Troubling Collaboration: Matters of Care for Visualization Design Study

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ABSTRACT

A common research process in visualization is for visualization researchers to collaborate with domain experts to solve particular applied data problems. While there is existing guidance and expertise around how to structure collaborations to strengthen research contributions, there is comparatively little guidance on how to navigate the implications of, and power produced through the socio-technical entanglements of collaborations. In this paper, we qualitatively analyze reflective interviews of past participants of collaborations from multiple perspectives: visualization graduate students, visualization professors, and domain collaborators. We juxtapose the perspectives of these individuals, revealing tensions about the tools that are built and the relationships that are formed — a complex web of competing motivations. Through the lens of *matters of care*, we interpret this web, concluding with considerations that both trouble and necessitate reformation of current patterns around collaborative work in visualization design studies to promote more equitable, useful, and care-ful outcomes.

CCS CONCEPTS

• **Human-centered computing** → *Empirical studies in visualization.*

KEYWORDS

design study, collaboration, interview study, matters of care, maintenance, diffraction

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1 INTRODUCTION

Collaborative visualization research — where visualization researchers work closely with domain experts — is an established approach for designing tools for people in the world. The standard method of inquiry for conducting collaborative visualization research is *design study* [56], which relies on deep, extended collaborations that incorporate the ideas, input, and feedback from domain experts throughout the process of designing and deploying visualization tools. Much work has been devoted to to furthering this line of inquiry theoretically through papers focused on different process models [39, 40, 62, 71], validation considerations [45, 55], researcher roles [10, 20], and standards for rigor [41].

Yet, relatively little work has directly tackled the ethics of design study, or more generally, that of visualization collaborations. Data feminism [11] and other critical visualization work focus on the ethics of data and the non-neutral, subjective nature of visualizations [8, 12, 61], examining the ways in which power, politics, history, and social systems are embedded within, and reinforced by, data and visualizations. These studies do not, however, consider the webs of power and responsibility within visualization research collaborations and processes. In this paper, we extend these critiques by questioning what impact collaborative visualization research, or more precisely, design study, has on visualization researchers and those with whom they collaborate.

We examine what Meyer & Dykes call *"the ethics of exit"* [41]: a concern about whether design study is conducted in an ethical manner by considering the lasting effects of collaborative visualization research on domain experts and the technology produced. In this work, we attend to *matters of care* [51] in order to reflect on values regarding what we care about, and how we care, in collaborations. A focus on matters of care asks us to pay close attention to the roles of individuals and how they relate over the course of collaborative visualization research; what and who are neglected as a result of unequally distributed attention; and who, ultimately, is in a position to care.

To examine the relationships and dynamics of care in collaborative visualization research, we conducted 20 interviews with people from multiple sides of the collaboration: visualization researchers — both students and supervisors — and the domain experts with whom they collaborated. Through our analysis of these interviews, we report on the complexities of design study, including concerns about and responsibilities for maintenance, and the entanglement of

personal, collective, and organizational priorities. The stories from the interviews trouble our preconceived notions of collaboration, revealing that design study *itself* exists in a complex web of interconnected relations: where care is situational and highly dependent on personal initiative, individuals are often juggling conflicting responsibilities shaped by power asymmetries, and frameworks for conducting design study result in structural neglect of essential components of collaborative work such as long-term care, maintenance, and mutual thriving.

The primary contribution of this work is a troubling of the types of care currently performed and valued in design study, offering a new perspective from which we can more care-fully consider how we work with others. Towards this perspective, we present the results of interviews that: bring forward the challenges around the long-term maintenance of tools, a phase of design and development that is otherwise neglected in models of visualization collaboration; and describe the power asymmetries between people within the collaboration that emerge from the inherent structure of visualization design studies. We contribute a set of considerations and provocations to encourage visualization researchers to pay attention to their positionality — in relation to others, to technology, and as reflections of authority and access to resources — in order to more care-fully conduct future collaborations. As a secondary contribution, we add our work to the nascent collection of HCI studies using diffractive reading [4, 32] for conducting qualitative analysis, where embracing differences that matter produces lively debate and analysis when working with qualitative data.

2 RELATED WORK

In this section, we present related work about collaborative visualization approaches, care in HCI, and matters of care as a theoretical and ethical perspective in research.

2.1 Collaborative Visualization Research

Visualization is an applied field, concerned with the impact its research has on the wider world: applying visualizations to real-world use cases is thus both common and encouraged [69]. A common way of characterizing the impact of visualization is through the degree to which it helps analysts discover insights about their data [19, 26, 54]. There are also consequentialist models for determining the value of visualization, which consider the impact the visualization has on users [15, 60, 66]. In both cases, this impact is often realized through tools designed *in collaboration* between people with expertise in visualization design and people with expertise in an applied domain.

While there are many approaches to conducting collaborative visualization research, in this work, we focus on those approaches that require building deep, extended relationships with *domain experts* — experts in the domain the visualization tool is targeting. More specifically, we focus on *visualization design study*, a commonly used methodology for collaborating with domain experts. Design study is *"a project in which visualization researchers analyze a specific real-world problem faced by domain experts, design a visualization system that supports solving this problem, validate the design, and reflect about lessons learned in order to refine visualization design guidelines"* [56]. With this definition, we consider design study and collaborative visualization research with domain experts to be similar concepts, with the key difference that design study is a formalized method of inquiry within the visualization research community. Thus, we refer to design study throughout this paper in order to situate socio-technical considerations of collaboration within existing theoretical models. Such theoretical considerations for design study include process models [39, 40, 56, 62], validation methods [42, 45], considerations for rigor [41], and guidance for contribution types [55].

Over the years, researchers have proposed numerous extensions to the original framing of design study. In critiquing the assumption of a dichotomy between visualization researchers and domain experts, Hall et al. instead offer *design by immersion* as an alternative approach to collaborations [20]. Here, the authors suggest a blurring of boundaries *"where the lines between visualization researchers and domain experts [...] move beyond working in a single domain."* McCurdy et al. explore *action design research* as a visualization methodology to explicitly consider how context and people shape collaborative research [39]. Crisan et al. contribute a *power interest matrix* to help researchers navigate organizational and regulatory constraints in design study [10]. Syeda et al. shorten the process of design study, using a *design study "lite" methodology* as a pedagogical tool for students as part of a service-learning visualization course [62]. Meyer & Dykes propose an alternative, non-positivist characterization of design study while raising concerns about the lack of ethical standards for the approach [41]. The work in this paper directly tackles these concerns.

2.2 Critical Visualization

Critical infovis [12] is a broad perspective that applies a lens from critical theory to question hidden assumptions and structures of power in visualization research. Active projects in critical feminist visualization scholarship are shining a light on hidden and unappreciated forms of labor in visualization design and scholarship [8, 11, 30, 65], challenging the assumption of inherent neutrality or objectivity in visualization design [8, 12, 27], and exploring the often fraught relationship between visualization and public audiences [5, 14, 33, 50]. Additionally, Lundgard et al. explore how traditional forms of intervention in visualization research can lead to unintended and unjust outcomes without proper care for the socio-technical milieu of the work [36].

Numerous studies have also critiqued knowledge contributions resulting from collaborative visualization research. Some critiques question whether research from a specific collaboration can be easily generalized or applied [69, 72], whereas others make a case for interpretivist perspectives that value specific, situated knowledge [41]. Correll points out that current rewards for collaborative research overemphasize novelty and user satisfaction, and instead calls for more concerted efforts to build visualization epistemologies [9]. In this work, we extend critical visualization perspectives to engage with collaborative design processes.

2.3 Care and Caring in HCI

Puig de la Bellacasa [1], seeking to *"encourage an ethos of care"*, introduces the study of *matters of care* [51] to highlight neglect and power in socio-technical relations while also providing a set of considerations for engaging with ethical and political issues. Matters of care are entangled with knowledge production, moving beyond *"responsible maintenance"* and toward a concern with exclusions, power dynamics, and relationships, recognizing that *"scientific and technological assemblages are not just objects but knots of social and political interests"* [51]. Matters of care urges researchers *"to ask 'For whom?', but also 'Who cares?' 'What for?' 'Why do we care?', and mostly, 'How to care?' "* [51]. Scholars have interpreted care not only as a critical framework, but also as *"a relational feminist ethic"* [38]. As a critique, a lens of care goes beyond paternalistic and reductionist ways of knowing [38, 46] by highlighting *who* has the power to care, *what* receives attention, *what or who* is ignored, and the effects that answers to these questions have on *how* we make sense and shape the world. Attending to matters of care, therefore, requires that we declare what we care for, engage in critique, and build relationships such that we can *"maintain and repair a world so that humans and non-humans can live in it as well as possible in a complex life-sustaining web"* [51].

The operationalization of care in HCI has been varied: as a reflective lens to understand the reciprocity of researcher-participant relationships [24, 53, 63]; as a design consideration that goes beyond techno-solutionism to engage with the politics of things [6, 29, 31]; as a complementary extension of participatory design practices, supporting design that fosters relationships and collectively enacts change [1, 35]; or as an explicit ethics of care that breaks from standard ethical perspectives via an emphasis on interpersonal dynamics rather than prescribed, universal recommendations [47].

The work in this paper is in conversation with other HCI research that focuses on care as a critical, ethical, or analytical framework [1, 2, 24, 29, 35, 53, 58, 63, 64]. Through a focus on matters of care, we consider the implications of, and power produced through, the socio-technical entanglements of visualization collaborations in order to guide practical considerations "*of how to treat others, and what becomes of others and oneself in addressing intermediate problems*" [47 referencing [70]]. We understand and interpret matters of care as an acute attention to:

- entangled and situated relationships [3, 21] present in visualization collaborations;
- neglected things as a source of necessary investigation and re-imagination;
- and the power relations that shape the nature of these relationships before, during, and after collaborating.

From this perspective, we understand research processes and artifacts as representations of relations and sites for enacting care. Specifically, we apply this lens to our personal experiences and those of the participants we interviewed, looking for opportunities that we, as "*knowledge producers might involve a modest attempt to share the burden of stratified worlds, filled with possibilities to re-imagine more just and equitable futures*" [51].

[1]Care and care ethics have a long and rich history touching a variety of disciplines, and a thorough review of that history is beyond the scope of this paper. We position our work within the considerations of care ethics found in STS and HCI, but note that the concept is credited as originating from Carol Gilligan's *"In a Different Voice"* [17, 18].

3 METHODS

The initial ideas for this study began as conversations between two of the senior authors about their discomfort when their collaborations with domain experts just *ended*. These endings felt more like abrupt exits, where the state of the tool and the impact on the collaborators were ambiguous. Heeding calls from other researchers to consider ethics when conducting visualization work [8, 11, 12], we wanted to explore how we might *ethically exit* design studies.

As we developed the study design, the two student authors added their own experiences conducting design studies. They surfaced feelings of guilt in abruptly leaving collaborations, and linked these feelings to personal relationships with collaborators and the ownership they felt over the tools they built, both of which were, at times, in tension with the demands of being a graduate student.

Our attention to maintenance came from the third senior author of this paper. He directed us toward a heated Twitter discussion [73] that was a response to a paper about sustainable projects that endure beyond *the exit*. This discussion was a critique of the paper's main author's underestimation of the invisible labor and infrastructure supporting research projects [13].

This discourse about the challenges of maintenance, combined with our personal experiences conducting design studies, shaped our interviews to center questions regarding maintenance and power structures within academic collaborations. This framing also guided our participant recruitment, highlighting the importance of conducting interviews across three separate roles: visualization graduate students, visualization PIs, and domain experts. We attempted to recruit triads of participants in these roles who worked together in collaborative visualization projects. We also oriented our interview questions around the end of projects to emphasize the work done at this phase of the collaborative process.

As part of our formative work, we also looked at different ethical lenses to guide our analysis. Matters of care was frequently cited in related readings about maintenance by centering the invisible, undervalued, yet necessary labor. Our discussions about care also led us to add interview questions about affect, focusing on interpersonal dynamics within collaborations. We spent three months deliberating over the interview questions to capture topics of interest to ensure we respected the time commitments and expertise of our intended participant pool.

In the rest of this section, we discuss our participants in more detail, as well as our process for conducting and analyzing the interviews, and considerations for anonymization.

3.1 Recruiting Participants

In order to find visualization researchers who conduct collaborative work, we sourced an initial participant list from research papers that explicitly cited design study as their method of inquiry. We scoped our literature review to include only peer-reviewed archival papers published in English. Using Google Scholar, we pulled 576 papers that cited the design study methodology [56] and were published between Dec. 31, 2018 – Apr. 30, 2021. We removed papers that did not meet our criteria, resulting in a total of 137 papers. We used

information provided in the paper to find the contact information of the first visualization author, a senior visualization author, and a domain collaborator. Although most papers were unambiguous about these roles, others were not as clear and we had to ask for clarification.

Using the list generated from the literature review, we emailed 156 visualization researchers and 79 domain experts asking them to complete a survey, with the main goal of recruiting individuals for interviews. The survey — which can be found in the supplementary materials [2] — consisted of 17 multiple-choice questions that we estimated would take no longer than 10 minutes to complete. We allowed participants to choose either a 10 USD spending card as compensation [3], or a donation in that amount [4]; 92% of participants chose to donate. Of the people we emailed, 40 visualization researchers and 19 domain experts took the survey, some more than once, resulting in 64 completed surveys.

Of the survey participants, only five agreed to be interviewed, and we thus turned to convenience sampling to recruit more researchers. We collectively brainstormed research groups that we knew engaged in collaboration-oriented research. These groups were often close colleagues and were not in the original sample because although they engage in academic collaborations, they did not cite design study methodology in their papers; this convenience sampling resulted in 17 additional recruited interviewees.

3.2 Interviews

The first and second authors conducted paired interviews. While one interviewer would drive the interview — responsible for asking questions and moving the interview forward — the other was responsible for observing — asking follow-up questions and keeping the interview on track when too much time was spent on a single topic. Specifically, we drew inspiration from the *tinkering* method proposed by Monforte & Úbeda-Colomer [43]. Tinkering as an interview method requires interviewers to reflect on their experiences *during* the interview process and to use their reflections to iteratively modify the interview questions and structure to better suit their research goals and flexibly react to emerging themes. We piloted the initial set of questions and interview method with two alumni of our lab and one former domain collaborator. Our interviews lasted one hour and each participant was compensated 20 USD, again with the choice of an e-card or the option to donate all or part of their compensation; 95% of participants chose to donate. All interviews were conducted in English.

The interview followed a semi-structured format, guided by four broad topics: collaboration logistics; the ending of the project; decision-making approaches; and feelings about the collaboration. These topics allowed us to probe into how maintenance, care, and power dynamics were distributed and experienced by different individuals holding different roles in the collaboration. More details about the interview questions can be found in supplemental materials.

After each interview, the two interviewers discussed the interview as well as the interview process. This discussion centered around noteworthy parts of the interview: what went well, what was interesting, and what was awkward. The discussion helped reveal some common themes across interviews and informed revisions to the questions for future interviews. Then the first author added the audio file of the interview to Otter.ai, a web platform for generating transcripts. She reviewed each automatically generated transcript and corrected mistakes in the transcription as well as anonymized the text. These anonymized transcripts were then shared with the interview participants to review and provide clarifications, if necessary. Only three participants added notes and suggestions to their transcript.

We conducted 22 interviews during the time period of Jan. 2022 – May 2022. We removed two interviews from our analysis due to poor audio quality and transcriptions, as well as issues with communication, resulting in a total of 20 final interviews. When reporting quotes from the interviews in this paper, we *tidy-ed* them up to facilitate reading by correcting grammar and cutting out extraneous filler words (like, yeah, etc.), particularly for interviews with non-native English speakers. We include the quotes in their original, un-tidy-ed format in supplemental materials.

3.3 Participants

We recruited visualization researchers and their collaborators with the goal of interviewing sets of researchers who worked together on a project. From the 20 interviews we were able to use, across 8 visualization faculty members, 6 visualization graduate students, and 6 domain experts, we had: 4 *triads* (PI, student, and domain expert); 2 *dyads* (student and domain expert); and 4 independent PIs.

The participants worked in diverse collaboration arrangements, illustrated further in the supplemental material. We spoke to researchers in North America and Europe. The visualization students ranged from those just starting their PhDs to those who had recently graduated. Domain experts were also at different career levels, including graduate students, post-docs, research scientists, and PIs of labs. The visualization PIs ranged from relatively new, assistant professors to experienced full professors. The collaborations lasted as short as six months to whole PhD careers, and spanned a wide range of domains from the natural sciences to the humanities. The access to resources also greatly varied: some students worked highly independently, whereas others had access to supportive infrastructure. The visualization teams were all in academia, while their collaborators worked across academia, companies with research labs, and non-profit organizations.

3.4 Anonymization

Given that we wanted to elicit unfiltered opinions and details about collaborations — the good and the difficult — *and* that the visualization community is relatively small, as a team we discussed at length the importance of establishing trust and communicating respect with our participants as core to our method. As such, the two student-interviewers told participants that only anonymized transcripts would be shared with the rest of the research team. Several students expressed gratitude for this anonymization in the interviews, conveying relief through statements like: *"This is going to be anonymous, right?"* In contrast, senior researchers were

[2] https://osf.io/cvrbs/
[3] https://www.tangocard.com/
[4] https://thrivelifeline.org/

more comfortable with their statements. One senior visualization researcher even began the interview saying, *"You do not need to anonymize me, because I don't think it's a good use of your time."* To anonymize within triads and dyads, we did not tell members of the same project if we were interviewing their colleagues, and we were careful to not reveal any information we learned in other interviews.

We have taken steps to continue to protect the anonymity of participants in this paper by removing identifiable information, with a primary concern being that collaborators would be able to identify each other. We use the shorthand **PI-#** to indicate visualization researchers who served as PIs in the collaboration, **GS-#** to indicate the visualization graduate student in the collaboration, and **DE-#** to indicate the domain expert. The numbers indicate unique collaborations, e.g. each triad will get a unique number. We do not provide the domain to ensure anonymity. Additionally, in the supplemental materials, we use an alternate ID schema to avoid chances of identification.

3.5 Diffractive Analysis

When deciding on an analysis strategy, we initially considered open-coding — a well-used method in visualization research — but decided against it for two reasons. First, open-coding in visualization research is often approached from a grounded-theory perspective that views codes as inherent categorizations of the data, resulting in a prioritization of intercoder reliability and a focus on frequencies of codes. In contrast, matters of care, and recent views on design study [41], rely on perspectives that embrace the situated roles of the researchers and their interpretations in the analysis process. Second, we found that our discussions as a research team were enriched by the variety of experiences and perspectives that we each brought, hinting at the productive potential of looking for and embracing *differences*, rather than similarities.

Ultimately, we used a form of *diffractive reading* [3, 4], an approach to analysis that has origins in feminist and interpretivist perspectives and has recently appeared in HCI [32]. Diffractive reading asks the researcher to pay attention to interesting differences in the data, as opposed to prioritizing similarities and patterns. In our diffractive analysis of the transcripts, we focused on what we each found interesting, which then centered our group discussions on differences we noticed across the interviews and each others' interpretations.

More specifically, our analysis — which was conducted by three of the authors — progressed in eight rounds: each round of analysis consisted of a close reading of transcripts, followed by a group discussion. We analyzed the transcripts in sets, first analyzing each triad, then dyad, and finally the remaining independent PIs. Each transcript required ~1 hour to read independently, followed by 2–3 hours of discussion for each set. The first author — who was involved with this analysis — took notes during these discussions and used a digital whiteboard to collect the emerging ideas and themes. We each brought our varying perspectives to the interview analysis: two senior researchers who have conducted, supervised, and critiqued design studies and a graduate student who has led several design studies. In these analysis sessions, our discussions benefited from our diversity of positionalities as we tried to relate and compare personal experiences with the source material.

After the transcript analysis, all the authors met and attempted to generate themes from summaries of the transcript discussions. However, we found that the resulting themes were dull because the summaries lacked the rich nuance and complexity of experiences that made the transcript discussions so interesting. To address this problem, the first author created summary cards — similar to the vignettes found in the supplemental material — in an attempt to re-saturate the analysis with important stories from the interviews. The resulting conversations were once again interesting, spurring the authors to share personal experiences and discuss how collaborations were different in interesting and unexpected ways. To report on these conversations, the first and last authors worked together to draft several narratives of the results (Sections 4 and 5), cutting and assembling prior discussions into important topics, and receiving feedback from the rest of the team. The writing process underwent three redrafts, with the last draft occurring after receiving feedback from the review process.

4 NEGLECTED THINGS: MAINTENANCE OF TOOLS

Two questions are inseparable when attending to matters of care: who/what receives care, and what are the *neglected things* that do not. These questions invite us to consider *"what this thing could become"* if it were to become something we cared about [51]. With this lens, we focused a large part of our interviews on maintenance. We saw maintenance of the visualization tool as the neglected thing — literally missing from established visualization process models [39, 40, 56]. These process models provide structures for how to collaboratively design, develop, and deploy a visualization tool, as well as emphasize the importance of reflection and formalization of design knowledge. This is, however, where they end.

But what happens to the tool at the end of the collaboration? What happens to the collaborators who come to use the tool as part of their workflow? While maintenance is missing from process models, it is not absent in *practice*: we found, instead, stories of care and attention, shaped by the specifics of the collaboration. We also heard about many positive outcomes of collaborations beyond the tool, like teaching collaborators more about visualization research, that provide models for success that do not rely on long-term maintenance efforts. We detail these results, presenting the complexity and difficulty of maintenance, and discuss possible ways through the entangled priorities it presents in Sect. 6.1.2.

4.1 Students and Maintenance

Given that most of the technical artifacts in academic settings are developed by graduate students, we asked students about their responsibilities to, and feelings about maintenance regarding tools they developed for their collaborators. Two of the graduate students expressed a firm commitment to maintaining the tools they built. These students, GS-12 and GS-8, framed their commitment to maintenance as a result of the personal relationships they established over the duration of the collaboration, but also pointed out the cost in doing so.

In GS-12's case, he was working with humanities scholars who did not have access to an engineering support team. So even though the project was complete and he had graduated at the time of our interview, he was still receiving emails about bugs and feature requests, and explained that he would continue making these changes for his collaborators, calling them his friends:

> GS-12: *I mean, after three years you work together with like three other people, you become friends. Right? So if they ask for help, you cannot say: "No, the project is done." You cannot do this, right? Because the personal relationship is something important in everything you do.*

DE-12 was an active user of GS-12's tools at the time of the interviews, commenting that the tools were vital to her research and were *"the best way to navigate my data"*. But, DE-12 also recognized the cost of maintaining the tools longer term:

> DE-12: *Yeah, there are some bugs . . . I'm making a list each time that I see [bugs]. I'm doing this, and I hope that maybe in the future, we could do another version update to it. Even if it's like, I already know that for everybody [maintenance] will be a nightmare . . . But at least I have this list.*

The importance of personal relationships was also emphasized by GS-8 who said: *"this is a relationship I would like to maintain"* in reference to her collaborators, who are also working in humanities fields. Her visualization work included building data management infrastructure for her collaborators, which they acknowledged as a critical piece of maintenance in their continued use of the technology:

> DE-8: *We need to update [the database] every year. Every time we go into the field, we need to give her new data [to] add to it.*

DE-8 noted that he was *"100% convinced that I will be using [the tool] in the next year, two years, five years."*, anticipating long-term use. Faced with this, GS-8 stated that the continuing maintenance will not only *"interfere with my other responsibilities"*, but also was invisible to her graduate supervisor. She described the invisibility as stemming from her deep engagement with her collaborators and her position within the team as the visualization expert:

> GS-8: *But in the end, I became the expert of the [collaboration] . . . I became the expert in [the visualization tools] in that project and in that collaboration, not [my] supervisor. So he wouldn't even know about the database.*

Despite the unrecognized labor, GS-8 chose to continue helping her collaborators with technical infrastructure because she saw her responsibility as a researcher, person, and collaborator extending beyond the confines of a strictly defined project.

Other graduate students who were working with domain experts in more computational fields described their maintenance strategy as posting code on GitHub. They described open-source code as a viable, long-term solution when resources for maintenance were limited and motivation lacking. For example, GS-11 contemplated the lack of incentive for maintaining an old project:

> GS-11: *[Our] code was, you know, open-source. It's posted on our lab's GitHub . . . [People] can use this, you know, if [they] want it . . . I would love to, like, keep it up, but there's not much of an incentive to keep it up.*

Mirroring a similar sentiment, GS-2 described maintenance as a cost-benefit analysis:

> GS-2: *I mean, I guess I would handle [maintenance requests] like other issues that may be posted on GitHub. So I would, like, consider [the posted issues] and consider the effort and gain. And apart from that, it's open source. So if [someone] wants to change something, they are free to do it.*

Discussions with graduate students illuminated other reasons why maintenance was difficult to prioritize. GS-11 talked about maintenance cutting into personal time after his project was completed:

> GS-11: *I hate saying this, but like, you know, that sense of structure isn't there for me to go work on that code when I could be doing family things, you know?*

GS-3 went further, lamenting the cost of maintenance in the face of technology that goes unused and breaks:

> GS-3: *If you build a tool to solve a specific problem, but it doesn't get used or breaks down, what are we really doing? What [is the point of] the tools that we're building for people? But um, yeah, I don't know. It's tough. I don't really know. Because I think it's also a ton of work. Right? For whoever is going to take [maintenance] on.*

Among the graduate students we interviewed there was no clear path to maintaining the tools they built, perhaps in part because it is a neglected activity in visualization design guidance. Based on our own experiences running design studies, we entered these interviews expecting to hear that maintenance was neglected, and shrouded with guilt, as we have felt in many of our past projects. Some students echoed this sentiment, expressing their desire to upkeep tools, but lacking the resources to do so. Others, however, surprised us, sharing stories where they went beyond project requirements, citing personal relationships with their collaborators as the driving factor. Across interviews, however, we never saw a lack of care. Rather, we more deeply came to understand how the burden and responsibility of maintenance *could be* shared when adequate resources are available, which we describe in more detail next.

4.2 Resources and Maintenance

In two of our participants' projects, a third-party software engineering team took the graduate students' research prototypes and re-engineered them to create and maintain production-ready code. In one of these projects, PI-2 had spent years establishing long-term relationships with his collaborators, stating that he found that long-term collaborations resulted in more productive research. He supported these collaborations by creating a startup to take research prototypes and refactor them as industry-ready tools:

> PI-2: *If you just provide [a] prototype as an output, plus a paper, and you're not able to maintain that, to support*

> *that, to extend that, then the collaboration is dead afterwards . . . And there, you need to also be somehow able to support this other phase that comes after publishing your paper. And that's also what motivated us to start the spin-off company because there we have this ability to support [long-term use] and to ensure that [the tool is] working.*

His student, GS-2, in describing her process of transferring her research code to the startup, mentioned the critical role that a former lab mate plays:

> GS-2: *And so there's one guy who was previously working at our lab, who was also involved with developing the tool [in the beginning] . . . And he now works [at the startup] to develop [the tool] further. So in that sense, there is this person who worked on both sides more or less . . . And [my] code is public on GitHub. And basically, I guess they [took my code] from GitHub and changed what they needed to.*

In the other collaboration with external engineering support, the maintenance infrastructure came from the software development team of a non-profit research lab that the domain expert works closely with. The domain expert described the interaction between the graduate student and the software development team:

> DE-3: *[The lab], they're building the, I think they're building the actual software platform in-house. But so [GS-3]'s working in depth with the programmers there to to make it work.*

This collaboration is unique in that GS-3 was the only graduate student we interviewed who stated that he initiated the collaboration out of personal interest in the domain. In describing how he worked with the software development team, GS-3 discussed the messiness of handing-off technology and how he had taken on the responsibility to communicate his code base:

> GS-3: *So I think one thing that I've tried to ensure in the long run is that I'm working in the same development environment that the internal IT team uses, that I understand what coding practices they use, and to kind of help them have some influence on the architecture of the tools that I built. [I'm working to understand what] their practices are basically. So there's a good hand-off with the technical team. And then beyond that, documenting, creating documentation for the tools, both for the [collaborators] and others around the [the collaboration team].*

The access to engineering resources exhibited in these two collaborations was unique in the interviews we conducted. In contrast, a number of PIs from other projects lamented about their lack of resources in relation to maintenance. PI-4 brought up the general scarcity of engineering resources in academia, saying *"we're never going to compete with Google"*, while PI-11 more broadly described the complex web of different priorities that maintenance is situated within:

> PI-11: *You know, there are things like students graduate and go on and don't continue doing things or funding runs out . . . Or the funding ran out long ago and all of the server infrastructure that you had for providing the data is now not compliant with whatever the current security stuff is. Therefore, who's going to take the effort to modernize that, given that we have no resources to do it, and it's not fun?*

Additionally, we heard many PIs express skepticism that the tools they build will endure. PI-9 described the ephemeral nature of technology and technological use when asked to consider the role of maintenance in collaborations:

> PI-9: *[Maintenance] requires that you are using a tool prominently in the long run . . . we're really coming to this question: How good can our software be? I don't know what happens if [GS-9 graduates and] goes somewhere else. Then systems are changing, hardware is changing . . . Also, your collaboration partner must be interested in the same question for a long, long time . . . And then a new question pops up. And probably the tool is not interesting anymore. Therefore, in general, yes [maintenance is important], but it doesn't apply to all applications.*

For similar reasons, PI-6 explicitly mentioned how she *"agonizes"* over all the different socio-technical reasons why research prototypes would not be used in the long run:

> PI-6: *I have thought about, you know, studies where you go back five years later, and you talk to all these people, and you're like, are you still using your system? And I bet the answer will be no, and if not, why not? And you know, is it going to be that the software bit rotted or the data pipeline died, or actually turns out, it wasn't useful, or, I don't even know if it was useful, because blah blah left the company, or actually have all [collaborators] left the company and none of us are there anymore. So like, there's all these reasons why people don't use your research prototypes in the long run. And I sort of agonize about that as a researcher.*

The fraught nature of the inevitable demise of tools was also felt by some of the graduate students. For example, GS-3 brought up the different ways in which software infrastructures contribute to the junkyard of broken tools:

> GS-3: *I imagine this world, you know, vis prototypes that are basically like broken down, pod racers, as web standards evolve, most of their stuff is just like, yeah, this junkyard, really cool tools that are basically unsupported and broken now.*

Even in collaborations where the research is conducted in environments conducive to maintenance, our interviewees highlight that there are other factors that may leave a tool defunct and unused. These points echo our own experiences in building now-broken-down *junkyards* of tools, and challenge our normative assumptions of what the goal of design study should or could be, even leaving it unclear why we collaborate in the first place. If many tools are neither used nor useful, we wonder if there are values above and beyond the use of the tool *per se* that we could more explicitly articulate.

4.3 Beyond the Tool

There were many instances of participants discussing the benefits of collaborating that extended beyond the visualization tool. We heard reports of productive *data counseling* [16]: collaborators learning something new about their data as a by-product of working with the visualization researchers, such as this comment from DE-8:

> DE-8: *And it was also good to reflect on the data. Because when you're explaining your data, you're also reflecting on it. [And thinking about] what kind of data do I really have, which is also something you don't always think about … That was also helpful.*

DE-3 also mentioned that the process of explaining one's data provided a nice opportunity to reflect:

> DE-3: *I think [the team has] appreciated [GS-3]'s research in their process because it has allowed them to articulate how they're actually doing [their research] and to think about how they use data and what they're paying attention to …And so actually talking about this explicitly has been kind of a nice opportunity for them to reflect.*

We also heard from both a graduate student and his collaborator that working together changed how they each thought about problems in their own domains. In this collaboration, DE-12 was a humanities scholar who was bringing data into her research over the course of the project. When asked to speculate what might happen if the visualization tool went away, she talked about how the experience of collaborating was in some ways even more valuable than the visualization tool itself:

> DE-12: *This, this has changed my perception of the research and my eye to the [objects of study] forever. I can now choose to look at the [objects of study] in a more traditional way or in this [data-oriented] other way. And [the visualization tool] doesn't matter because of course I had this experience with [the visualization researchers].*

In other interviews, we heard of other benefits to collaboration. In some instances, the collaboration was seen as a way to inform other domains about visualization research beyond surface-level assumptions. For example, DE-8 admitted that at the start of the collaboration he was skeptical that complex, nonstandard visualizations would be well-suited for his data — admitting that he *"knew very little [about] data visualization"* — until he saw his data in a tool that GS-8 built:

> DE-8: *I also didn't know what to expect, because, you know [GS-8] showed me some cool graphs, but I was thinking, that's not for my type of data, maybe. But suddenly, she made it really interactive, and like, really a tool that you can use. And so yeah, it was beyond my expectations to be honest.*

In another interview, PI-4 spoke about the importance of valuing collaborators' time by providing help and support outside of the visualization research scope, which sometimes looked like *"[the collaborators] get[ting] to walk in with the prettiest poster, or [that] they get to go to their funding agency with something that's a little bit more compelling"*.

Across our interviews, maintenance was not always a neglected thing; rather, it was a reflection of the structures that shaped the collaborations: wrapped up in access to resources, and highly situated in the personal and organizational needs of individuals. Comparing our own experiences with the stories we heard, our ideas about deploying tools became troubled, and we began to wonder how we could promise a tool when so many other factors outside our control impact its long-term use and usefulness. Engaging with matters of care, it became less obvious to us that maintenance was the *only* way we, as visualization researchers, could demonstrate care to our collaborators when projects ended. We speculate about what other care-ful considerations there might be in Section 6.

But first, in the next section, we move onto stories about relationships and the power asymmetries that arise in visualization collaborations.

5 POWER: ASYMMETRIES IN COLLABORATIONS

> PI-6: *[Our collaborators] spend [their] time talking to us. And what [they] get at the end is a tool.*

This sentiment expressed by PI-6 is a common assumption about design studies: in exchange for time, data, and domain problems, domain experts get a custom visualization tool that will help them gain new insights. But visualization collaborations can be long, requiring domain experts to be giving, patient, and trusting that promises will be kept. Furthermore, in design studies conducted in academic settings, the work of designing and building a tool is typically done by a visualization graduate student, who is usually funded and supervised by a visualization PI. Design study collaborations are built upon these power asymmetries.

Across our interviews, individuals spoke about their relationships with others, as well as about their goals in collaborating, which were often things other than just new visualization tools. Like concerns of maintenance, we saw a complex and entangled picture emerge of all the competing considerations in collaborations. Through an interpretative lens that centers care, we report on varying objects of care within the collaboration itself, and the ways in which care is a *"selective mode of attention"*, focused on some objects, while excluding others [38].

5.1 Visualization Team's Objects of Care

From the perspective of the visualization team, the normative expectation for design study is twofold: to create something impactful — a tool that will support insights by domain experts — and to also publish a paper, contributing new knowledge to the visualization community. But these two goals can be in tension when the needs of domain experts do not obviously require visualization novelty. Across interviews with graduate students, we saw a common attitude of putting the needs of domain experts first:

> GS-8: *If something is useful [for domain experts], at the end, you will find the research project or research theme to write about …So from my point of view, I was not looking for novel visualization designs, I was looking for things that actually worked for [my collaborators].*

GS-3 similarly notes his overriding desire to support his collaborators:

> GS-3: *So for a while, there was attention to, I wanted to make something shiny and cool and complex and complicated and blah, blah. But you know, I think that's completely outweighed by the fact that I want to make something useful for people. As a researcher, I think that's an interesting path. That leads to a lot of interesting questions and what role visualization plays in a broader ecosystem of analytic tools, rather than just being constricted to a very narrow definition of what visualizations could be.*

PIs also prioritized their collaborators, many of whom they had worked with for years. PI-4 described how she cared that her collaborators felt that their time in the project was worthwhile, while also being respectful of resources:

> PI-4: *So I want to make sure that the time [domain experts] spent with us, was time that was worth it to them as well. And so maybe they also just have fun with us. That's good, assuming that we're all working and getting towards something that is using the resources that we've been granted well.*

But sometimes the tension between visualization research and supporting collaborators is more difficult to resolve, illustrating the imbalance of power embedded within the structure of the collaboration. Visualization researchers have more agency within the collaboration, benefiting from the labor of the domain expert. For example, GS-2 saw the collaboration as an opportunity to get real-world feedback on her tools, which she promoted as a unique aspect of doing collaborative visualization research:

> GS-2: *It's kind of nice to have people testing your system and trying out use cases and also providing datasets, and yeah, that's nice. And also having input from a domain expert, which if you don't have a collaboration with such a group of experts, it's not so easy.*

GS-2's collaborator, however, discussed her side of the work within the collaboration as sometimes tedious and time-consuming. DE-2 recalled a frustrating breakdown in communication when she spent time working with the wrong version of a prototype:

> DE-2: *And I sometimes spent weeks working on an older version, and finding issues or [problems] that were actually solved in a later version. So this communication of which is the current version, how do we get it? That was lacking. But after I raised the issue, that improved, [but] I was still kind of pissed to have wasted some time. But what can you do?*

In this exchange, DE-2's wasted efforts in testing code were perceived as an issue she had little control over.

The tension of testing new prototypes was also expressed by another domain expert who runs a large natural sciences lab. He explained that testing prototypes was difficult because it was seen as wasting time when the testing would only confirm what the lab members already knew about their datasets. He was open about this challenge:

> DE-11: *My lab is awful at testing … it's like pulling teeth to get anyone in my lab to spend, like, 30 minutes testing, to make sure that a new version doesn't have breaking features.*

When it came to providing data, several domain experts explicitly discussed the considerable time it took them to prepare datasets for their visualization collaborators. Expressing frustration regarding the time and energy required, DE-9 described collaborations where he was asked for data and then asked to interpret it for the visualization researcher during their process of writing a visualization paper. He pointedly expressed his disinterest in his role as a data provider:

> DE-9: *I think that's the main problem … some people take data … and they just analyze them … And then they ask the domain scientists: "What do you think of that?" … And I don't even understand what I'm seeing. … So [it's] probably a great visualization, … but I'm not really able to understand it. And at this point, I'm fine that they're playing with my data. But don't ask me for a physical interpretation.*

DE-9 also expressed how he felt disenfranchised by visualization paper deadlines, which he viewed as disrupting productive tool development in favor of focusing on visualization novelty:

> DE-9: *It's an issue when you have to work together and publish together … It's complicated, when you have poking deadlines [for] visualization articles that we need to submit, right? … So you just develop this concept, this prototype, and then you sell it to the visualization conference of your choice. And sorry if I'm being sarcastic.*

The stories we heard from visualization teams struggling to balance the needs of their collaborators with their own academic needs to publish, as well as the generous support from domain experts in supporting visualization research, reflect our own experiences in design studies. Hearing about the implicit prioritization of visualization research made us start to question if design studies are collaborations working towards a common goal, or if they are an opportunity for diverging but mutually beneficial research. From this latter perspective, the power asymmetries that arise from the long-term nature of design study set up ways that visualization researchers could end up caring more for their own goals than their collaborators'. We suggest possible ways to counteract this asymmetry in Section 6.

5.2 Power Asymmetries Within the Visualization Team

During our interviews, we asked PIs to reflect on their relationships with students who were doing the day-to-day work of conducting collaborative research projects. Many PIs expressed an awareness of the power they had in these relationships:

> PI-4: *When you're working with students, there's this inherent power imbalance … So my suggestions probably take on a lot more weight than they would otherwise.*

From this position of power, PIs commented on the responsibility they felt toward their students, expressing strong commitments

to the students' success. PI-11 emphasized that the training and development of his students were his top priority:

> PI-11: *My real product is not papers, my product is people. I view it very important that the people that I'm working with [are] getting the training they need and [are] developing as they should.*

Other PIs echoed this sentiment and discussed the specific ways in which collaborations were opportunities for training students. PI-7 mentioned how he saw initial discussions with collaborators as an opportunity to teach the student about interviewing:

> PI-7: *Most of the time, the students do [a requirements analysis] for the first time. And so I'm really trying hard to be in the room together with the student and the potential user . . . After the interview is over, I usually also try to spend time with the students [asking them]: did that make sense? What do you think about it? How did it work for you? Do you see this, and that, and the other thing?*

PIs also talked about their work to make sure the overall collaborative setting for their students was conducive to success. PI-3 expressed her responsibility to set up infrastructure that included funding, time commitment from collaborators, and larger teams of expertise, all oriented around the student:

> PI-3: *It's not just the funding, it's the time commitment. I need this amount of [the domain] expert's time . . . It's [also] about saying, we might need to bring in, for example, this person with a more of a social science, ethnographic background. We need this type of expertise to come in and tell us about X . . . The students need to come into an infrastructure like this.*

The ways in which PIs actively supported their students, however, were sometimes at odds with goals that PIs had for their own research agendas. At the heart of conversations with PIs were long-term visions they had for their research and collaborations, which meant that they were often thinking about sources of funding. PI-9 stated that the success of a project in meeting promised deliverables to a funding agency could impact her ability to secure future funds. This was stated as a challenge for the PI in a situation where a student-led project took an unplanned direction:

> PI-9: *If you cannot prove that you did what you promised, you might have a hard time next time to get funding . . . it's not his problem, this is my problem to get this solved. And he had to think about his future and his future looks different.*

Individual student projects were also seen as opportunities to make a case for longer term investments in collaborations. For example, PI-6 secured initial funding from a company for six months with the goal of demonstrating interesting research gains:

> PI-2: *For this shorter term [collaboration], the project['s goal was] to also motivate [the collaborating company] to invest more in a research collaboration. So there was basically, for me, the metric for success was to show what added benefit we can provide, like going beyond just the publication. So for us researchers, of course, and for [GS-2], also, the publication is still the most important thing that comes out of that. But for me as a PI, it's also about, like, what comes after that, what's the bigger picture?*

Commitments to, and work toward, long-term collaborations were expressed by most of the PIs, in large part because *"the longer a collaboration lasts, the more productive it becomes"* (PI-2). The side effect, however, is that early-stage collaborations, while necessary, are often less interesting from a visualization research perspective. For example, PI-9 talked about her seven-year collaboration with a set of domain partners, in which *"the last two years we really started becoming efficient"*. She described the lengthy process of building trust in these collaborations:

> PI-9: *In many projects, I experience that the first three years is a get-to-know-each-other. It just takes so long. And in the beginning, they are only happy if I provide them with some very minimal, very primitive visualization stuff. That is kind of useless for us . . . You can't publish it, it's kind of boring, [it is what] you have learned in your first [visualization] course. However, for them, this is kind of the first step to understand, what is visualization capable of? What can I do with it? What can I reach?*

For the PIs, this commitment to the collaboration was at times a source of tension with their commitments to their students. Specifically, PIs called out the challenge of balancing student progress with the long-term nature of collaborative research, or what PI-3 referred to as the work of scoping projects so that students *"will actually not do the 100-year PhD"*. This sentiment was reflected by PI-7:

> PI-7: *Is it worthwhile to have a student spend half a year, year, or even longer on this? What's the outcome for that student? Is it worthwhile?*

Ultimately, PIs juggle many responsibilities: to their students, their collaborators, and themselves. These responsibilities are not unique to visualization research, but are perhaps heightened and put into tension by the inherent power asymmetries embedded within design studies. Redirecting care throughout a collaboration is something we have not done consistently or systematically in our own projects, and it is not something explicitly described in existing visualization process models. In Section 6, we propose a series of provocations to help visualization researchers consider more fully the objects of their care throughout a design study.

6 CARE-FUL DESIGN STUDY

> *'Staying with the trouble' that care sets in motion does not mean that we are left without means to act or intervene; rather, it is by staying in the thick of things, by analyzing care's non-innocent politics that our responses can be slowed down enough to make them more care-ful* [38].

"Staying with the trouble" stems from feminist scholar Donna Haraway's call to stay in a place of uncertainty and discomfort, where beliefs and values are challenged, in order to gain new insights [22]. Haraway's notion of *trouble* has origins in her earlier, influential work that situates knowledge within many relational

and entangled contexts [21]. Grounding care, then, in the complexity of politics, power, and interpersonal relationships is a form of situated knowledge-making. The trouble that care brings is in recognizing the ways that care is directed and distributed unequally. From this perspective, in the following sections, we reference the sets of relations that create and are shaped by the neglected things and power asymmetries heard across interviews.

At the heart of the following section is a set of questions that challenge normative design study. In *"analyzing care's noninnocent politics"*, visualization collaboration becomes less an opportunity for a cool dataset or test bed for visualization tools, and instead a site of entangled interests, varying access to resources, and different levels of autonomy. With this, we question *when* and *for whom* design study serves as an appropriate research methodology. Closely related, we ask the community to reassess the rewards set in place for tool development. Given the complexity of engineering and maintenance, and the benefits beyond the tool, we explore other opportunities to conduct collaborative visualization research. Lastly, we turn our attention to the term collaborator and the set of assumptions it carries. The interviews exposed a varied set of relationships, all locations for care that do not fit the current molds of interacting with collaborators. We pose the following provocations to begin discussions of how we might *stay with the trouble* to learn how to conduct more intentional and care-ful design studies.

6.1 Care within Visualization Teams

6.1.1 Is design study good for students? We would like to consider that design study might not be good for all students and all contexts. Across our interviews, most collaborations were initiated by PIs, leaving students with minimal agency but the majority of responsibility. Design studies are known to be difficult visualization research projects, requiring many different kinds of skills: engineering, design, and qualitative methods [41]. Our interviews highlighted additional collaborative needs, such as navigating organizational nuance, expressing compassion for collaborators, and managing expectations across various stakeholders. This makes conducting design study a challenging task for any researcher, let alone a visualization student who may have the least amount of agency and is in the process of developing their skills as a researcher. So is design study an appropriate methodology for graduate students?

Sometimes. Throughout the interviews, PIs and students alike spoke about the benefits of collaboration, such as gaining personal enjoyment, having the opportunity to make a clear impact in the world, and training in a broad range of methods and skills. In particular, design study can be a training ground for how to design and develop effective visualization tools. Alternative methodologies, like the *design study "lite"* [62] are opportunities for lower stakes and lower commitment visualization projects that allow for a focus on learning. Giving students agency in choosing collaborators — as was the case with GS-3 — can move them into a more equitable position. Paying attention to the power asymmetries in collaboration suggests that we at least make both the costs and benefits of design studies more legible to students.

6.1.2 Is the PI open to supporting a care-ful design study? Answering this question requires PIs to consider whether they have the time, energy, and resources to support students and collaborators throughout a design study, and beyond. Moving forward with care is a dedication to building and sustaining relationships, encouraging and welcoming ongoing conversations about technical, organizational, and social infrastructures as opportunities for PIs to check in with the students and collaborators they care about. But, care-ful design study is also an appeal for PIs to consider the *neglected things* within collaborations, like the life-cycle of research artifacts and, in particular, their maintenance.

When it comes to the maintenance of tools we develop in a design study, there is no clear guidance about who is responsible for that maintenance, and to what end. In some interviews, we saw graduate students take on that responsibility, but this work could be unrecognized, without a foreseeable end date, and incur both personal and professional opportunity costs. In other projects, we heard about open-source code bases as ways to divest oneself of sole responsibility for a project, but even this divestment requires well-documented code and technical know-how for the next person to pick it up. And despite maintenance being seemingly in the control of visualization researchers, we also heard that some tools were rendered obsolete by external tech-stack changes, or by domain experts moving onto other questions. These tensions lead to a troubling question: if we aren't designing tools that will be useful in the real world, then, as GS-3 said, "*what are we really doing?*"

An attention to matters of care asks us to grapple with the complexities of maintenance; to take these complexities and consider, honestly and open-eyed, what it is we care about and what we may be neglecting. From this lens, we care-fully consider the trouble of maintaining a tool beyond a design study by re-imagining the role of visualization tools.

First, we put forth *designing for the graveyard* as an admission of research prototype fragility and as an opportunity to consider other goals for design study. Design study could, for example, serve more explicitly as a method of visualization inquiry [41], where we use the design process as an opportunity to experiment with more abstract visualization ideas with the input and support of domain experts, such as exploring what might happen if we embrace complexity in our designs [30, 37]. Or, we could change the medium of the final output, shifting the focus from delivering technical solutions to other forms of visualization like sketches [67, 68] or physicalizations [23, 25, 48, 65]. We could also focus on making the novel design components of our tools legible and reusable for future researchers even if the tool as a whole is not, allowing them to sort through the *junkyard* for components to reuse, ideate with, or survey. We might even imagine building lightweight, throw-away prototypes that are meant to answer quick, specific domain questions, enabling a sort of technology-aided data counseling. We saw examples of these varied goals in our interviews, with domain experts sharing their delight in opportunities to reflect on their data and learning new data-oriented practices; and with PIs pointing out the myriad opportunities for students to learn useful practical skills. In a care-ful design study, we could employ *designing for the graveyard* to redirect our attention and resources on what is happening during the design study, rather than what might happen after.

A second option for care-ful tool development might be to meet a domain halfway by developing new visualization capabilities within a community's existing software systems. When considering

whether a new, flashy, bespoke tool is likely to survive on its own, we might choose to instead lean on existing technological and social infrastructures that are already supported by a community, putting aside the perfect visualization solution in favor of a productive step that moves existing tools forward. This might look like plug-in visualization libraries for the tools domain experts are currently using, like Cytoscape [57]. Or, building visualizations inside of widely used environments like R. From our own work, UpSet [34] is an example of a research prototype that was built as a highly interactive tool supporting grouping, filtering, queries, and more. But when it was translated into R and Python as a much more simple, static visualization, it found a significantly higher user base — and arguably impact — by meeting analysts in an environment they already use. This re-imagining of design outputs suggests we need to change our expectations of novelty, complexity, and evaluation, since the visualization would be scoped by the constraints of the given system or environment. It could also be an opportunity to meet domain experts and their ecosystems of technology where they are at, and to possibly see longer term use of the visualizations we design.

6.2 Care with Collaborators

6.2.1 Are we heroes or collaborators? We ask this question as an opportunity to pause and consider our expectations of collaboration. Collaborative visualization research has occasionally been characterized as requiring *heroic* efforts and interventions [9]. Across interviews, we saw the work domain experts did to help visualization researchers make progress toward their visualization goals. The process of design study — as articulated in the *nine-stage framework* [56] — asks collaborators to provide data, time, and feedback upfront before ever receiving a tool. At times, this work was reported as frustrating and not seen as relevant for the domain experts' own goals.

From a care perspective, we suggest moving away from the heroic idea that collaborators will be rewarded for their efforts with a transformative visualization tool [9] to, instead, seeking opportunities to support domain experts along the way. We ask visualization researchers to slow down and pay attention to the work that their collaborators are doing and to look for opportunities to help them achieve their goals incrementally, whether that be helping them have *"the prettiest poster"* as PI-4 suggested, giving a tutorial about visualization best practices [52], or even conducting data counseling using lightweight methods like data-engagement interviews [44]. In one of our projects, the leading graduate student helped our collaborators by producing histograms and other standard charts for one of their publications [59] while he was working with them on a multi-year design study [28]. Focusing on these types of intermediate goals can shift our focus from the tool as the end goal, to looking for opportunities that support and build collaborations incrementally.

6.2.2 Are domain experts collaborators or participants? After some of our interviews, we were left wondering whether some domain experts filled the role of a study participant more than a collaborating partner. At times they served as people giving ecologically valid feedback on new visualizations, as beta-testers of prototypes, and as dataset providers. But we also heard about domain experts co-ideating on shared research problems, and serving as sources of inspiration for thinking and working differently. We acknowledge that the roles and responsibilities of everyone involved in collaborations change over time; a lens of care is an invitation for us to pay closer attention to both relationships and the context that shapes them.

When working with collaborators, we encourage the visualization team to more clearly articulate goals, outcomes, and expectations over the course of a design study. There is a tension between the fluidity and serendipity of academic research and the fixed and strategic need to build and evaluate technical work. Through open and candid communication, through the de-emphasizing of *final* tools as the desired or only output of design work, and through the acknowledgment and rewarding of otherwise underacknowledged forms of labor, situations where collaborators feel powerless or un-cared for may be lessened.

7 LIMITATIONS OF THE STUDY

All our interviewees were recruited from collaborative visualization projects that resulted in successfully published papers. We often wondered how our interviews and analysis may have differed if we were able to talk to visualization researchers and their collaborators when the collaboration failed — failed to produce a paper or failed to be a productive collaboration. We speculate that we may have heard more critical feedback within teams, and possibly different suggestions for how successful visualization collaborations *should* be conducted.

We also struggled in our initial recruitment process of finding interviewees through a survey sent to authors of papers that explicitly claimed their research to be a design study. Of 64 emails sent, only five resulted in interviews. We thus decided to turn to our personal networks of visualization colleagues to recruit participants, potentially skewing the perspectives we heard. Specifically, it is important for us to note that these personal networks resulted in interviews with participants from North America and Europe, conducted in English and representative of a Western perspective.

Another limitation of the study is that we did not speak to any of the software development teams or other individuals responsible for the domain experts' technical infrastructure. We are missing a critical perspective of the teams of engineers and IT staff that make it possible to host old projects online. We see this as an opportunity for future interview studies that can contribute to a more robust understanding of visualization in the world.

In this paper, we focused on where participants were located in terms of labor and organizational power, but we did not collect specific demographic information such as gender, sex, race, age, ability, or ethnicity. Following Patricia Hill Collins' concept, *matrix of domination*, we acknowledge that different facets of intersecting identity result in differences of systemic privilege and power [7]. We see it as a shortcoming of our analysis to not have included these aspects of identity.

Of final note, we spoke only to academics and other researchers. This decision excludes visualization practitioners who are employing similar methods in their work [49]. We suspect that different organizational constraints would foster or inhibit different methods of care.

8 CONCLUSION

Collaborative work is where visualization research can make itself known, and can have a concrete impact on real people with real problems. Yet, collaborations are inherently complicated, given that they are situated in organizations and individuals with their own needs and goals. We interviewed visualization researchers and domain experts who collaboratively engaged in visualization research to better understand how individuals navigate the priorities of maintenance and interpersonal dynamics shaped by differences in power and objects of care. What we found were collaborations troubled by the essential condition of a deployable visualization tool, and the power asymmetries between individuals and across roles.

In this paper, we explore how matters of care can suggest careful alternatives to standard methodologies that center the value of supporting one another by paying closer attention to relationships, considering lasting impacts beyond delineated endings of projects, and the possibility that collaborations are valuable beyond technical artifacts. Through the notion of matters of care, we hope to encourage visualization researchers to slow down and stay with the trouble by explicitly considering the labor required to conduct design study so that we may take responsibility for the ways in which our research affects and is affected by one another.

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