage the sociocultural affordances of data physicalization to include the public in creative participatory research practices. Physicality and materials in data physicalization help participants interpret and express meaning. Offenhuber proposed considering the unexpected possibilities of materiality to "establish meaningful contextual relationships," [231]. The sociocultural qualities of materiality can surface the socially interconnected community properties to inform how to make data visualization more "personal" [243]. A public viewer in spontaneous data interactions in public spaces does not have an information goal like the task-oriented users studied in lab settings, which must be considered for public-facing design [51]. Therefore, we suggest diverging from an *information goal* to a *relational community goal* that can build upon the past multisensorial user studies and complement forthcoming research programs in novel directions.

Our use of yarn in a wooden frame showed that participants initially saw familiar materials and shapes, but the meanings they ascribed to it shifted in two ways. First, slower-paced explorations and discoveries of data mapping were evident in how they came to understand the data. Second, as time passed, subsequent shifts in how they related to the data mapping and perceived their community surprised the participants and onsite facilitator. Being able to see prior contributions of the growing data physicalization was important data that helped visitors become socially aware. Similarly, Kim et al. [171] suggested further exploration of socially aware data visualization because they found "personalized interaction through social comparison" affected participants' critical thinking about data in a computer-supported user study. Our similar finding surfaced through interaction with data physicalization and provides an example of how data physicalization complements data visualization research. As a result, we suggest further studies using aggregate data trends from the local community with an anonymous national comparator. In the following, we situate this finding in a broader discussion about future research directions in data physicalization as an approach to qualitative inquiry about community interactions with data.

What would data visualized for socially-oriented, interactive properties involve? How could relational data be visualized with community members? How would visual or physical design elements or mappings for social engagement look or feel?

7.7.1 Considering Socio-Visual Properties

We used *community-data interaction* as a design orientation grounded in a constructivist worldview. Restivo and Steinhauer [259] advanced a *socio-visual* theory that parallels our intentions for data visualization research and design practices for public engagement . Our study showed potential socio-visual properties of *social comparison*, *less textual or numeric input* associated with perceived social safety, *sense of expressive freedom* in physicality, and *personal anonymity*. Our findings suggest further research into the socio-visual properties implicit in data physicalizations.

7.7.2 Further Research Opportunities

Through a community-oriented lens, we build on formative studies of how the public interacts with data. For example, Wang et al.'s criteria of "social engagement" and "affective" response observed through behaviors such as laughter, mimicry, or conversation [312] can be broadened to include participants' expressions of community awareness, belonging, and identity in relation to data. Data physicalization can also serve as a boundary object [184] or a cultural probe in community settings, prompting reflection on visual elements that may make data feel more personal. Our suggested approach extend Peck et al.'s work on personalization [243], build on Sprague and Tory's exploration of community-oriented goals in visualization uptake [278], and resonate with He Ai et al.'s proposal to examine receptivity to climate data in relation to community and social safety [137] (see Table 2 in Figure 7.10).

We encourage the data visualization community to consider the many social worlds interconnected with how the public uses and perceives visual information. In this spirit, we offer a way to conceptualize future directions and envision the development of a socio-visual language [259] to design more socially engaging data visualizations for and with the public.

7.7.3 Limitations

There are several limitations to our study. The small number of participants who engaged in our study quite likely misrepresents the region's diversity. Additionally, communities can be defined in ways that differ from our definitions. We recognize that public participation with data can be polemical [288]. Furthermore, the facilitator is part of the interaction and needs cultural awareness and sensitivity to harmful colonial histories and extractive research practices, including understanding the "epistemic burden" placed on community members in data-driven research practices [251]. The physical setting, perceived safety, and social risk may shift if one's response, though anonymous, is potentially distinguishable by other participants present and should be considered. Importantly, the facilitator's comfort levels with facilitation, interviewing, and personal conduct are integral to the inquiry and influence participants' responses, interactions, and openness. Therefore, my distinct personality and cultural training as an on-site researcher influenced the overall experience.

Depending on the data and topic shown in the physicalization, it may be inappropriate to visualize aggregate communal responses to avoid biasing individual responses or stigmatizing community members. However, in some instances, it could be a welcome influence, such as seeing collective energy consumption trends that influence the individual decisions of household energy usage [56]. We recognize that this is only one event, one community, and a relatively small number of participants. However, we experienced the richness of an in-situ community setting to open research possibilities. Designing data visualization with distinct small communities is relevant in an interconnected world with diverse ways of thinking and knowing. We hope that, similar to how curb-cutting helps many more people beyond the original intention of helping wheelchair users, our study will be part of many more studies with various communities. We begin with locally distinct interpersonal data interactions to explore how data can help socially situate and connect people with their community.

7.8 Summary

This chapter contributes to sub-question two by presenting social dimensions of how members of the public interacted with data physicalization and their personal perceptions of the word "data". This work informs my broader research question by demonstrating how data can be visually and physically represented to support socially oriented community engagement. We used a participatory data physicalization, *Wound Up in a Pandemic*, to conduct research through design for social community engagement. Through community members' interaction with physical data representation in a community arts center, we learned about their experiences interacting with physicalized data. We employed *community-data interaction* as a research and design orientation to foreground participants' personal connections to the social networks represented in the data. Particularly, we see its potential to inform the design of data visualization for public engagement that promotes community-oriented awareness. As a design object, *Wound Up in a Pandemic* supported community engagement through physical tasks and interactions with the onsite researcher and the data. Participants reported that transforming data into a physical form was simple, clear, took time and offered a sense of social safety; it allowed them to self-reflect, think, grapple with, and critique the data, safely expressing themselves in relation to potentially contentious data. We suggested future directions in exploring relational data properties and socio-visual mappings to engage different communities in the public in socially meaningful ways.

I contrast the social-relational dimensions I explored with the public in this chapter with those of researchers and designers in my collaborative papers. The next chapter, in Part III of my thesis, proceeds to a content analysis of my collaborative reflexive papers, taking steps towards informing my broader research question on how data visualization and its process activities facilitate and support social interactions among researchers and members of the public.

“Wound Up in a Pandemic”

Figure 7.1: A photo of a data physicalization co-constructed with members of the public in a community arts centre on Vancouver Island, Canada.

Figure 7.2: *Wound Up in a Pandemic* in situ.

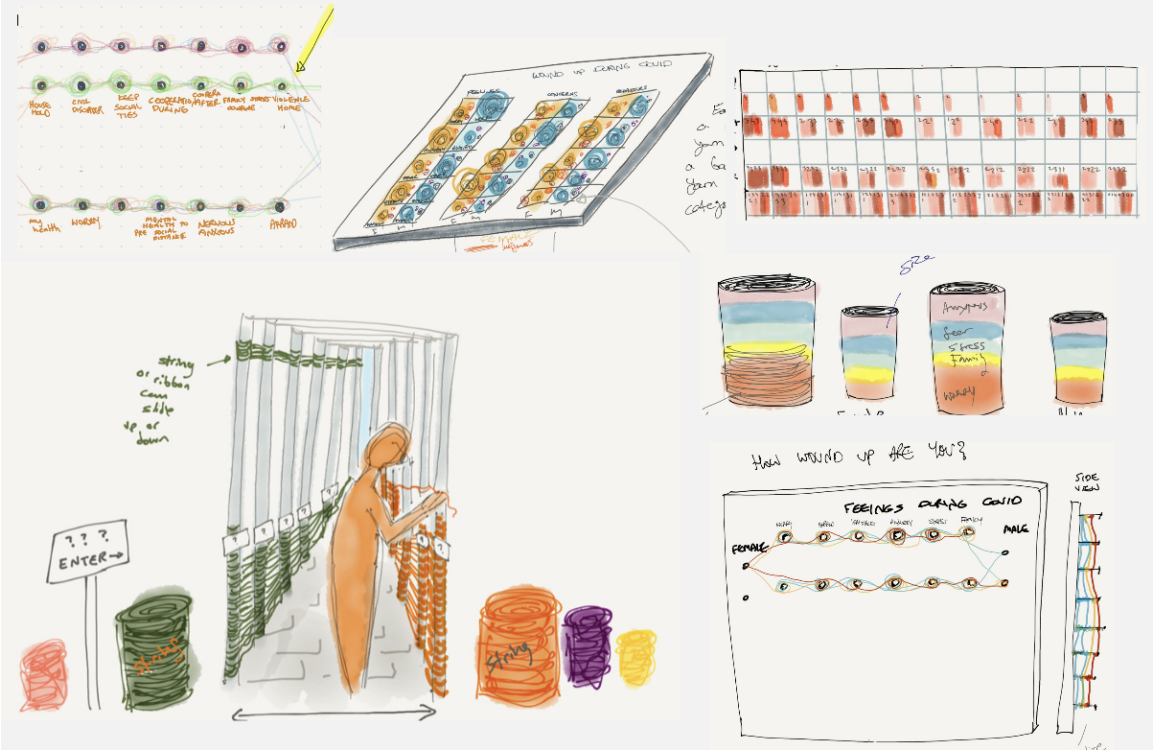


Figure 7.3: Sketches illustrating creative exploration of material use, spatial arrangement and interaction.

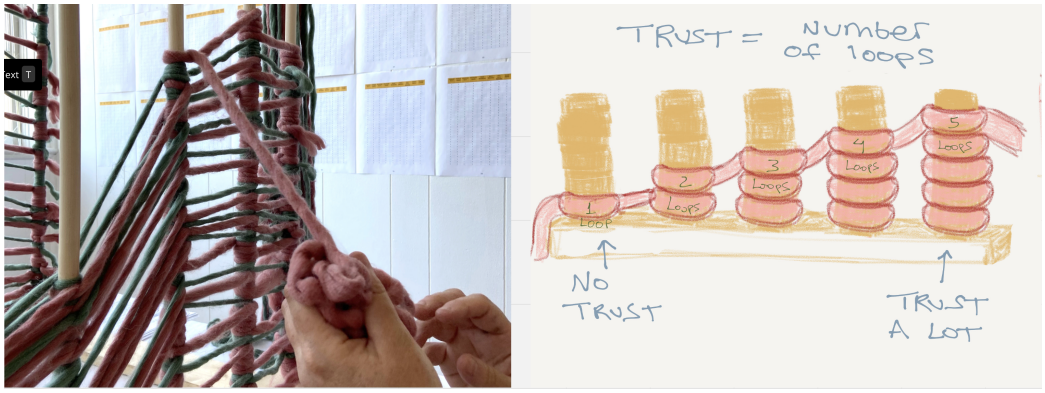


Figure 7.4: The right figure shows a close-up view of a visitor winding wool around each labelled attribute. The left figure illustrates the magnitude of trust, with the number of loops wound around each bar: the bar on the far left with one loop indicates the lowest level of trust, while the bar on the far right with five loops represents the highest level of trust.

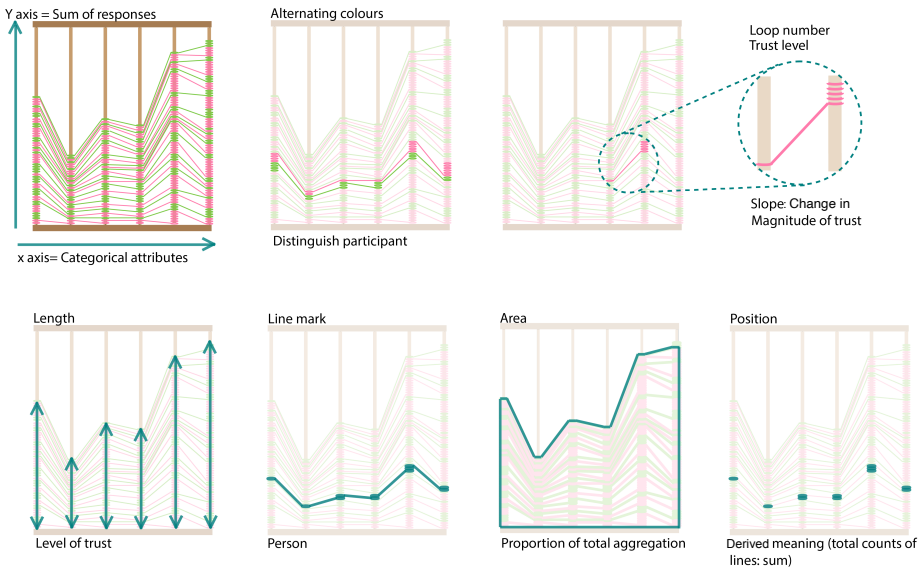


Figure 7.5: Diagrams highlighting different variables and illustrating how data trends can be interpreted through the visual representation.

Figure 7.6: The image on the installation of the left display with the two parallel frames, labelled "Statistics Canada" and "You and the Visitors" to guide participants in initiating the winding process. The left on the left illustrates the "You and the Visitors" frame with each bar labelled by its data attribute.

Likert Question

Using a scale from 1 to 5, where
1 means cannot be trusted at all and **5 means can be trusted a lot**,
How much do you trust information from each of the following sources?

Health Authorities, Federal Government, News Broadcast,
Non-Government Websites, Social Media, Family & Friends

Figure 7.7: Question retrieved from public open data source *Statistics Canada Survey Impacts of COVID-19 on Canadians, 2020: Trust in Others.*

Figure 7.8: Constructing the wooden frame within the gallery.

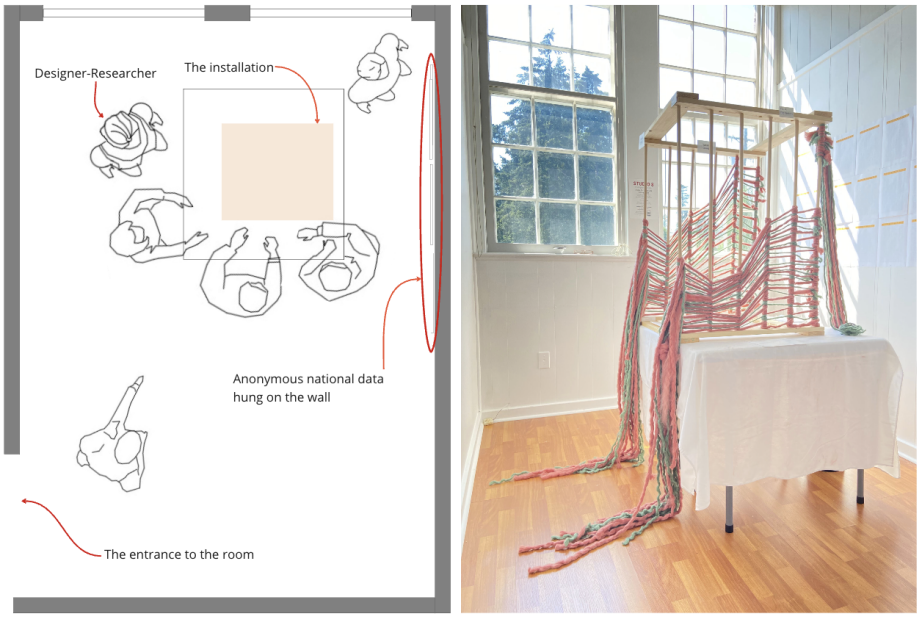


Figure 7.9: The installation setting.

Socially-Oriented Design Considerations Based on Themes

Physicality Mediates Interpretation	Slowness	Sociability	Relational Data Interaction	Perceived Safety & Freedom
Input visualization for physical input directly into a physicalization	Time is a socially-oriented design element for thinking and expression	Include community Members in active consultative roles	Ability to compare local data input to aggregate trends	Playful and familiar design that seems approachable and easy to complete
Sociocultural context of the space surrounding the physicalization	Ability to participate depends on social roles and schedules: parents, professionals, children	Consider power dynamics between "the expert" and "the public"	Researcher-designer present for the interaction with tasks such as listening, conversing, and asking open questions	Less textual and numeric data representations and instructions
Balance familiar material with culturally and locally relevant meanings: Ask the locals	Multi-tasking and relationships to time (mono/polychronic cultural time orientation)	Acknowledge researchers' role in community building or participating	Access to provide direct and indirect feedback: such as data input, or in conversation	Anonymity

Figure 7.10: Design considerations

PART III
Analysis & Reflections

Part III includes Chapters 8 and 9 with a content analysis of my co-authored papers in my PhD to identify *how* social exchanges happened among the co-authors, and *what* the exchanges were like, and the contexts in which the word "engagement" was used. My reflexive analysis is on all of my collaborations listed in Appendix C and explores my research question:

How can data visualization and its process activities facilitate and support social interactions among researchers and members of the public?

Chapter 8

Analysis: What are Social-Relational Approaches in Data Visualization Research?

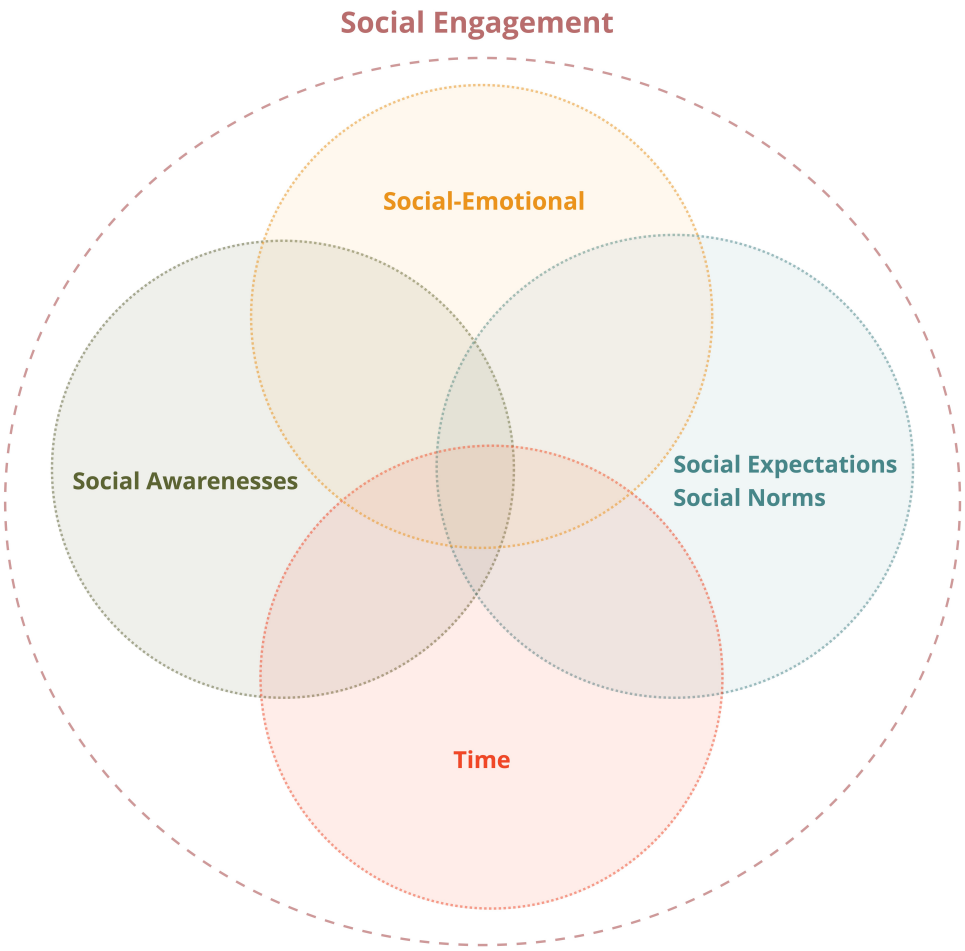


Figure 8.1: Social Themes: researcher-designers
- Interconnected themes I produced from deductive thematic analysis applying the construct "social" and "interaction" to my collaborations with 36 researchers in my 10 projects listed in Appendix C.

In this chapter, I explore how academic researcher-designers in data visualization approach research in social-relational ways by examining researchers' social interactions. According to Helen Longino's philosophy of science, interactions between two or more people are situations where knowledge is created [191]. Therefore, working by myself, I focus specifically on social interactions as they theoretically embody the social dimensions of knowledge creation in data visualization.

To explore sub-question 1, I apply reflexive thematic analysis [41] on the social interactions that occurred in 10 of my co-authored works listed in Appendix C. The papers report on collaborative interactions with 36 of my colleagues. The textual content in the papers is the evidentiary data to support my findings and reflections below. I refer to my research questions by first examining *how* interactions happened as summarized in Table 8.1. Then, I analyze and summarize the interactions into social-relational themes shown in Table 8.2. This chapter describes my methods and themes that I generated by myself to deepen my reflexive practice. I conducted this analysis myself. In Chapter 9, I contextualize my findings through a reflective discussion to explore my main research question.

Data visualization research and design include social interactions that inform my research question. As artifacts or processes, data visualizations can facilitate interactions between people and visual data. Within these interactions, people enact or embody social behaviours and norms, challenge social norms, and discuss their values and personal experiences.

Academics or researcher – designers: Individuals who are researchers and/or designers in the academic fields of data visualization, human-computer interaction (HCI), or art and design.

8.1 Theoretical Framework: Interactions as Sites of Knowledge-Making: Exploring Social-Relational Aspects in Researchers' Interactions

The sociality of interactions is a theoretical concept proposed by Helen Longino, a feminist philosopher of science and a proponent of social epistemology. She argues that knowledge is "social" and occurs within an *interaction*. Below, she explains that when two or more people interact through joint activities, they change each other in some way. In the following excerpt, Longino posits that there is a *mutual affecting* through an exchange of ideas on a shared topic that creates knowledge:

> There is, however, another meaning of "social" available to epistemology as well as to other areas of philosophy. Individuals don't just respond to their environments or to their groups, they interact with each other. By interaction, I mean the mutual affecting of two or more agents in a way that alters each, consistent with their persistence as entities. Interaction can be verbal, as in conversation. It can be physical, as in a mutual

> embrace or a struggle. Interaction is a stronger notion than that of joint action. We may both attend a concert together. This would be a case of joint action. When we discuss the concert with each other afterwards, however, we are interacting. In our exchange of ideas, we are each changed, at a minimum by learning what the other thought of the concert, but perhaps less minimally by modifying our opinion as a consequence of learning of the other's assessment. Interacting is also a different notion than that of sharing. We may share an identity, a nationality, a belief, without ever interacting. An interaction with respect to a shared belief or identity involves conversation or discussion about it. Whereas joint action involves doing things together and sharing involves holding things together, interaction involves exchange of some kind.

[189, pp.2]

The two questions below are based on the *sociality of interactions* I adapt from Longino. I used Longino's theoretical mechanism of interactions to focus on 1) exchanges between researcher-designers, and 2) on the mutual effects from their interactions, such as social, emotional, and community-oriented feelings or considerations reported in the papers.

How did exchanges among researcher-designers happen?
What were exchanges like among researcher-designers?

8.2 "Sociality" as a Construct for Deductive Analysis

Sociality helps me identify the social-relational aspects and explain how, with my co-authors, we created the knowledge reported in the papers using social-relational approaches in data visualization. The term *sociality* includes the terms "social" and "interactions" as the constructs I used for deductive (closed) coding in reflexive thematic analysis [41] (for a summary of methods, see Appendix B.1).

Definition of "Social" in the context of DataVis and/or HCI
Interactions between two or more people who identify as academic researcher-designers in DataVis and/or HCI in a group of researchers who share a mutual goal of exploring research and design practices in data visualization.

Definition of "Interactions" in the context of DataVis and/or HCI
Defines communicative activities among people such as discussions, sketching, listening and responding, or writing with the above collaborators who are members of a research group with similar research goals. Interactions are marked by communicative exchanges, resulting in each participant being personally changed or influenced by these interactions. The reported knowledge outputs or insights in the selected academic publications demonstrate changes to personal and/or group social dynamics, attitudes, or ideas from their interactions.

The papers I co-authored include two or more researchers who collaborated and then reported on the collective knowledge they produced from their interactions. Therefore, I collected their interactive activities, socially based group experiences, and social knowledge outputs. I then analyzed them using the constructs "social" and "interactions" (see analysis protocol in Appendix B.1). Then, I generated themes to characterize the social-relational dimensions I found shown in Table 8.2. I used data visualization to reflect on the themes depicted in Figure 8 based on my analysis and experiences participating in these research interactions.

8.3 *How* did exchanges among researcher-designers happen?

Activities from Researchers' Collaborations

Researchers' Group Activities	Definition
Group members contribute to a shared repository	Data collection, data organization in-person or online. Building trust and rapport via check-ins, either online or in person.
Sketching & Drawing	Place self-sketches around a circle on a digital whiteboard to share personal experience.
Reading & Writing	Annotations by participants to convey ideas. For example, spatially organizing digital "sticky notes" to comment or group information.
Discussions	Verbal exchanges by sharing personal experiences on a particular theme, responding to others and questioning.
Body-Based Communications	Body gestures to convey ideas and to show respect to others.

Table 8.1: Themes describe researchers' social activities researching, teaching, and designing data visualizations.

8.4 *What* were exchanges like among researcher-designers?

Themes Describing Dimensions of How Researchers Socially Related to People, Data or Visualizations in Collaborations

Theme	Definition
Social-Emotional	Emotions or feelings in sociality, such as the emotional labour of research participants or researchers in higher education or research settings. Feelings are part of responding to community-specific experiences that data represent. Activities and interactions are related to adhering to or changing social norms, such as racism or sexism, feelings of social validation and recognition, social awkwardness or vulnerability, a sense of social insecurity, internal tensions within oneself and one's community, and self-compassion. Positive feelings, such as serendipity and a sense of surprise from being together, include rapport, group synergy, team cohesion, mutual trust, and a sense of togetherness.
Social Expectations, Social Norms	Power dynamics, social protocols, showing respect, intentions, social responsibility or accountability, shifting social roles of the researchers, and personal identities.
Social Awareness	Awareness of social diversity and how different social contexts affect people's experiences interacting with data visualizations. For example, social and epistemic diversity influence scientific practices and considerations for personalizing information for learners and users of data visualizations in classrooms and the public sphere. This includes familiarity with social norms and an awareness of being an insider or an outsider among distinct social groups, as well as the dynamic social roles and responsibilities of researchers. Leveraging and appreciating social diversity is essential to designing relevant experiences with data visualizations for individuals connected to social networks. In research settings, understanding social and epistemic diversity benefits knowledge production in data visualization. In health, social awareness enables the understanding of community strengths and opportunities to design bespoke communication strategies that influence people's health behaviours using data visualizations.
Time	Time is an inherently social dimension that includes balancing multiple social responsibilities, diverse information settings, and different modes of accessibility or barriers to participation in learning, teaching, or research.

Table 8.2: Themes describe social-relational dimensions of academics researching, teaching, and designing data visualizations.

8.4.1 Research and Design Approaches Include Social-Emotional Dimensions

Researcher-designers in data visualization appreciated positive group dynamics because they improve emotional aspects of research practices, such as feelings of trust and rapport. Some participants reported personal vulnerability and social tensions in research or design activities and considered the social vulnerability of public community members in these contexts.

This theme includes positive feelings such as serendipity and a sense of surprise from group reflections, including rapport, group synergy, team cohesion, mutual trust, and a sense of togetherness as discussed in Chapters 3, Appendix 5, and Appendices C.2.3, and C.2.4. For example, authors in "Me-ifestos for Visualization" (in Appendix C.2.3) reported feelings of surprise from collective reflections as fellow researchers: "What surprised us was how deeply revealing the ensuing discussion was about our values and desires for the world. . . . The answers highlighted the situated understandings of empowerment, ranging from constructivist teaching and physicalization to co-design a policy intervention".

Similarly, spending time together online and seeing each other's faces was essential to building trust and rapport in the project "Distributed Synchronous Visualizations" in Chapter 3.

Researchers described emotions related to sociality, such as the emotional labour of research participants or researchers in study settings, as discussed in the Inbetweeny paper [252], or in the context of teaching data visualization [21]. Feelings through engagement with data physicalizations and ethical considerations are part of responding to community-specific experiences that data represent, as mentioned in "Unpacking Sustainability in Physicalization Practices" [218]. Negative feelings were also reported: Social validation and recognition, social awkwardness or vulnerability and a sense of social insecurity, internal tensions in oneself with one's community, and self-compassion were reported. For example, while showing one's sketches in Sketching Introductions Appendix 5, some experienced social awkwardness and felt "on edge". Some forgot to mention their names while pointing to their sketches. Similarly, in the paper "The Inbetweeny Collective", we discussed feeling personal vulnerability during self-and group reflections, as demonstrated in the following quote: "Recording our experiences felt authentic, humbling, vulnerable, and sometimes insecure—fueled by an internal tension of positioning oneself, yet never feeling quite at home." [252, pp.4].

8.4.2 Social Awarenesses of researcher-designers

Researchers approached their peers, community partners, their students, or themselves with social awareness of different social contexts that may affect people's experiences interacting with researcher-designers in teaching, collaborations, or interacting with visual or physical data. For example, in "Challenges and Opportunities in Data Visualization Education", social diversity refers to diverse learners of data visualization and their personal experiences and distinct social contexts such as history, gender, and access to resources [21]. In addition, some expressed that they transfer the cultures and norms of the scientific field through education, which was also related to a sense of social responsibility, as stated in the quote: "Education not only embodies the knowledge, methods, and culture of a discipline and presents these to the world, but it also influences the skills, principles, and values that both learners and educators will shape the future of that discipline." In "Sustainability in Physicalization", we refer to "intention" as a sustainability dimension that..."[Intention] includes the designer's beliefs, motivations, and aspirations for their practice and highly reflects value-sensitive design approaches [218]"

Researchers' beliefs and personal experiences contribute to their research practices. They also learned from the different personal perspectives and experiences of their colleagues in reflexive group activities. For example, in both "The Inbetweeny Collective" and "Me-ifestos" we wrote about how researchers' values and expertise drive teaching practices and research interests. In "Embracing Disciplinary Diversity in Visualization" in Chapter 4, we propose that understanding social and epistemic diversity in research settings benefits knowledge production in data visualization, and then provide case examples of various research methods in data visualization. They aimed to increase awareness of the benefits of including epistemic diversity. We invite peers in data visualization research to be open to the multitude of worldviews in science that influence the kinds of problems and methods researchers use.

Researchers described an awareness of being an insider or an outsider among distinct social groups, an essential social awareness for ethical research and design practices. For example, some consider how to personalize information for learners, while others discuss the importance of personalizing data visualizations and the public sphere. I and my co-authors of "The Inbetweeny Collective" [252] and "Sustainability in Physicalization" [218] encourage developing an awareness of researchers' privileges, positionalities, and sensitivity to local histories of people in community-based research. In community health settings, I and my co-authors of "Visualizations for Communication during the COVID-19 Pandemic" Appendix C.2.4 explain that social awareness helps researchers to understand community strengths and opportunities to design bespoke communications strategies to influence people's health behaviours using data visualizations. Moreover, they urge leveraging social diversity to create relevant experiences with data visualizations for diverse public audiences in the event of a future pandemic. In higher education context of "Challenges and Opportunities in Data Visualization Education" [21], we consider personalizing learning materials, types of data, and activities to serve as a point of connection for individual learners to relate to data visualization in personal and socially relevant ways.

8.4.3 Time as a Social Dimension

Researchers related concepts of time in social ways, such as balancing multiple personal and professional responsibilities, multiple information settings, and timely dissemination of data visualizations. They also discussed the time concerning different modes of accessibility to resources and barriers to participation in learning, teaching, or research. Time was mentioned in all the papers as a consideration of the time constraints of faculty members in teaching, or the limited time of learners in "Challenges and Opportunities in Data Visualization Education" [21], the hurried to designing and implementing COVID-19 visualizations for the public in "Visualizations for Communication during the COVID-19 Pandemic" Appendix C.2.4, and "Distributed Synchronous Visualizations" Appendix C.1.1. Time was enmeshed with social cohesion and building rapport, such as the time spent together in person or online, while seeing each other's faces and body gestures were relevant to building comradery and social trust in "Distributed Synchronous Visualizations"

Appendix C.1.1. In the vertical timeline in "COVID Gowns" C.2.4, time was a consideration of an ongoing pandemic and how a user may not only find distortion of a horizontal bar chart over time but also quickly see the most updated information at the top of a page because most people quickly scroll through on their handheld devices.

8.4.4 Social Expectations & Social Norms

Researchers follow social norms and expectations but may also challenge them to change social protocols and standards of practice for more equitable participatory futures in research and design. For example, in "Distributed Synchronous Visualizations" [193], we demonstrated social-cultural norms for respectful interactions, such as social etiquette and culturally shared gestures, including waving goodbye, maintaining eye contact, and smiling in online meetings. This was related to improved rapport and a sense of comradery. In the paper "Unpacking Sustainability in Physicalization Practices" [218], we proposed value-based and culturally informed design intentions that align with researcher-designers' sense of social accountability and ethical considerations for sustainable data physicalizations. The dynamic social roles of researchers and personal identities influence research interactions or encounters with data visualizations. For instance, in "Challenges and Opportunities in Data Visualization Education" [21], researchers wrote that "teaching is a privilege and a responsibility" [21, pp.9].

Activities and interactions in research or with data visualizations were contextualized by following or changing social norms, hierarchies, and biases. In "Sketching Introductions" Chapter 5, we subtly challenged the social conventions of collegial introductions by introducing an individual's position using a sketch they made instead of saying aloud one's rank or credentials. Researchers in all the projects took the time to reflect on their positions and privileges. For example, in "The Inbetweeny Collective", one of my co-authors describes his privilege while also feeling in-between gendered norms: "As an aging white male, I have undoubtedly benefited from privilege, many of which I may not even recognize. However, as a highly sensitive, empathetic, and (not very) self-secure person by upbringing, I have never fit in a traditional masculine box, too." [252, pp.9]

8.5 Multiple Meanings for "Engagement"

The word "engagement" is often used to describe user interactions in data visualization and HCI, and may imply implicit assumptions about social-relational experiences or intentions, as well as cognitive, embodied, or other sensory modes. My goal was to deepen my understanding of the social-relational qualities when people engage in interactions with others in data visualization research and design practices. Therefore, analyzing in which contexts the word "engage/[d]/[ing]/[ment]" was used outlines how researcher-designers relate to facets in their work in social ways.

"Engagement" encompassed all themes shown in figure 8 and used in varied contexts and distinct social dimensions as summarized in Table 8.3.

8.5.1 Method of Analysis

I analyzed how researchers and designers of data visualization and physicalization used the word "engagement". I summarized the context of "engagement" in Table 8.3 as described in all the papers except the poster, depicting a vertical timeline. In the paper "Embracing Disciplinary Diversity in Visualization" [192], we didn't include the word "engage." Instead, the paper includes the word "embrace[ing]" to invite open-mindedness to differences in epistemic positions, which I qualified as a type of social-relational engagement because "embrace" refers to an open-mindedness to unfamiliar perspectives and worldviews, with social acceptance or openness as part of celebrating social and epistemic differences rooted in disciplinary cultures, conventions, and life experiences.

Contexts of the Word "Engagement" in the Papers

Themes of "Engagement"	Contexts
Feeling	Comradery, sense of social belonging or exclusion, sense of motivation, personalization, sense of reward.
Accepting	Open-mindedness, acceptance or openness to social or epistemic differences, perspective taking.
Taking Responsibility	Educators and researchers perceive their responsibility for facilitating learning and education creatively and practically.
Doing	Questions, active learning, creativity, interviewing, active workshops, reflecting on oneself or in a group
Being Part of a Group	Building communities of practice, connecting with organizations or networks of practitioners.

Table 8.3: Themes describe researchers' uses of word "engagement" in the papers.

8.5.2 Engagement: User Encounters

Throughout the papers, the "engage/[d]/[ing]/[ment]" was characterized as an encounter with an object, a person or a group of people, the Self, an activity, a change of perspective, or feeling.

8.5.3 Engagement: Assumed to Evoke Feelings Related to a Social Self

In "Distributed Synchronous Visualizations" [193], less engagement was felt when colleagues couldn't see each other's faces with the cameras turned off in online meetings, a quality related to social synergy and building rapport. Engagement is associated with feelings of social belonging during online "hangouts." In "Visualizations for Communication during the COVID-19 Pandemic", engagement was mentioned along with feelings of trust by the public and "personalization" of

public data visualizations of COVID-19 so a user could feel a sense of social connection after interpreting meanings of data visualizations relative to their personal lives, "Personalization may enhance engagement, foster trust, and improve outcomes in marketing, health-care, and public information campaigns." Notably, we did not expand on the social-relational aspects I described. However, by looking at how engagement was used in the context, we perceive a correlation between trust and *engagement* that could result in a user feeling personal connections by interacting with visually represented data. Feeling trustful is part of the social-relational themes (Table 8.2).

8.5.4 Engagement: Assumed to Promote Social Critique, Motivation & Social Responsibility

In the paper "Challenges and Opportunities in Data Visualization Education"[21], engagement was mentioned in the context of educators' and researchers' responsibility to "engage in knowledge transfer, develop creative and practical approaches to education, and lead the research necessary to understand and improve education" [21, pp.1]. We questioned how engagement relates to one's sense of motivation in the following quote: "How do we understand and respond to the factors that motivate people to engage with visualization learning?" [21, pp.5].

8.5.5 Engagement: Participation in Activities

Engagement was characterized as activities with data or "engaging" with collaborators, consistent with the list of activities in Table 8.1. For instance, in "Sustainability in Physicalization" [218], engagement referred to interviewees participating in interviews and hands-on interactions with data physicalization, as well as designers who created data physicalizations or were familiar with sustainability. In "Distributed Synchronous Visualizations" [193], engagement with data helped researchers generate more questions about the data they wanted to visualize. In "Challenges and Opportunities in Data Visualization Education", engagement was social because it included student group interactions alongside educational materials that participate in inspiring coursework: "...support active learning and engagement with course content and visualization terminology, as well as inspire students through exposure to other students' work [21, pp.7]." We also refer to engagement occurring through "doing" visualization and feeling a personal connection to themselves in the data while feeling supported in task accomplishment: "Examples of learning visualization by doing, through engagement with personally relevant data sets and supporting people in their daily visualization tasks, and materials that support them" [21, pp.7]."

In "Me-ifestos for Visualization" (Appendix C.2.3), engaging refers to doing the reflexive exercise over coffee and an invitation to continue the discussion. In "Sketching Introductions" (Appendix 5), engaging refers to sketching and presenting the sketch. The engagement was also an act of identifying the self linked with emotional and affective aspects through reflexivity.

8.5.6 Engagement: Participating in a Group and Openness to Different Approaches

Engagement related to interaction with professional communities and creating communities of practice in data visualization included responsive educational and research support considerations. For example, in "Sustainability in Physicalization" [218], engagement refers to community members interacting with a physicalization. Engaging with communities in "Challenges and Opportunities in Data Visualization Education" [21] is regarded as having the potential to teach researchers about distinct socio-technical knowledge of groups of people who may use data visualizations, as noted:

> "Connecting to networks of practitioners could help engage with people and organizations in practice to understand their approaches to visualization and their need for education [...] This will require concerted, collaborative efforts to conduct and share research and transfer this into educational offerings, future thinking (such as that on the relationship between visualization and AI [135]), engagement with those who can identify the needs for skills and knowledge and embrace change, and flexibility at all levels" [21, pp.8]

We acknowledge the relevance of collaborative efforts, which include social activities such as accepting different approaches and being open to societal and technological change.

8.5.7 Engagement: Reflecting on Scientific Practice and Social Position

Reflexivity as engagement was anchored in social-relational approaches to contemplating professional practices, relationships with others and oneself, social privileges, and social inequities. For example, in "The Inbetweeny Collective" [252], engagement involved exploring the challenges of researchers taking on multiple social roles. In "Distributed Synchronous Visualization", reflexivity occurred through autoethnography, a study methodology that explores the concept of "the self." The paper outlines the details of our social and relational aspects in online design work.

My overarching research question is: How can data visualization and its process activities facilitate and support social interactions among researchers and members of the public?

8.6 Contrasting Social Dimensions of the Public and Researcher-Designers

I explore my overarching research question above with a final overview of the overlapping social themes I generated from the public interacting with data physicalization, as well as my collaboration with researchers. I noticed that each group perceived their agency with data differently—some public participants were aware of their vulnerability to being adversely impacted by data concerns such as misinformation and privacy breaches, and were cautious and critical of data. Meanwhile, researchers were concerned with educating others, including those with less expertise in the field, on data visualization and data literacy. Researchers considered awareness of sociocultural facets, ethical practices, and their responsibility to lead innovations in data visualization, collaborate with different communities, and reflect on their privileged positions in society. These findings may highlight the varying power dynamics and assumed authorities surrounding data. Working with data physicalization with the public demonstrated that data physicalization can support meaningful interactions where multiple social dimensions are part of the interrelated socialities to be considered and designed for. Below, I present the social dimensions that illustrate the power differences and potential for contributing, handling, and visualizing data in social-relational approaches.

Themes from both groups contrast similarities and differences depending on which group they identify with—the public or a researcher-designer—and how they socially relate to data visualization. For example, public participants mentioned feelings of safety and freedom when inputting their data into a physicalization over computer input or pen and paper. These expressions suggest that some people may be cautious and distrustful of how their data could be mishandled. Meanwhile, researchers discussed their social responsibility when working with public participants and students in data visualization, demonstrating a sensitivity to their social power and influence in the visualization of data.

I found that data visualization and physicalization supported mutual social exchanges in both groups. Public participants directly input their data into a physicalization while interacting with the researcher. They recognized the socially oriented affordances of data physicalization to support direct public data input in conversational settings. They envisioned different applications of data physicalization for civic engagement. My research suggests that data visualization may provide a sense of agency and reciprocity as part of a broader set of social-relational experiences with data visualization artifacts and research and design processes. The following combined themes from researcher-designers and community members from the public elucidate social-relational dimensions of data visualization and engagement.

8.6.1 Sociability—Social-Emotional

"Sociability" for the public group aligned with the theme "social-emotional" for the researcher group, including feelings associated with the social settings. These themes include *mutual exchanges* between the participants, the researcher, or others in the room. Both groups discussed emotions—in Section 7.6 with the public, and summarized in Tables 8.2 and 8.3 among academics. Both groups reported social-relational experiences and shared personal stories about their lives and perspectives on data.

My research suggests that social-emotional elements are integral to social-relational experiences such as a sense of being included, togetherness, or recognition. Conversely, feelings of insecurity and community-related tensions may also occur. Therefore, designing for sociability and techniques of direct input into data visualizations and their processes may enrich social-relational engagement.

8.6.2 Safety & Freedom—Social Awareness

These themes illustrate perceived power differences within social relationships and personal perceptions of interacting with data visualization processes. Both represent their distinct social groups with individual lived and felt experiences, different responsibilities, and vulnerabilities in data work. For example, researchers discussed the importance of considering broader social contexts in which their students or audiences were situated. Researchers' awareness of context, including their social privilege as credentialed experts, was contextualized by their ethical values.

Public participants demonstrated an awareness of the vulnerabilities of providing their data. For instance, some distinguished how winding their data into a physical representation of a questionnaire felt safer and allowed a sense of freedom due to the lack of textual and numerical formats in conventional multiple-choice questions. Some appreciated the anonymity of inputting data via physicalization as well. My findings suggest further exploration into perceived freedoms and safety in social-relational interactions with data visualizations in the future.

8.6.3 Slowness—Time

Time was mentioned in similar ways for both groups, where the benefits of more time enabled reflection and deeper connections with people and their data. For public participants, winding yarn to represent data visually took longer than answering multiple-choice questions. They reflected on how this time allowed them to engage more deeply with the data, reflect on it, and interact with the material. The slower pace also enabled more meaningful conversations between the researcher and the participants. Researchers also expressed the challenge of time constraints, especially in educational settings with little time to design learning sessions, or time constraints for students to complete assignments. However, in online coworking, extra time spent together at the onset of the pandemic contributed to building mutual trust and fostering collaboration, which enhanced a sense of social togetherness.

I suggest that time should be a social-relational consideration when designing interactive experiences with data visualizations, balancing time in research and design interactions for deeper reflection, while keeping in mind time constraints and other social-relational factors adapted to specific settings.

8.6.4 Social Expectations and Norms—Relational Data Interaction

I observed a reciprocal relationship between the practices, values, conventions, social norms, and expectations of researcher-designers. Their values motivate their work, the questions they ask, and how they address them in their research or design. Similarly, public participants contributed their personal perspectives and ideas in a data visualization-based activity and also mentioned their personal influences and those of their family and friends on their perceptions of trust and data. While researchers work within the boundaries of their academic conventions, they also strive to continually refine and improve research practices, incorporating social complexity and diversity. Public members appreciated interacting with a researcher-designer through an unconventional data-supported conversation.

Given my findings, I propose future studies examining non-conventional data gathering and research methods that include visualizing data within qualitative research spaces. Furthermore, future work can investigate data visualization techniques in participatory research and their effects on social-relational experiences.

8.6.5 Data Visualization Designed for Social Reciprocity

Throughout my research, I observed, listened, and participated in mutual exchanges with my fellow researcher-designers and generous public community research participants. I found that data visualization process activities supported social reciprocity, referring to the reciprocal exchanges of knowledge, ideas, and ongoing feedback among people. Social-relational experiences happened as a result of reciprocal social interactions. Reciprocity is the mechanism that enabled me to learn about social interactions in data visualization. Thus, I encourage more researchers to center social reciprocity in interactions with data visualizations.

Social reciprocity in data visualization design and research is a concept that may be helpful to address asymmetries in perceived personal and community agency when using, making, or critiquing data visualizations. For example, when researcher-designers teach others about data, the concept of social reciprocity can reframe how classroom experiences can be structured to optimize social reciprocity and consider the social-relational dimensions at play. Ensuring that makers and users of data visualizations feel included may lead to improved social and relational experiences for many who interact with data visualizations and meet researchers in the field.

Through my research, I provided examples of social-relational engagements with data visualization activities. I suggest that social-relational experiences are likely to affect the data shared, collected, and then used in research and deployment. Furthermore, social-relational

experiences contribute to knowledge production in scientific inquiry; therefore, they should be considered and designed for in human-data interactions or community-data interactions where visualization mediates or facilitates interactions in socio-visual ways.

The next and final chapter includes my reflections and concludes my thesis.

Chapter 9

Reflections & Conclusion

9.1 Reflections

Through four years of research and collaboration with 36 colleagues, I thought about and studied data visualization from a community perspective. I still find it compelling that data visualization is considered a 'visual language', showing or tangibly physicalizing organized abstractions of complex human worlds. I was immersed in the social realm of researching and designing data visualizations, learning how to use this visual language. The data visualization community is a thriving social realm shaped by many researcher-designers contributing to conversations that consider social contexts and power differences in society. While it was apparent that sociality surrounded our data practices, I struggled to articulate an impasse I experienced when designing data visualizations for public engagement at the onset of the COVID-19 pandemic [193]. I sought to conceptualize the foundational relationships among people, their communities, and data in our collective society. Furthermore, although my colleagues and I recognized in our papers that sociality is implicit in data visualization, I did not understand how to incorporate social dimensions into the visual language of data. Below, I reflect on the dichotomy that motivated my research questions and how my research provides a formative understanding of what social-relational approaches may be like in the field of data visualization.

I draw upon theoretical perspectives from feminist social epistemology, intersectional feminisms, and participatory design-based research methodologies because they foreground social and relational dimensions in research and ways of knowing. These perspectives inform my PhD research, reframing data visualization not only as a representational tool but also as a space for social interactions where meaning and knowledge production can occur within communities of people.

9.1.1 Tensions in Social-Relational Data Visualization Practices

Tension and sometimes personal discomfort in reflexive and relational collaborative practices emerged as discussed in Chapters 5 and 6. Feminist scholarship encourages "staying with the trouble" [133], reminding that unsettling feelings are to be expected. I was unsettled when the COVID-19 pandemic began. I witnessed families and communities being torn apart. The social

unrest inspired my thinking about ways to visualize data to evoke a sense of belonging to a broader community, as people felt uncertain, worried, and afraid for their families. I was a nurse in community-based healthcare, and then I transitioned into public health research. I knew that health outcomes were better when individuals felt supported by and were actively part of their communities, including partners, family members, friends, colleagues or neighbours.

Data visualizations supported messages that "we're all in this [pandemic] together" [4], but the data visualizations published then showed the distribution of aggregate disease counts — it was unknown if the visualizations served to unite people and promote pro-social health behaviours. Yet, data visualization was used for public health intervention and social behavioural change. Aligned with community-based nursing care, I sought more holistic ways to utilize data to acknowledge people's feelings and foster a sense of community through interaction with data visualizations. In this final chapter, I explain how my findings support my thesis and research questions. The headings summarize the main points.

9.1.2 Reframing Data Visualization as a Social-Relational Approach in Research & Design

I took steps to explore the implicit social and relational properties of data visualization processes and interactions. My formative work is a step in characterizing the social qualities inherent to processes and interactions among researchers and public participants. In the following, I contextualize the social-relational aspects of data visualization that I found in my research. Below, I summarize the potential of leveraging the social-relational dimensions for research and design across multiple disciplines and community contexts in the future:

- Researcher-designers in my collaborations are aware of social aspects in their collaborations with colleagues, community research partners, and students. Moreover, they aim to enhance practices and research programs to be more socially inclusive.
- Social reciprocity as a design consideration has the potential to leverage community knowledge through data visualization as an interactive, cyclic process, enabling input from diverse perspectives, including those of researcher-designers and the public.
- There is a nuanced interplay between themes of sociability, social awareness, time, social norms, and reciprocity, all of which shape how people interact with data. For researchers, these themes may inform the design of data visualization activities and guide ethical considerations in their work.
- There are social-relational dimensions to engagement with data that I found by interacting with data visualization.
- Implicit social-relational properties are made explicit through my qualitative research. They may support design considerations for public engagement with data visualization.

9.1.3 Terms for the Socio-Visual Aspects in Data Interactions

The terms, themes and descriptions I outline in Chapter 8 relate to the social-relational experiences in data visualization practices, or the socio-visual dimensions. The themes are neither definitive nor comprehensive. I consider the multifaceted aspects of how individuals and communities interact with and perceive data visualizations. Therefore, through my thesis work, I propose data visualization as a research and design approach because it has the potential to both accommodate and express complex socio-visual interactions. I consider data visualization and physicalization as generative relational design approaches that may influence how individuals perceive, feel, and connect with others through visual data.

9.1.4 Data Visualization as a Research and Design Approach

In my dissertation, I explored how data visualization and physicalization can be used in research and design for social-relational experiences. I learned that sketching as a research approach shifted introductory formalities and prompted reflexivity on one's practice in academic group settings. For example, in Chapters 5, the practice of sketching oneself in academic introductions was used for a social-relational purpose, aiming to shift socially constructed hierarchies in collaboration. I used a sketch-based research approach in academic collaborations, which prompted reflexivity and fostered interpersonal understanding among collaborators. Instead of introducing themselves by voicing their rank and role, participants sketched in response to a topic question and then introduced their sketches. The sketches facilitated fun, curiosity, vulnerability, and also tension, as people were not accustomed to presenting themselves through their personal sketches. Similarly, in Chapter 7, I explored data physicalization as a design probe to examine public perceptions of data through an interactive participatory activity. I learned that data physicalizations and sketching personal data can be used as design probes to explore sociality within data-supported interactions. By immersing myself as a researcher with participants in data physicalization, or making personal sketches, I learned about the subtle social experiences related to the data visualization process. For example, data physicalization, as a research probe, supported my inquiry about how people in their communities interact with and perceive data about COVID-19. Furthermore, participants were open and curious about the physicalization activity. They asked critical questions and provided unsolicited critiques about my design and/or the data themselves in relationship to the data.

9.1.5 Using Data Visualization or Physicalization for Community-Based Research for Public Engagement

My work provides examples of how data visualization and physicalization can facilitate the study of public engagement with visual data, offering playful, embodied interaction capabilities to support public feedback. Public feedback on data visualization design is relevant to data visualization because community critique and feedback may reframe, guide, and advance yet unknown research directions in the field [272, 47]. The pandemic response revealed the need for research to focus

on tailored visualizations coupled with the right collaborators. My research takes steps to shed light on public participation in data visualization and on the social-relational aspects that academics may consider. However, more research is needed to understand which data-based communication strategies to use, when, and for whom in data visualization, based on a deeper understanding of social-relational interactions with data. Through my research, I demonstrate the potential of using data visualization and physicalization as participatory research approaches. In doing so, I observed that some academics and members of the public are open to engaging with data visualization research and design in social and relational ways. I also collaborated with researchers in data visualization who are committed to working in community-centred ways and to considering social-relational dimensions in their work. In addition, public research participants expressed excitement about novel data

In the case of COVID-19, data visualizations were used in global pro-social design efforts to promote behavioural change through data-based communications. However, such efforts require a multi-disciplinary team where multiple experts can inform the safety and ethics of interventionist efforts with data visualizations. My collaborations demonstrated the potential of working in cross-disciplinary teams and practicing reflexivity. Based on my analysis, considering social-relational aspects in reflexive spaces is likely to contribute to meaningful discussions among academics. Moreover, the discussions may shape academic cultures and research approaches over time.

I expanded upon Hornecker et al.'s concept of "implicit properties" in data physicalization by including both the public and researchers to highlight its social-relational dimensions. My work builds on Hornecker et al.'s review of 241 papers on data physicalizations, in which they describe "implicit properties" as factors that go beyond data mappings such as setting or metaphor because these influence how people interpret and experience physicalizations [147]. They proposed a common language for describing how data can be physically encoded to support comparison, analysis, and discussion across a wide range of physicalizations. As they explain, "the design vocabulary of physicalization should consider how we perceive and experience physical environments and objects, multi-modal perception and interaction materiality, cultural symbolism, and spatial relationships" [147, p. 9]. Building on the notion of a design vocabulary for physicalizations, my research explores a socially integrated approach that uses data physicalization's design affordances to surface implicit social-relational properties within social interactions.

My analysis examines the practical and theoretical aspects of sociality in data visualization, highlighting social-relational interactions among researchers, designers, and members of the public during the process of creating, using, or interpreting data visualizations. Some of my insights may suggest the power dynamics inherent in data collection and representation, particularly when considering public trust in data and the experts who manage and share data visualizations. I used readily available and familiar materials, such as yarn, pen, and paper, to make the research practice accessible to people outside a lab, independent of internet connection, computers, and technical computer skills. These materials are easily transportable and provide an informal

activity for my research. In data visualization, Burns et al. found that research papers about "the novice" user were based on in-lab studies with graduate students in their 20s [46]. Accessible, hands-on, creation-based research practices may open opportunities for people to participate in data visualization research outside university campuses.

9.2 Conclusion

In my dissertation, I examined the social and visual dimensions in data visualization processes through collaborations with academic researchers, data visualization designers, and members of the public. To explore the social-relational dimensions surrounding data visualization work, I analyzed my collaborative PhD projects through the lens of social epistemic philosophy. My findings suggest that the academic researchers and designers in my projects refer to user engagement in the context of personal feelings, acceptance, accountability, and a sense of group belonging. Social-relational themes, including time, social expectations, social norms, and emotional dimensions, contextualize social-relational academic interactions through professional practices. In contrast, members of the public in my collaboration expressed social-relational themes of safety and freedom, slowness, sociability, and relational data interactions, where visual data serves as a means of relating to other people and with an academic researcher present. Moreover, some of my projects demonstrated that participatory, hands-on activities with visual or physical data representations, and the pacing of these activities, can have social-relational outcomes, pointing to further research. Foregrounding reciprocity and attending to the social contexts of both researchers and members of the public can be further explored to develop more socially engaging ways for visual communication. Overall, my work contributes to a more nuanced understanding of social-relational engagement in data visualization. These findings expand the current understanding of visual data to facilitate social, relational, affective, and participatory processes. More broadly, my thesis contributes to critical discourse in design research, human-computer interaction (HCI), and qualitative methodologies that aim to explore the scope of personal and community experiences with data. Global challenges, such as the climate crisis and potential future pandemics, underscore the need to examine further the interrelated social dynamics and power structures surrounding data visualizations. Future work can include more exploratory research and social-relational considerations to inform community-centred communication strategies for public engagement.

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Appendix A

Contributions

A.1 Academic Magazine (peer reviewed)

A.1.1 Embracing Disciplinary Diversity in Visualization

Tatiana Losev, Justin Raynor, Sheelagh Carpendale, and Melanie Tory. 2022. Embracing Disciplinary Diversity in Visualization. IEEE Computer Graphics and Applications. 42(6) (2022), 64–71, IEEE Computer Society Press.

A.2 Conference Papers

A.2.1 The Inbetweeny Collective: Reflexive Dialogues on the Liminality of Researchers' Lived Experiences

Denise T. Quesnel, Tatiana Losev, Ekaterina R. Stepanova, Sheelagh Carpendale, and Bernhard E. Riecke. 2024. The Inbetweeny Collective: Reflexive Dialogues on the Liminality of Researchers' Lived Experiences. In Proceedings of the Halfway to the Future Symposium (HttF '24). Association for Computing Machinery, New York, NY, USA, Article 6, 1–10. https://doi.org/10.1145/3686169.3686204

A.2.2 From Exploration to End of Life: Unpacking Sustainability in Physicalization Practices

Luiz Morais, Georgia Panagiotidou, Sarah Hayes, Tatiana Losev, Rebecca Noonan, and Uta Hinrichs. 2024. From Exploration to End of Life: Unpacking Sustainability in Physicalization Practices. In Proceedings of the 2024 CHI Conference on Human Factors in Computing

Systems (CHI '24). Association for Computing Machinery, New York, NY, USA, 12 pages. https://doi.org/10.1145/3613904.3642248[1]

A.2.3 Challenges and Opportunities in Data Visualization Education: A Call to Action

Benjamin Bach, Mandy Keck, Fateme Rajabiyazdi, Tatiana Losev, Isabel Meirelles, Jason Dykes, Robert S Laramee, Mashael AlKadi, Christina Stoiber, Samuel Huron, Charles Perin, Luiz Morais, Wolfgang Aigner, Doris Kosminsky, Magdalena Boucher, Søren Knudsen, Areti Manataki, Jan Aerts, Uta Hinrichs, Jonathan C. Roberts, Sheelagh Carpendale. 2023. Challenges and Opportunities in Data Visualization Education: A Call to Action. IEEE Transactions on Visualization and Computer Graphics 30(1). (presented at IEEE VIS 2023). IEEE Computer Society Press. Pre-print available for open access https://arxiv.org/pdf/2009.02306

A.2.4 Distributed Synchronous Visualization Design: Challenges and Strategies

Tatiana Losev, Sarah Storteboom, Sheelagh Carpendale, and Søren Knudsen. 2020. Distributed Synchronous Visualization Design: Challenges and Strategies. In 2020 IEEE Workshop on Evaluation and Beyond-Methodological Approaches to Visualization (BELIV), IEEE (online).

A.3 Workshop Papers

A.3.1 Slow Data and Healthcare Co-Design: Exploring Tensions through Duoethnography and Data Physicalization

Gina Freeman, Tatiana Losev, Sheelagh Carpendale, Barry Wylant, B., and Lora Oehlberg. (2023). Slow Data and Healthcare Co-Design: Exploring Tensions through Duoethnography and Data Physicalization. In workshop Data as a Material for Design: Alternative Narratives, Divergent Pathways, and Future Directions. ACM Conference on Human Factors in Computing Systems, CHI 2023. Association for Computing Machinery, Inc.

A.3.2 Me-ifestos for Visualization Empowerment in Teaching (and Learning?)

Jan Aerts, Wolfgang Aigner, Benjamin Bach, Fearn Bishop, Magdalena Boucher, Peter C-H Cheng, Alexandra Diehl, Jason Dykes, Sarah Hayes, Uta Hinrichs, Samuel Huron, Christoph Kinkeldey, Andy Kirk, Søren Knudsen, Doris Kosminsky, Tatiana Losev, Areti Manataki, Andrew Manches, Isabel Meirelles, Luiz Morais, Till Nagel, Rebecca Noonan, Georgia Panagiotidou, Laura Pelchmann, Fateme Rajabiyazdi, Christina Stoiber, Tatiana von Landesberger, Jagoda Walny, Wesley Willett. Me-ifestos for Visualization Empowerment in Teaching (and Learning?).) 2022. In workshop, alt.VIS workshop, IEEE, Oklahoma City, U.S.

[1] Awarded Best Paper at CHI Conference 2024

A.4 Poster Papers

A.4.1 COVID Gowns: Breaking Scales with an Unknown End

Sarah Storteboom, Tatiana Losev, Neil Chulpongsatorn, Jackie Yu, Sheelagh Carpendale, and Søren Knudsen. 2020. COVID Gowns: Breaking Scales with an Unknown End. In Poster Presentations. IEEE Transactions on Visualization and Computer Graphics, Oklahoma City, U.S. 2 pages.

Appendix B

Analysis Protocol

B.1 Methods Overview: Deductive Thematic Analysis of 10 papers Based on the concept of "social" and "interactions"

The following is a summary of my methods and an explanation of my qualitative findings that address my research question.

- Applied Helen Longino's definition of "social" and "interactions" from Sociology and Philosophy of Science to define my analytical parameters for coding
- I coded for the following: interactive activities; any social dimensions or social considerations from the reported findings
- 1st pass of papers in my dissertation to recall their contents and my memories of the collaborations
- 2nd pass of papers identifying the concept of "social" based on the above criteria generated 61 codes.
- I input codes and their names/descriptions into a table
- 1st pass of code list on social dimensions: I noted 12 broader descriptive codes about sociality
- 2nd pass I colour-coded the list of 61 codes by the 12 thematic groupings, see Figure B.2
- 3rd pass, I spatially reorganized the 12 thematic groups in Miro to generate meanings from how they are interconnected with their contexts
- 4th pass, I generated four main themes to characterize the social dimensions in researchers' interactions: social-emotional dimension, social awarenesses, time as a dynamic social dimension, and social expectations based on social norms, see Figure 8
- I spatially organized researchers' group activities on a digital whiteboard to understand how social-relational approaches occurred, see table 8.1

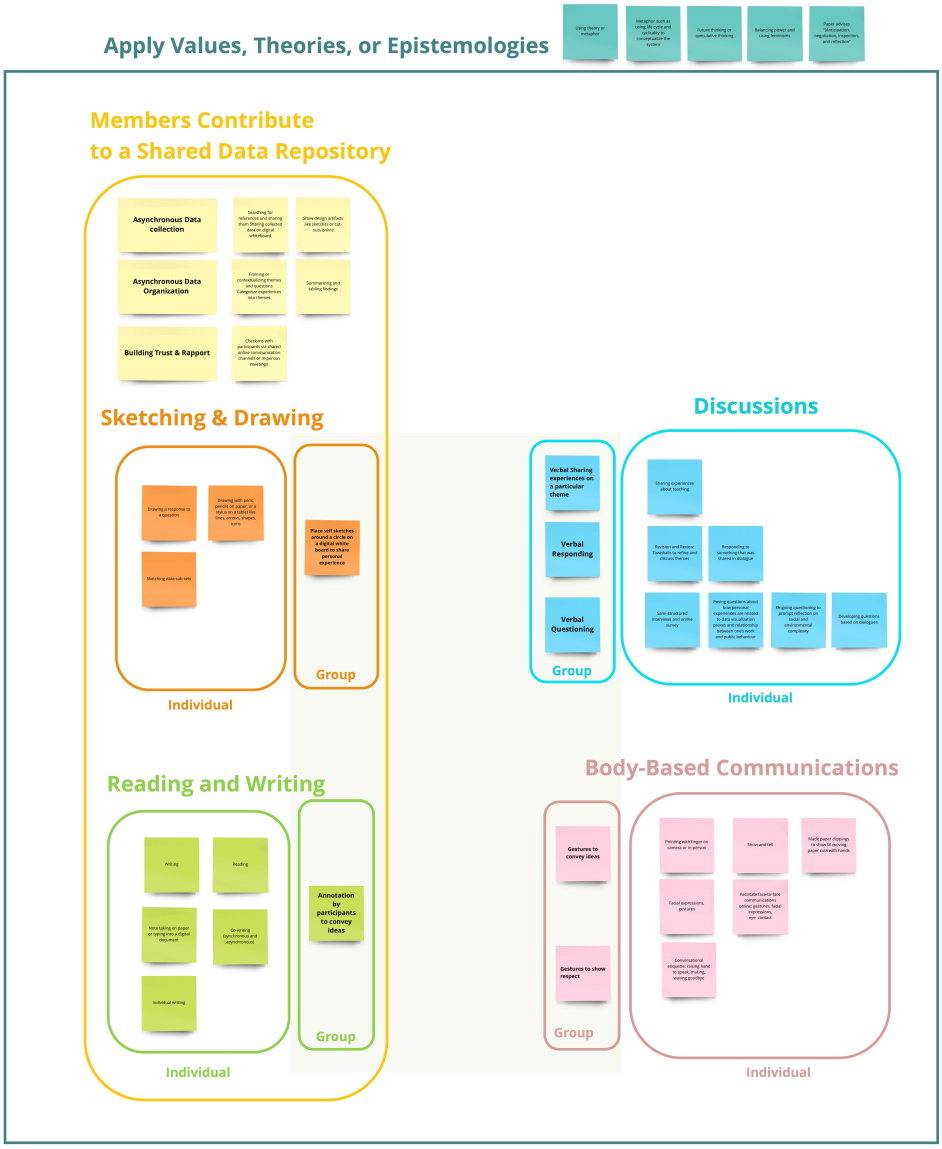

Figure B.1: **Summary of Researchers' Activities to Generate Knowledge in Groups Organized by Individual and by Group Purposes** — Researchers' activities in social settings include contributing to a shared data repository, sketching and drawing, reading and writing, and discussions with verbal and gestural communication.

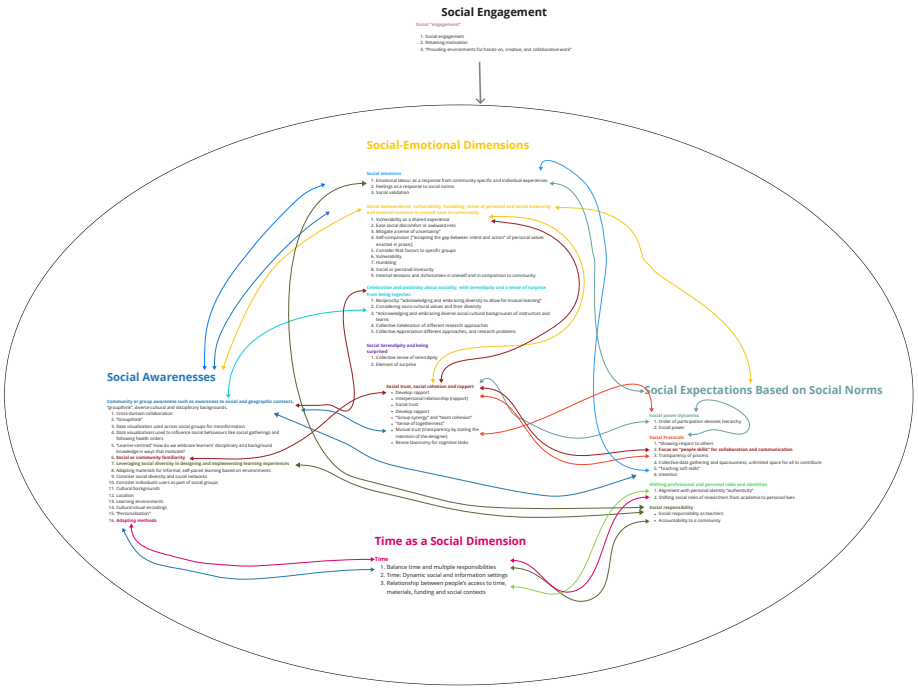

Figure B.2: I generated 61 codes that represented social-relational dimensions within interactions among my colleagues. I categorized them based on broader social relational themes. Then, I drew arrows to the interconnected codes and noticed overlaps among all the themes. This part of the analysis informed my broader Venn diagram of social-relational themes from my collaborations.

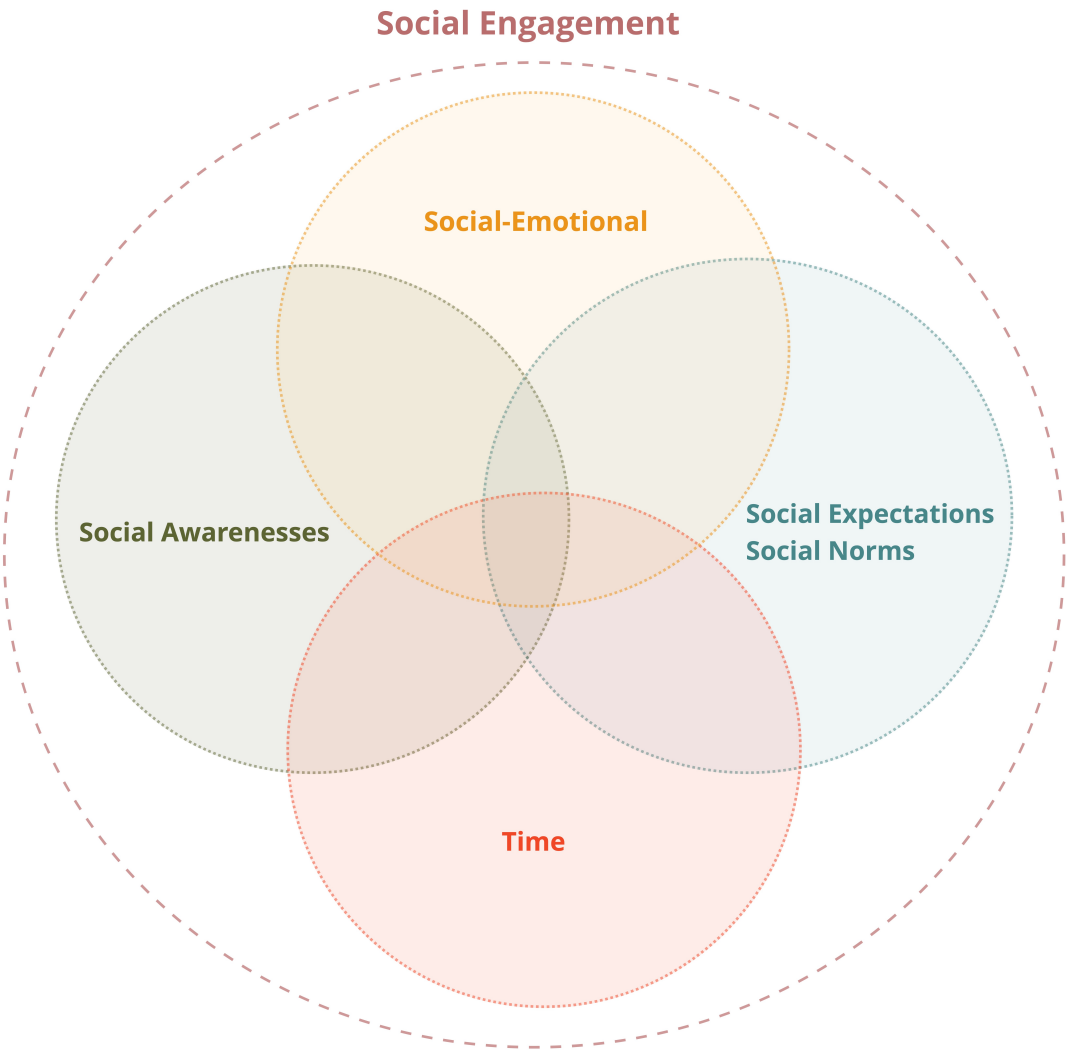

Figure B.3: I made a Venn diagram to show the interconnected social-relational themes I found in my research and design collaborations based on my analysis described in Chapter 8.

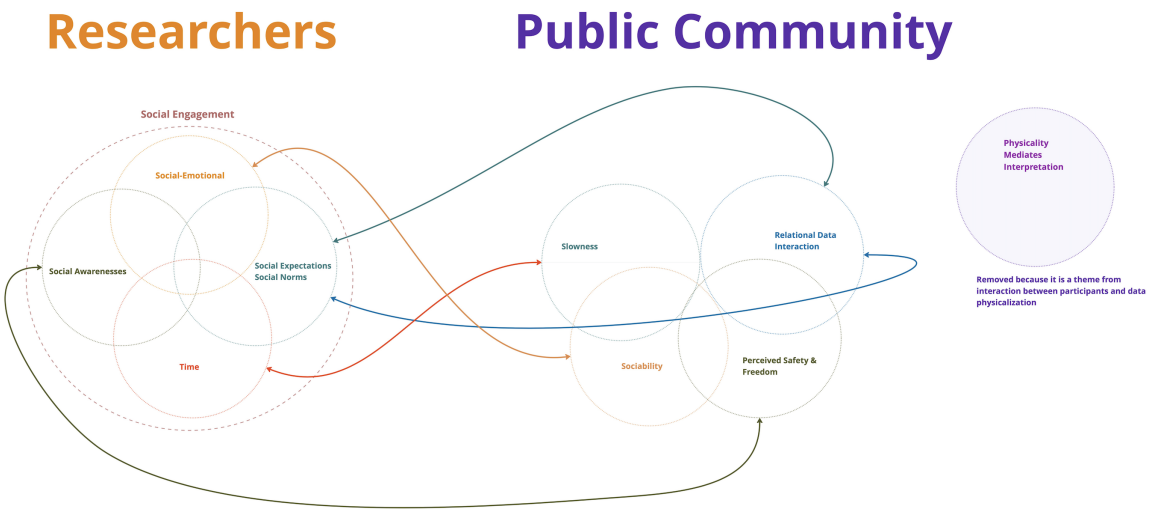

Figure B.4: I compared the social-relational themes I found in my work with community members in the public and themes I found in my collaborations. I removed the theme related to physicality or materiality from the public co-construction of data physicalization in Chapter 7 because its focus is more on design and does not share similarities with the themes found among researchers.

Appendix C

List of My Collaborations and Co-Authored Papers or Manuscripts Included in the Analysis

The following lists my co-authored papers or manuscripts divided by the selection of papers included in the dissertation and the ones that are only used for my reflexive analysis in Chapter 8 and only included in the Appendix.

C.1 Co-Authored Papers Included in the Dissertation and the Analysis in Chapter 8

C.1.1 Distributed Synchronous Visualization Design: Challenges and Strategies

Tatiana Losev, Sarah Storteboom, Sheelagh Carpendale, and Søren Knudsen. 2020. Distributed Synchronous Visualization Design: Challenges and Strategies. In 2020 IEEE Workshop on Evaluation and Beyond-Methodological Approaches to Visualization (BELIV), IEEE (online). https://arxiv.org/pdf/2009.02306

C.1.2 Embracing Disciplinary Diversity in Visualization

Tatiana Losev, Justin Raynor, Sheelagh Carpendale, and Melanie Tory. 2022. Embracing Disciplinary Diversity in Visualization. IEEE Computer Graphics and Applications. 42(6) (2022), 64–71, IEEE Computer Society Press https://files.osf.io/v1/resources/kdws9/providers/osfstorage/632e22376c2401101850964e?action=download&direct&version=1

C.1.3 Sketch Introductions: Shifting Introductory Formalities in Collaborative Design Practices

A manuscript I co-authored with Bhairavi Warke, Will Odom, Diane Gromala, and Sheelagh Carpendale and reprinted with their permission.

C.1.4 The Inbetweeny Collective: Reflexive Dialogues on the Liminality of Researchers' Lived Experiences

Denise T. Quesnel, Tatiana Losev, Ekaterina R. Stepanova, Sheelagh Carpendale, and Bernhard E. Riecke. 2024. The Inbetweeny Collective: Reflexive Dialogues on the Liminality of Researchers' Lived Experiences. In Proceedings of the Halfway to the Future Symposium (HttF '24). Association for Computing Machinery, New York, NY, USA, Article 6, 1–10. https://doi.org/10.1145/3686169.3686204 `https://dl.acm.org/doi/pdf/10.1145/3686169.3686204`

C.1.5 Wound Up in a Pandemic: Community-Data Interaction in the Making

A manuscript I co-authored with Foroozan Daneshzand, Diane Gromala, Bon Adriel Aseniero, and Sheelagh Carpendale. Revisions in progress for the Journal of Visualization and Interaction (JoVI).

C.2 Co-Authored Papers Included in the Analysis in Chapter 8

C.2.1 From Exploration to End of Life: Unpacking Sustainability in Physicalization Practices

Luiz Morais, Georgia Panagiotidou, Sarah Hayes, Tatiana Losev, Rebecca Noonan, and Uta Hinrichs. 2024. From Exploration to End of Life: Unpacking Sustainability in Physicalization Practices. In Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems (CHI '24). Association for Computing Machinery, New York, NY, USA, 12 pages. https://doi.org/10.1145/3613904.3642248[1] `https://arxiv.org/pdf/2402.09860`

C.2.2 Challenges and Opportunities in Data Visualization Education: A Call to Action

Benjamin Bach, Mandy Keck, Fateme Rajabiyazdi, Tatiana Losev, Isabel Meirelles, Jason Dykes, Robert S Laramee, Mashael AlKadi, Christina Stoiber, Samuel Huron, Charles Perin, Luiz Morais, Wolfgang Aigner, Doris Kosminsky, Magdalena Boucher, Søren Knudsen, Areti Manataki, Jan Aerts, Uta Hinrichs, Jonathan C. Roberts, Sheelagh Carpendale. 2023. Challenges and Opportunities in Data Visualization Education: A Call to Action. IEEE Transactions on Visualization and

[1] Awarded Best Paper at CHI Conference 2024

Computer Graphics 30(1). (presented at IEEE VIS 2023). IEEE Computer Society Press. Pre-print available for open access https://arxiv.org/pdf/2308.07703

C.2.3 Me-ifestos for Visualization Empowerment in Teaching (and Learning?)

Jan Aerts, Wolfgang Aigner, Benjamin Bach, Fearn Bishop, Magdalena Boucher, Peter C-H Cheng, Alexandra Diehl, Jason Dykes, Sarah Hayes, Uta Hinrichs, Samuel Huron, Christoph Kinkeldey, Andy Kirk, Søren Knudsen, Doris Kosminsky, Tatiana Losev, Areti Manataki, Andrew Manches, Isabel Meirelles, Luiz Morais, Till Nagel, Rebecca Noonan, Georgia Panagiotidou, Laura Pelchmann, Fateme Rajabiyazdi, Christina Stoiber, Tatiana von Landesberger, Jagoda Walny, Wesley Willett. Me-ifestos for Visualization Empowerment in Teaching (and Learning?).) 2022. In workshop, alt.VIS workshop, IEEE, Oklahoma City, U.S https://sorenknudsen.com/assets/publications/aerts2022me-ifestos.pdf

C.2.4 COVID Gowns: Breaking Scales with an Unknown End

Sarah Storteboom, Tatiana Losev, Neil Chulpongsatorn, Jackie Yu, Sheelagh Carpendale, and Søren Knudsen. 2020. COVID Gowns: Breaking Scales with an Unknown End. In Poster Presentations. IEEE Transactions on Visualization and Computer Graphics, Oklahoma City, U.S. 2 pages. https://sorenknudsen.com/assets/publications/storteboom2020covid.pdf

Visualizations for Communication during the COVID-19 Pandemic

A manuscript I co-authored with Nicolas Medoc, Klaus Mueller, Nicolas Reinoso Schiller, Max Sondag, Yong Wang, Michael Wybrow, Hajo Zeeb. Dagstuhl Seminar 24091 “Reflections on Pandemic Visualization” (Feb 25 – Mar 01, 2024) https://www.dagstuhl.de/24091