Published by the Association for Computing Machinery
Special Interest Group for Design of Communication
ISSN: 2166-1642

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Communication Design Quarterly
https://sigdoc.acm.org/publication/
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ABSTRACT
This article is the introduction of the first of two Communication Design Quarterly special issues focused on conceptualizations of infrastructure. This introduction explains the inspiration for these two special issues and details the growth of infrastructural research across the humanities and social sciences. This article also explains the structure of the issue and argues that the articles found across these two issues make a strong case for centering infrastructural knowledge in our work going forward.

CCS Concepts
Information systems

Keywords
infrastructure, writing studies, design, user experience, UX

INTRODUCTION
The introduction to a special issue is always a bit of a unique genre with unique challenges. The editors need to give background on a topic without narrowly defining terms in ways that should be left up to the contributors, and the editors need to justify the exigence for the unifying theme without narrowing what “counts” as relevant. The challenge is even more unique when there are two back-to-back special issues that will each have their own introduction, and this is the first of two Communication Design Quarterly (CDQ) special issues focused on infrastructure (broadly defined). Consequently, we’re going to walk that fine line here by starting in what may be a strange place: a more personal explanation of why the two of us—Jordan Frith and Sarah Read—pushed so hard for a collection of writing and design work that centers conceptualizations of infrastructure. And to explain those origins, we have to go back a few years to a friendship that was born out of a serendipitous interest in rethinking both how infrastructures shape writing and design and rethinking the infrastructural role writing and design plays in the world.

An important piece of background to this story is the fact that the last two decades have seen a marked growth across the social sciences and humanities in research focused on infrastructure, a point we examine in more detail in the next section. The increased interdisciplinary focus on infrastructure, however, has—with a few notable exceptions (DeVoss et al., 2005; Grabill, 2010; Johnson & Johnson, 2016; Swarts, 2010; Vee, 2013)—mostly not made its way into writing and design research. That began to change recently, in part through work we published that explicitly tied technical and professional communication work to infrastructural theory. Sarah drew from extensive ethnographic work to examine how writing actually works as infrastructure for other infrastructures and developed a framework for understanding the infrastructural role writing plays within organizations (Read, 2019, 2020). Jordan built upon Sarah’s framework and performed a qualitative analysis of a major technical standard to show how writing also externally works as infrastructure by building a base that shapes how other organizations create products for end users (Frith, 2020a, 2020b). He argued that writing becomes embedded within objects in
invisible, often ignored ways. We barely knew one another when we started that work, but the overlap was obvious, and we started talking. Since then, we have been friends and collaborators, and we both knew that if we really wanted infrastructural research (broadly defined) to become a more central part of our discipline, we could not do it through our research and conversations alone.

Consequently, these two special issues were born out of a conversation over ramen at the 2019 SIGDOC conference in Portland, Oregon. The two of us do not agree on everything, with Jordan more interested in the infrastructural theory side and Sarah more focused on merging rhetorical and genre theory with infrastructural work. But despite our relatively minor differences, we both were devoted to growing the role of infrastructural approaches in our disciplines. Consequently, we both felt that for infrastructure to be a more central concept in our discipline, we needed to draw from the broad expertise of multiple authors, and a special issue in an inclusive venue like CDQ was the best way to do it. We then pitched the idea of a special issue focused on infrastructure to CDQ and put out a call for abstracts as soon as it was approved. Then we waited. And waited. We both worried that maybe the idea of infrastructure as a way to conceptualize and understand writing and design was simply too out there, and we feared that we were maybe stuck having a theoretical conversation with one another. But then in true academic fashion, the abstracts began pouring in right before the CFP deadline, and we were overwhelmed by both the quantity and the quality of the submissions. So many authors proposed so many interesting ways to center infrastructure in writing and design work, and we decided to split into two separate special issues because we had more than enough quality submissions to support that choice. Even with two issues, we had to make difficult decisions and reject exceptional abstracts. The sheer breadth of innovative work represented in those submissions signaled that there is a strong future for centering conceptualizations of infrastructure in writing and design research.

This is the first of those two special issues. We titled this issue *Communication and Design Infrastructures*, and the second issue will be titled *Writing Infrastructures*. The two issues share many similarities, and there is not a fully clean dividing point between the articles featured in each issue. However, they do differ in some ways, with this issue focused more on material infrastructures and collaborative infrastructures and the next issue focused more on the infrastructural functions of writing. But before we dive deeper into this issue and the articles it features, we first want to provide background on the development of infrastructure as a significant object of research across the social sciences and the humanities, which we do in the next section. Our goal is not to provide a “correct” framework for conceptualizing infrastructures of writing and design or even how best to examine the infrastructural roles communication, writing, and design can play within organizations. Rather, we decided that this introduction should provide background on the growth of infrastructural research, which some have argued has become significant enough to label an emerging field of “infrastructure studies” (Sandvig, 2013).

After we provide background on the growth of infrastructure studies, we then outline the different articles in this issue, which range from examinations of Git as a boundary infrastructure to analyses of how automated data infrastructures may shift how we understand user participation research. We conclude by reiterating the shared goals of these two special issues and foregrounding some of the articles found in the next issue. What we ultimately hope these special issues show CDQ readers is that infrastructural research has much to add to research on writing and design, and equally importantly, we believe the excellent work the authors did across these two issues shows that research on writing and design has much to add to the growing body of transdisciplinary infrastructural research.

**THE GROWTH OF INFRASTRUCTURAL RESEARCH**

In one sense, infrastructures don’t seem like a natural fit for research in the humanities and social sciences. Almost by definition, infrastructures are designed not to be noticed. As Star and Ruhleder (1996) put it, they often remain invisible and only become visible when they break down. Whether we are talking about material infrastructures like roads or fiber optic cable or discursive infrastructure like internal documents or standards, they remain in the background of the more typical objects of studies in most fields. After all, most humanistic and social scientific research focuses more on the interfaces with which people interact, the texts that shape discussions, the apps people use to network, and so on, than on the mostly ignored infrastructures that make those practices possible (Parks & Starosielski, 2015).

Infrastructural research has, however, seen significant growth across the social sciences and humanities over the last few decades. Researchers from various disciplines have increasingly begun to analyze the agential role infrastructures (defined broadly) play in shaping practices and holding together—or not holding together—various parts of the social world. What’s maybe most interesting about this growing focus on the importance of infrastructure is just how transdisciplinary the move has been. Researchers from disciplines such as communication studies (Frith, 2019; Mukherjee, 2020; Parks, 2005; Starosielski, 2015), anthropology (Anand et al., 2018; Appel et al., 2018; Harvey & Knox, 2015; Larkin, 2013), information science (Bowker & Star, 1999; Kling, 1991), computer science (Dourish & Bell, 2011), and many more have begun speaking a somewhat common language and communicating across traditional disciplinary lines to situate understandings of the important role oft-ignored infrastructures play in our lives. These conversations have become common enough that some researchers now argue that “infrastructures studies” has become its own identifiable transdisciplinary field of study (Sandvig, 2013).

The history of infrastructure studies as a semi-coherent body of transdisciplinary scholarship is not just background for background’s sake. Instead, we argue the history of the field is relevant to the different objects of study and, in a few cases, the somewhat different conceptualizations of infrastructure found among the articles of these two special issues. And while we have no intention of “defining” infrastructure as a concept or using this introduction to carve out a supposedly “correct” framework for infrastructural research, we do want to give background on the development of infrastructural research to better situate a few different ways infrastructure can be analyzed.

Infrastructural research has its roots in the 1990s in more technical fields like information science and engineering. Scholars like Kling (1991), Star (Star, 1999; Star & Ruhleder, 1996), and Bowker (Bowker, 1994; Bowker & Star, 1999) began exploring the “soft” social infrastructures of science and engineering to examine the role these infrastructures play in holding together larger projects. As Sandvig (2013) documents, these scholars came from disciplines
that were comfortable describing and explaining technical, material infrastructures, but these disciplines had less of a vocabulary for describing the “soft infrastructure” of people, policies, and collaborative platforms that were key to various projects. This research from information science, especially research by Susan Leigh Star and Geoff Bowker, then became central to what Sandvig describes as the “relational” strand of infrastructure studies, and we want to briefly detail two major contributions here to help contextualize just why and how scholars have embraced a relational approach to infrastructure.

Formative early research introduced a number of approaches and theories that still dominate infrastructure studies to this day, and multiple articles across both these issues draw from some of this early work. One example was Bowker’s (1994) introduction of “infrastructural inversions” as a broad methodological approach for studying infrastructure. “Infrastructural inversions” are basically a foreground/background flip where researchers look beneath the surface to examine the infrastructures—whether material or discursive—that shape the higher-level practices that are the more typical area of focus in the social sciences and humanities. In other words, infrastructural research, regardless of discipline, tends to analyze the mostly invisible objects and processes in the background of more typical areas of study: the satellites that shape communication (Parks, 2005), the collaborative organizations that shape scientific output (Star, 1999), the documents that become embedded in objects (Frith, 2020b; Read, 2020), the agential role of highway projects in Peru (Harvey & Knox, 2015), the phenomenology of computing infrastructures (Dourish & Bell, 2007, 2011), the analysis of economic infrastructures (Buhr, 2003), and so on (see Read, 2019 for more detail on different definitional approaches to infrastructure). In other words, infrastructural research inverts objects of focus to analyze how higher-level practices are shaped by the layers of infrastructure found below.

Infrastructural inversions are a key approach in infrastructure studies, but the reason Sandvig labels this group “the relationists” (2013, p. 91) is because of one of the key concepts in infrastructure studies that emerged in earlier work: Susan Leigh Star’s argument that infrastructures are relational (Star, 1999; Star & Ruhleder, 1996). In other words, arguing about or trying to define whether something is or is not an infrastructure is not really the goal of most infrastructural research. Rather, as Star and her colleagues argue, infrastructures are relational and do infrastructural work through practice, not through any deep ontological categorization. Or, to put it slightly differently, “we ask, when—not what—is an infrastructure” (Star & Ruhleder, 1996, p. 113) For example, a cell tower is an infrastructure to most of us. It remains in the background and is mostly ignored except in moments of breakdown when we cannot get a signal. But for tower technicians, that same tower is not an infrastructure; it’s a primary object of focus. And as both authors of this article have argued, the same is true of discursive infrastructures. Writing, whether internal documents or documents like standards, do infrastructural work for some audiences while remaining a primary object of focus for others.

Relationality is a key concept for many infrastructural researchers, and it is deployed by multiple authors throughout both of these issues. But as Sandvig (2013) points out, a different approach to infrastructural research has also developed and—while it still draws from relational researchers like Bowker and Star—has a different starting point and slightly different object of analysis (though there is significant overlap). Sandvig (2013) labels this group “the new materialists” and points out these researchers tend to come from more humanistic backgrounds and focus more on the “hard infrastructures” of communication, writing, and design (Frith, 2019, p. 91). Influential examples of the materialist approach includes work like Parks’ (2005) cultural analysis of satellite infrastructures and their relationship to globalization or Starosielski’s (2015) anthropological approach to the study of undersea cable. Whereas the relationists tended to start with the social to invert infrastructures, the materialists tend to perform those inversions by focusing on the “hard” infrastructures of communication and design, a trajectory shaped in part by disciplinary starting points.

We don’t want to overstate the differences between new materialist and relational approaches. They draw from similar theories, and in many cases are almost indistinguishable. Both often focus on social justice issues and how infrastructures can embed inequality in often invisible ways (Busch, 2011; Frith, 2019; Graham & Marvin, 2001). Equally as important, they are both united in the core belief that infrastructures matter and are more than bases upon which more interesting things just happen; instead infrastructures—whether social or material—shape higher level practices. But despite the similarities, this history can be important because it shows just how widely infrastructural approaches can be applied across various research domains. For some researchers, the contribution may come in exploring how the “soft infrastructures” of communication inform material practices. For other researchers whose audience already has expertise on the “communication” part but maybe less so on the “material” part, the contribution may come in uncovering the agential infrastructural role of various material forms that remain in the background. In other words, to quote Star (2000), “it’s infrastructure all the way down” (p. 1), and regardless of the specific approach or object of study, thinking infrastructurally means uncovering that which is hidden; it means digging into the layers of practices and materials that shape higher-level practices that are more commonly researched. And these two special issues embrace the capaciousness of infrastructural thinking by examining a wide variety of the often-invisible layers of infrastructural practice that are key to the work people do as practitioners of communication, writing, and design.

THE STRUCTURE OF THIS ISSUE

Once we decided we had more than enough excellent abstract submissions to make two special issues, we then had to decide how to group the articles in the two issues. We decided that this first issue would group together articles that focus more on technical infrastructures like Artificial Intelligence and Git as well as the buried communicative infrastructures of social collaboration. The second issue focuses more on the infrastructural role of writing, though we want to be clear that the articles across the two issues are all in conversation with one another, and the split between the two is far from clean. The articles in this issue feature discussions of writing and design practices, just as the articles in the next issue include discussions of technical and collaborative infrastructures. We both believe the separation into two separate issues illustrates how capacious infrastructural research can be, but we also don’t want to overstate the split: the two issues are more similar than they are different, and we hope they are read together as a framework for just how widely infrastructural research can be applied in our discipline.

The introduction to the next issue will obviously focus more on those articles, so here we want to outline the articles in this issue.
and provide a roadmap for how they broadly fit together as part of what we hope becomes an even more prominent conversation. To return to an earlier point, our goal in putting together these special issues was not to direct infrastructural research in one way or another. We did not tell authors how to define infrastructure or which bodies of theory from which they should draw. While that kind of consistency across a special issue can certainly have its benefits, we decided early on that writing and design research would be best served if we let authors be creative in how they approach the role of infrastructure in their research. Nevertheless, the main thing we wanted to ensure across these two issues was that the focus had to be on infrastructure (broadly defined), however the authors chose to conceptualize the term. We wanted explorations of the often-invisible practices and products that shape outputs in communication, writing, and design, and the articles in this issue (and the next) maintain that unifying focus even as they analyze widely different objects and draw from occasionally different theoretical frameworks.

The first two articles focus on a topic that has long been central to technical communication and design: users. In the first article, “Infrastructural support of users’ mediated potential,” Nupoor Ranade and Jason Swarts use infrastructural thinking to reconceptualize the role of users and user research in the design process. The authors argue that to build better user models we need to carefully consider how users are situated amongst multiple social and technical infrastructures. And maybe most importantly, we need to consider how users’ ability to communicate in certain ways (or not communicated in certain ways) is shaped by those infrastructures. In particular, they argue that conceptualizations of the role infrastructures play in communication can help researchers and practitioners more accurately model user behaviors for communication design. Their approach draws from both infrastructural theory and cybernetics research to introduce a unique approach to user design: the concept of “mediated potential.” Mediated potential is a framework for more accurately conceptualizing the “user + infrastructure” relationship for user modeling, and to return to the previous section, their framework includes close attention to both the “hard” and “soft” infrastructures that fall under the infrastructure studies umbrella.

The second article shares the focus on the relationship between infrastructures and user design, though the authors use an infrastructural approach to head in a different direction. In the article “Automated infrastructures,” John T. Sherrill and Michael J. Salvo explore how core concepts of participatory design may be impacted by the growth of infrastructures of artificial intelligence and automation. They draw from Star’s anthropological approach to infrastructure to make an impassioned argument that new data infrastructures can be useful for participatory design, but they should not replace the expertise of technical communicators. To make their argument, they introduce the concept of automated infrastructures for design and show how increasingly complex data infrastructures can provide designers with more detailed user profiles. However, no matter how powerful those infrastructures become, they argue that the role of the technical communicator who engages users and interprets user data should not disappear. Importantly, they do note that the role of the practitioner may have to change as these design infrastructures grow, but the practitioner should remain the bridge between data infrastructures and users regardless of broader infrastructural shifts in the product design process.

Users remain central to the other three articles in this issue, though the focus shifts more from user modelling and more towards how people use individual infrastructures and how people work behind the scenes to maintain them. The third article, titled “Building ethical distributed teams through sustained attention to infrastructure” and written by Michelle McMullin, Hadi Riad Banat, Shelton Weech, and Bradley Dilger focuses on the Corpus and Repository of Writing (Crow) project. The authors situate the corpus as an infrastructure, but they dive even deeper to conceptualize the collaborative processes that hold the project together as its own kind of infrastructure. Their work as a project team is driven by the concept of sustainable infrastructure, which involves building both social and material infrastructures that are able to be maintained over time and are able to quickly introduce new members to the deeper infrastructural process. Their article innovatively conceptualizes how mapping strategies for collaborative work can make infrastructures more visible and argues that infrastructural visibility is key to developing equitable, socially just infrastructural research practices.

The fourth article shares the focus on both the role a database can play as infrastructure and the importance of building infrastructural collaborative practices. That article—“Writing infrastructure with the Fabric of Digital Life platform”—is written by Katlyne Davis, Danielle Mollie Stambler, Jessica Lynn Campbell, Daniel L. Hocutt, Ann Hill Duin, and Isabel Pedersen, who are all members of the Building Digital Literacy (BDL) research and pedagogy team. The article analyzes the Fabric of Digital Life (FABRIC) archive as a pedagogical infrastructure that reaches across multiple institutions. The FABRIC archive tracks the emergence of various technologies and is collaboratively created. As the authors describe, students are able to both access and contribute to the archive and doing so requires teaching digital literacies like metadata that themselves do infrastructural work. And maybe most importantly, the authors use the FABRIC project to show how similar classroom work can help make invisible infrastructures visible to students. In that way, they are in conversation with the previous article by arguing that emphasizing visibility is key to building more socially just infrastructures. To drive that point home, the authors develop an innovative framework for analyzing data from the FABRIC project. Their framework combines infrastructural theory with Walton, Moore, and Jones’ (2019) 3Ps framework to put distinct bodies of research into conversation and reconceptualize the role privilege, positionality, and power play in how we relate to infrastructures more broadly.

The final article—“Alternate histories and conflicting futures”—continues the focus on collaboration through infrastructure by analyzing the software Git. As Eric J. York argues, Git is one of the most influential, dominant collaborative infrastructures of all time. Git is used in the majority of large coding projects to make collaborative editing and version control possible with a large number of contributors. York first analyzes Git as collaborative infrastructure before drawing from infrastructural theory to argue that Git works as a “boundary infrastructure” that crosses lines of expertise and retains shared meaning. Like the previous two articles, York’s work focuses on the role infrastructure—in this case a dominant platform—plays in collaborative processes, and like the previous two articles, he also argues that infrastructural analyses can help build more socially just infrastructures. As he points out, knowledge of Git has become essential to collaborative software design, which can lead to hegemonic practices that researchers must make visible.
CONCLUSION AND LOOKING FORWARD

The five articles that comprise this special issue (six if you count this introductory article) help show how broadly infrastructural thinking can be applied to communication, writing, and design. Some of the articles include more materialist focuses on platforms like Git and automated data infrastructures, while others do include materiality but focus more on the social infrastructures that undergird larger projects. We argue in this issue introduction that what is so exciting and valuable about infrastructural approaches to communication, writing, and design is that they can encompass all of these different topics. Beneath almost all higher-level practices, there are layers upon layers of infrastructures—both social and material—that shape those practices. Infrastructural theories can help researchers in our discipline look below the surface and peel back those layers.

Importantly, every one of these articles makes a unique case for why it’s important to extend our research to the often-hidden infrastructures that shape our work. Ranade and Swarts show that users need to be understood within their infrastructural context, while Sherrill and Salvo argue that technical communicators need to evolve their role amongst new design infrastructures. The Crow team argues that equitable research infrastructures must include high levels of visibility that can be furthered through social mapping practices, while the BDL team shows how infrastructural research can be combined with the 3P framework to build equitable pedagogical and research practices. York examined how infrastructures can become so dominant that, even as they work as boundary objects, they also can become their own form of gatekeeping in possibly inequitable ways. These articles drew from somewhat different frameworks and different objects of analyses, but they all highlight in their own unique ways how inverting the foreground/background relationship and peeling away material and social infrastructural layers can make significant contributions to our research.

This collection of articles, of course, is only half the story we hope to tell with these two special issues. While these articles work in conversation with one another, the next special issue of *CDQ* will further build upon that conversation, showing more areas of divergence and emergence as more authors use infrastructural approaches in their work. We hope this introduction has helped make part of the case for why communication, writing, and design research should become a bigger part of infrastructure studies as a loosely organized, transdisciplinary area of research. More importantly, we believe the authors who contributed their excellent work to this issue makes that case more persuasively than we ever could in a special issue introduction.

The goal of both this issue and the next is to put a wide range of authors into conversation through a shared focus on infrastructure. And we hope this conversation shows just how much our discipline can contribute to infrastructural research more broadly, while also showing how infrastructural research can contribute a great deal to our disciplinary work. This issue is the first part of that conversation that we hope continues to happen across our journals and conferences, and we are excited to see the publication of the second issue, which will include everything from conceptualizations of citational practices as infrastructures that are in a moment of breakdown to analyses of how infrastructural writing becomes embedded within oysters. Infrastructure, after all is everywhere and shapes everything almost all the time. Consequently, we are excited to see how the contributions of authors in this issue and the next help shape the conversation in our discipline as we peel back more and more layers to understand the infrastructural role of so many different aspects of communication, writing, and design.

ACKNOWLEDGEMENTS

We want to thank all of the authors in this issue for their excellent contributions. It’s their work that makes this issue what it is. We also want to thank the former *CDQ* editor—Derek G. Ross—for seeing the potential in this issue and giving us such fantastic guidance. Ironically, Jordan is taking over as *CDQ* editor and will be the editor by the time this issue comes out, but both this and the next special issue were completed well before the position even became open. Consequently, we are very appreciative for Derek’s guidance and the *CDQ* editorial board’s feedback on the special issue proposal. And as we mentioned before, we are so thankful for every contributor who took the time to share their work and help us along the way.

REFERENCES


Utah State University.


### ABOUT THE AUTHORS

Jordan Frith is the Pearce Professor of Professional Communication at Clemson University. His primary research focuses on mobile media and communication infrastructure. He is the author of 5 books and more than 35 journal articles in a variety of disciplines, including communication studies, technical communication, media studies, and geography. He has also published in public venues like *Salon, Slate*, and *The Conversation* and edited multiple journal special issues. He is now the editor of the X-Series on Parlor Press and the editor-in-chief of *Communication Design Quarterly*.

Sarah Read is Associate Professor and Director of Professional and Technical Writing in the English Department at Portland State University. Her publications include single-authored and collaborative articles in *Technical Communication Quarterly, Journal of Business and Technical Communication, Written Communication, College Composition and Communication, Programmatic Perspectives* and the *Journal of Writing Research*, as well as the conference proceedings of SIGDOC (Design of Communication (ACM)) and Pro Comm (IEEE). In addition, she has published four book chapters in edited collections and recently co-edited (2022) a double special issue of *Communication Design Quarterly* on the topic of Infrastructure. She currently serves as Vice-Chair of SIGDOC.
Infrastructural Support of Users’ Mediated Potential

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ABSTRACT
As one kind of designed communication, technical communication is created for readers we assume use the content for some situated purpose. Understanding users and their situations to be varied, communicators rely on simplified models of both to create usable content. In many cases, this approach works, but in some commercial sectors, companies are recognizing a need to engage with users directly and to include them in the production of communication. Including users in the production of communication may ease the burden of communicating in ways that are sufficiently detailed, accurate, inclusive, localized, and timely, but these ventures also create challenges of collaboration that direct attention to how users are situated in infrastructures that allow them to act as effective readers and collaborators. This article presents a model of users, situating them amid infrastructures that extend their ability to take rhetorical action. The authors explain and demonstrate a heuristic for analyzing infrastructure as an extension of a user’s “mediated potential” for rhetorical action.

CCS Concepts
Information systems

Keywords
user modeling, social cognition, infrastructure, mediation

INTRODUCTION
As one kind of designed communication, technical communication is created for readers we assume use the content for some situated purpose. Understanding users and their situations to be varied, communicators rely on simplified models of both to create usable content. In many cases, this approach works, but in some commercial sectors, companies are recognizing a need to engage with users directly and to include them in the production of communication. Including users in the production of communication may ease the burden of communicating in ways that are sufficiently detailed, accurate, inclusive, localized, and timely, but these ventures also create challenges of collaboration that direct attention to how users are situated in infrastructures that allow them to act as effective readers and collaborators.

We are accustomed to thinking about how organizations and units within organizations act as social and technological infrastructures that mediate writing practice (e.g., Angeli, 2018; Spilka, 1998). Users, too, are situated within social and technological infrastructures that help them recognize means for accessing, interpreting, and using the information they receive. When these infrastructural systems overlap, as they do in collaborative documentation ventures, users appear far more complicated than simple user modeling would suggest.

The purpose of this article is to expand our understanding of users by examining how their capacity to access, process, use, and contribute to communication is entangled with their connections to local and networked socio-technical infrastructure. By theorizing the abstract function of infrastructure, we will argue for a model of users that accounts for their “mediated potential,” a capacity to use or produce communication enhanced by engagement with infrastructure.

After discussing how users have been modeled in the service of communication design, we will contrast that portrayal with one that situates users ecologically, within a socio-technical infrastructure. We then discuss infrastructure and its mediating effects, considering how user + infrastructure is a useful frame for thinking about how
users can engage with and create technical communication. The latter half of the article demonstrates how the concept of “mediated potential” can offer a better picture of users and suggests ways for collaborative documentation ventures to carry forward.

**USERS AND USER MODELING**

The concept of the *user* in technical communication is related to research on audiences that has occupied rhetoricians and compositionists over the years (Breuch, 2018; Park, 1982). The term “user” implies active engagement with content and reflects the instrumental nature of technical and professional communication (Moore, 1996). Accordingly, Albers’ (2004) method of multidimensional audience analysis accounts for audiences’ needs and expectations in relation to levels of knowledge, detail, and cognitive abilities. This approach encourages the modeling of users on a personal level. Similarly, persona-driven approaches also account for demographic and cognitive abilities.

Communicators tend to talk about users in terms of personas or as components of “scenarios” in which users enact scripts for engaging with content. This treatment of users as knowable factors in communication design is a kind of user modeling similar to what is seen in human-computer interaction (HCI) design. In HCI, a user model is “a representation of information about an individual user that is essential for an adaptive system to [...] behave differently for different users” (Brusilovsky & Millán, 2007, p. 3). Users might be modeled in terms of their knowledge, interests, goals, background, and traits like cognitive and learning styles (pp. 5–14). Models provide insight about how users might expect to interact with information (Lehmann, Lalmas, Yom-Tov, & Dupret, 2012, p.165; Scheve & Thalheim, 2006, p. 513). Consequently, by measuring user characteristics, information and information systems can be keyed to those characteristics to make content easier to find and process (Pirolli, 2007).

User models represent what can be measured and labeled about users relative to each other or relative to a standard. We can measure characteristics such as education level, knowledge level, proficiency level as well as personality characteristics (Scheve & Thalheim, 2006, pp. 514–515). Consequently, these models take what is complex about users and their contexts of action and “decomposes” that body of knowledge into more manageable “knowledge elements” (Brusilovsky and Millán, 2007, p.18). That is, user modeling involves the development and application of classification schema that regularize information about users and make them understandable across contexts (Bowker & Star, 2000, p. 72).

The appeal of understanding users through the lens of this kind of modeling is that users appear as a bundle of measurable variables. These models “emphasize information about the person” even if there are considerations of situation and environment collapsed into that profile (Allen, 1990, p. 513). Although this outlook on users might appear expedient, it offers only a limited view of users and their experiences (Williams, 2007) and carries the ethical danger of reducing human experience to those measurable outcomes (Katz, 1992). This is the problem with user models based on classification: they erase a lot of the differences between users within and across situations (Bowker & Star, 2000, p. 264). User experience is far richer in its historical, emotional, and geo-political contexts (St. Amant, 2017; Walton, Moore, & Jones, 2019). Even so, the need to understand users in the complexity of their situated experiences does not absolve us of the need to produce systematic knowledge about users and their experiences (Haraway, 1988, p. 579). It requires us to find a systematic way of engaging with the local circumstances of user experience. This is where an infrastructural approach to understanding users and their mediated potential for action is of value.

**INFRASTRUCTURE AND MEDIATED POTENTIAL**

Our view of infrastructure owes reference to 2nd wave cybernetic research (Pickering, 2010) and distributed cognition (Hollan, Hutchins, & Kirsh, 2000; Hutchins, 1995) in that it focuses on the user and their socio-technical infrastructure as a cohesive unit of study. In this sense, we include people and their social relationships as well as technologies and their cognitive, physical, and organizational affordances as aspects of an infrastructure. This socio-technical infrastructure is co-extensive with a user, forming a system. The infrastructure shapes a user’s sense of what is possible and appropriate (e.g., Star & Ruhleder, 1996, p. 112; Wiener, 1965, p. 6, 42). The infrastructure, in turn, is shaped by what has been accomplished.

As systems of socio-technical mediation, infrastructures are not only complex and layered in the present; they are complex and layered across time (Cole & Engeström, 1993). The voices of others, present in the form of technologies, interfaces, and texts speak from the past to mediate actions in the present (p. 20). Infrastructure is something that is always present but is something that users look through to the actions that they want to accomplish (Star & Ruhleder, 1996, p. 113), and it changes how users see potential courses of action (Gibson, 1986; Sura, 2015). As Dourish and Bell describe it, infrastructure is “the practical organization of space (that is, how spatial arrangements provide an infrastructure for the ongoing achievement of concerted action) and the cultural organization of space (that is, how the organization of space becomes an infrastructure for the collective production and enactment of cultural meaning)” (2007, p. 415).

As communication scholars have read it, infrastructures matter, foremost, not only because they are often made out of texts (Geisler et al., 2001; Read, 2020) but also because these infrastructures (textual or not) influence the social relationships that people cultivate, which are mediated by information (Hart-Davidson et al., 2007). A well-designed infrastructure can let users be the kinds of users they want to be. It enhances users’ potential for action, whether that would be accessing, processing, or creating information. Furthermore, well-designed infrastructures not only support individual users but also broker interactions among humans and non-humans (Read, 2019, p. 246).

This outlook on infrastructure allows us to see users in at least two ways. From one viewpoint, users are comprehensible as parts of an infrastructural, cybernetic system, in a steady state of existence: a set of capacities measurable within the system. By itself, this is a potentially insidious way of understanding users. Another viewpoint is to see infrastructures as living things that are iterated and potentially changeable between iterations. Infrastructures not only constrain and shape user action but create opportunities by affording user action as well as novelty and innovation. As people are introduced to and begin working in an infrastructure, they acquire an experiential understanding of its associated practices, standards, and expectations. As a system of constraints
and expectations, infrastructures are learned via participation in a community (Star & Ruhleder, 1996, p.113). Infrastructures grow out of practice whereby experiences acquire “thingness” through a process of “reification” (Wenger, 1998, p. 58). These “things” can become actual things like protocols, conventions, standards, texts, technologies, and spaces as well as identities and relationships. Infrastructure, in its thing-like state, mediates the incorporation of new people or other infrastructural components. In the way that a ship is built around an infrastructure that assumes a particular practice of navigation (Hutchins, 1995) and a cockpit assume a particular practice of flying (Hutchins & Klausen, 1996), other infrastructures assume particular ways of knowing and being (Wenger, 2000, p. 226, 238).

Infrastructures do not merely reproduce themselves. Infrastructures also hold the potential for creative experience and the ability to reflect on and learn from that experience. Infrastructures present the possibility for not only sharing work in a more efficient and controlled way but also for novel problem solving, which appears to be the intended destination of collaborative communication projects that seek to build infrastructures for engaging with users. Infrastructures foster the development of a variety of coalitions that are needed to get work done, and there is a great deal of invisible work in an infrastructure that needs to be supported and surfaced (Star, 1999, p. 386).

The work that needs support is creative and it builds from users finding new ways to draw on their experience and make legitimate contributions to a project within the limitations of the available infrastructure. All infrastructures support such user engagement (some more than others) by building what we suggest thinking about as a user’s “mediated potential” for action.

Mediated potential describes a kind of agency that arises from the support provided by infrastructure. The following are qualities of infrastructure that directly contribute to a user’s mediated potential for action:

- Oversight: the ability to see one’s own and others’ contributions
- Feedback: the ability to convert contributions into processable information.
- Adaptation: the ability to reflect on an action in process and make adjustments to the infrastructure or product of that action.
- Trust/Accountability: the ability to foster a sense of belonging, reciprocity, and common goals, and to be responsible for one’s contributions.

We will briefly describe these qualities before applying them to two descriptive cases.

**Oversight**

People who contribute to a community of practice and rely on a common infrastructure sometimes inhabit the same place (i.e., a hospital, an office, a field station). The shared space, its arrangement, and its lines of sight create a space for action that supports different kinds of oversight (peer, supervisor, automated) for shaping contributions that are consistent with convention (Suchman, 1996; Goodwin & Goodwin, 1996; Sellen & Harper, 2002). Oversight as an infrastructural quality refers to spatial, technological, and social factors that allow human and non-human actors to observe the actions of others. Oversight mediates a user’s potential for action by ensuring that they recognize the outcome of their own actions and review them for consistency along with the contributions of others. Furthermore, oversight enables easy error identification and correction (Heath & Luff, 1996; Hutchins, 1995). Some oversight and roles may be by design, and others may be ad hoc.

**Feedback**

Feedback is information about an activity. If the activity is expected and conventional, the feedback may be relative to a standard (Wiener, 1965, pp. 6–7). Feedback helps bridge the gulf of observation between how an individual thinks about and takes action (internal) with the expectations built into the infrastructure (external) or that potentially arise from it. Humans and nonhumans alike are blackboxes whose inner workings we understand through reflections of their actions but cannot otherwise understand without designing feedback systems to turn what can be observed into data (Pask, 1961, p. 12). That is, human beings are not capable of sharing thoughts, experiences, or emotions holistically, only partially. And for that information to be shared it must be converted to some tangible, mobile form (Latour, 1986) whether as language or demonstration or something else. Feedback as a characteristic of infrastructure supplies some kind of sign, like a light, a sound, a badge, an email, or spoken language, all of which needs to be interpreted as an indication of progression or regression on a task. For users, an infrastructure supporting feedback allows them to contribute or comment upon actions taken by others and to do so in a way that can be conventionally interpreted. It supports the creation of infrastructural relationships to generate and/or interpret feedback.

**Adaptation**

Adaptation is the ability to interpret feedback relative to one’s goals and to determine whether action is heading in the right direction or diverging from it. In cybernetics research, response to feedback was automated, algorithmically. Systems monitoring feedback had control thresholds to understand how to regulate whatever activity was being monitored (e.g., traffic). But in infrastructures supporting rhetorical work, there is more uncertainty. The goals of action may be clear but the contribution of any one step may not be, requiring the guidance of “a manager” to interpret feedback heuristically or relative to a changing goal (Beer, 1972, pp. 72–75). As an infrastructural quality, adaptation may refer to a collection of tools for intervening in a course of action (e.g., commenting, flagging for review). It may also refer to flexibility in the way that work can be accomplished. As a form of mediated potential, adaptability refers to a user’s ability to evaluate a course of action, choose a new one, assess feedback about the change, and perhaps articulate a better understanding of what is valued as an outcome.

**Trust and Accountability**

For people to stay engaged in a work project, they must trust that others who are contributing are doing so in good faith and with good intentions (Frith, 2017; Walton, 2013). Achieving this trust and commitment to an overall goal is important, but so too is accountability. Building a sense of trust is partly accomplished by identifying links/connections with others. These links may be strong or weak, describing how close or reliable or active those relationships are (Granovetter, 1983). The links may also be latent, but the infrastructure is capable of supporting them (Haythornwaite, 2002). Links also have a degree of distance (e.g., how many connections one is away from the CEO) which
opens channels for communication that can help create actual and visible accountability. Infrastructures not only facilitate these small acts of relationship building – they also potentially make them visible. Organization charts, review cycles, review chains, messaging all help promote links, which as they become denser and closer, promote greater reciprocity or the trust that what one puts in one gets out (Carroll & Rosson, 2003; Faraj & Johnson, 2011). As an infrastructural quality, trust and accountability are created by visibility and access to the various contributing actors but also through transparency of how they are acting. As a form of mediated potential, users gain trust by making themselves accountable to comments and guidance from others. As trust grows, users have a greater ability to make meaningful, continuing contributions.

To illustrate these characteristics, imagine a situation in which a user might be a technician using a field manual to troubleshoot a fiber optic connection at a busineess park. Technical communicators can develop effective field manuals to support that work by recognizing the need to establish clear goals and standards for proceeding in the work (Trust/Accountability). The field technician’s ability to complete the job may also be enhanced by a field manual that allows the technician to test their assumptions, to evaluate possible courses of action (Oversight, Feedback), and then to make adjustments to those plans based on the feedback from the system or the clients (Adaptation). Furthermore, the field manual might provide information allowing collaboration with the home office (Oversight, Feedback) and allow the technician to pass along assurances to customers (Trust/Accountability). In this way, effective manual design takes into account the ways that the field technician’s capacity for action (on site) depends on fostering a relationship within the local and remote infrastructures in which that work takes place.

The same kind of support is at work in the cases described in the next section. By focusing on cases of collaborative document creation, we aim to illustrate how users interact with socio-technical infrastructure, extending their ability to participate in the design of communication. Although this heuristic for reading infrastructure and mediated potential is applicable beyond these cases, the high visibility of the socio-technical infrastructure in the following cases helps us illustrate the mediating effects most clearly.

DESCRIPTIVE CASES
Our descriptive cases will focus on the version control platform GitHub and a large-scale documentation project supported by a user community via a wiki. Before applying the user model to these projects, it is important to bring forth the characteristics of these collaborative projects/platforms, their architecture, as well as the affordances and challenges they provide for the purpose of knowledge production. The architecture and design of these platforms highlights the opportunities for social interaction, which can be used to identify and describe the mediated potential for action. To summarize from earlier sections, infrastructures are complex and layered over time; they are made of texts and allow human and non-human interactions thereby influencing social relationships through knowledge production; and users are significant components of infrastructures who have the ability to change the knowledge production platform with each interaction.

Our first case is a pull request on the GitHub platform. GitHub is an online platform that provides hosting services using the tool Git (a version control system) which allows efficient management of any information developed collaboratively (for example source code, documentation) by users. The multi-layered platform allows users to create a personalized local copy of information, make changes, and, with the permission of the owner of a central repository hosted on GitHub, integrate local changes with the central repository. Every permitted, updated version of information is saved in the central repository, and locally revised versions are saved in local repositories. These characteristics allow multiple collaborators to work on the same projects without interrupting each other’s progress. This process of locking a personal copy of a problem until it is solved, and then merging the solution with the rest of the content, is continuous. It is likely for users to review new problems on each visit.

Similarly, wikis, our second case study, are collaboratively owned and edited projects. They are among some of the oldest and most familiar pieces of internet knowledge infrastructure that are still in wide use today. A wiki typically consists of a series of articles developed by users, held together in an overarching organizational structure, maintained through version control for content and an underlying communication channel for users. Members of the wiki community register as contributors to the site and make contributions under their usernames. Additions or changes are reviewed and retained, rejected, or further changed by other members of the community or by site administrators. For this study we look at the wiki set up for the Imager documentation and its community.

As defined by Forte and Lampe (2013), open collaboration projects are collaborative and distributed efforts made possible and facilitated by ICT. They define a typical open collaboration system as an online environment that (1) supports the collective production of an artifact, (2) through a technologically mediated collaboration platform, (3) that presents a low barrier to entry and exit, and (4) supports the emergence of persistent but malleable social structures (Forte & Lampe, 2013). Distributed and collaborative projects are challenging for several reasons, but an underlying factor is that they provide users with more agency to author, review, and repurpose content (Andersen, 2013; Andersen & Batova, 2015). And that work requires rhetorical effort that becomes possible by the extension of users’ production potential made possible via infrastructure. By reaching that rhetorical potential, users are better supported for meeting the challenges of participatory knowledge creation, such as:

- **Information production**: how individual users come to recognize what counts as a valid contribution to a project. What are the genre features and what are the means available for a person to make a legitimate contribution? Methods of producing information should be compatible with those made by others. Products of that work should be recognizable as contributions, and they should afford engagement and review by others.

- **Information curation**: how contributions are selected for integration into a project. As contributions are evaluated for integration, how are they identified, categorized, and assessed? Once a contribution is selected for integration how is it labeled or described to provide guidance for others about how to build upon it?

- **Information integration**: how contributions made by users become a part of the overall project. Assuming that contributions are made and reviewed by others, how
are users assisted in updating the project, making sure that their contributions are lasting and becoming the foundation for subsequent contributions? One’s potential to make change, to respond to the rhetorical situation and create new conditions for subsequent contributions relies on infrastructural support.

- **Identification**: how are individual contributors or blocs of contributors known within the overall project? What connection do they have to the project and to other contributors? A user’s perceived expertise or ability to contribute may ride on how they identify and contextualize their contributions.

- **Community Guidelines and Policies**: how do individuals come to know the community and what it values from contributions to the overall project? What expectations does the community have for accountability, trust, reciprocity, and engagement? How does the group build social capital and ensure that those users who participate in the group enterprise have the community’s needs in mind?

Distributed, collaborative documentation projects like GitHub repositories and wikis are fairly common. Moreover, these projects embody the central concern about creating documentation for highly situated user groups: allowing them flexibility to be active in shaping and applying that content. By providing a deliberate infrastructure for rhetorical participation, platforms like GitHub and wikis explicitly illustrate how infrastructure allows users to be more active as both producers/consumers of communication. Moreover, these projects embody the central concern about creating documentation for highly situated user groups: allowing them flexibility to be active in shaping and applying that content. By providing a deliberate infrastructure for rhetorical participation, platforms like GitHub and wikis explicitly illustrate how infrastructure allows users to be more active as both producers/consumers of communication. Our aim in the coming sections is to show how doing the work of information production, curation, and integration is how users contribute to those rhetorical situations, but that work must be supported infrastructurally.

**Mediated potential #1: Pull request on GitHub**

The basis for this analysis is a pull request (PR) from Microsoft’s product documentation titled, “Added procedure to open Performance Monitor #2562” or “CS 1”, hosted using GitHub. A PR is an event that takes place when a contributor is ready to begin the process of merging new content with the existing content in a repository. While creating a PR, users need to sign into GitHub. Users enter the backend space of the content storage where they can edit the content, create a PR, and submit it to be considered for merging with the main content. The content of the PR varies based on the user’s experiences of using content, circumstances for change, and the format in which the user decides to convey their message. For example, if a user finds inaccurate information such as a UI component mislabeled in its documentation, the user can replace it with the correct label name in their PR that is then submitted to the moderators for review. However, if the site’s navigation is not working correctly, they can decide to provide feedback as a comment. After making the desired change, users push the PR so that it can be merged with the main documentation. It is important to note that while GitHub is not the only tool that provides capabilities for collaborative authoring, its infrastructure is supporting users to take rhetorical action that promotes user agency and co-authoring.

In CS 1, user thethales created the PR (https://github.com/MicrosoftDocs/windows-driver-docs/pull/2562) to add a small snippet of content – a new procedure to open PerformanceMonitor (https://github.com/MicrosoftDocs/windows-driver-docs/pull/2562/commits/6be04e06cb2335ae0912025ba52cae0e4eb8241). The PR was assigned to the designated official DOMARS by Ted Hudek, another user associated with Microsoft, and handled by DOMARS until it was merged with the original content that appears on the public facing documentation site (https://docs.microsoft.com/en-us/windows/hardware/drivers/debugger/ determining-whether-a-leak-exists). Several scenarios for users’ mediated potential are created through the various possibilities for action afforded by GitHub’s infrastructure.

**Information production**

There are two ways to develop content on GitHub: first, create a new repository and write or upload new content to the repository; second, create a pull request to propose adding, deleting, or modifying existing content. A pull request (PR) is used by GitHub users to produce content. A repository is essentially an online folder containing a coding project’s files, revision history, and discussion history among collaborators. Before users can contribute to a repository, they must open requests and propose the changes so other users can review and comment. This process is called “open pull request” on GitHub.

To propose a change or leave feedback that requires changing the content directly, users first click on the Edit button, enter the backend space to access tools to make necessary content updates, including writing a comment for content managers, and submit a pull request to notify the documentation managers or a request to accept the change. This method can be categorized as a hybrid feedback mechanism, between invisible and visible (Ranade, 2021), since users can see the content they create, but the input may not necessarily be publicly visible. There can be various layers of access, but, primarily, it can always and only be viewed by content managers and users themselves (who created the request). This connection builds trust among users and gives them the confidence to contribute. While the pull request is partially private, it is not anonymous. Users who contribute willingly must accept to share their GitHub account details which makes it possible for them as well as for content managers to track changes. This established accountability is necessary to make changes that are required for the documentation.

Other users can only view the content added if they open the backend as well. PR creators are not contributors until their request gets merged into the original content. This provides them an opportunity to share their experiences with other content developers and with a complete understanding that their experience might be unique and not reproducible by others. Before including the new content, other users can check for its accuracy for adaptation.

**Information curation**

Users can propose what the group should do with content and also aid in research and information gathering activities (Zhen, 2021) related to the project. Although GitHub primarily serves as a content storage and version control system, the repository itself acts as a storage place for conversations made by all collaborators while making decisions about what content must be published.
The repository becomes a digital collection of justification for changes, back and forth messages between stakeholders, and research evidence, as well as a discussion forum for any other content related to that specific repository. Versioning is achieved through timestamps associated with all these conversations, in addition to dates attached to published content. When publication cycles were fixed, rhetorical changes associated to time were only recorded for specific versions produced over definite time intervals. A continuous development, the continuous integration (Ranade, 2021) model allows for constant updates to documentation projects published in real-time. Thus, the feedback channel also acts as a tool for oversight and the conversation threads make contributors accountable for their actions.

Owners (or moderators) can message users who wish to contribute (or propose a change). Until the content is merged, a discussion can take place in the discussion forum where any user can participate. Not all users can view changes being made or proposed to the public facing content until they have been merged. This space allows collaborators to communicate about changes, express ideas, assign tasks, discuss details, and conduct reviews. These actual and potential coalitions influence whether and how contributions are merged into the main project. Since all users go through the standard system of proposing changes, the infrastructure adds another layer of trust.

Information integration
After users propose changes using PRs, original creators or moderators of the content can review those changes and relevant discussions to decide whether to integrate the content for adaptation. If they decide to integrate the changes, they can merge the copy created by the user with the original "master" document. Once a pull request is merged, the entire content on it including the organization structure, content style, and formatting get copied into the main repository, giving users power and agency to control all aspects of the content they propose.

Identification
Users who want to create a pull request, post to the discussion forum, and/or comment on existing content spaces are required to have a GitHub account. The account names are unique and help distinguish one user from another. Identification is only partial because although the GitHub account name is unique, users can choose to not disclose any personal information. Some users, however, prefer to share these details to gain credibility. The GitHub infrastructure supports such rhetorical work by allowing users to create need-based profiles to establish accountability and trust that other platforms may not be able to deliver as seamlessly.

For the PR in this case study, three different users’ identities are revealed which describes their occupation and location. The account names of these users can be tracked from the 1) contributors listed on the public facing documentation site’s webpage; 2) user names listed on the GitHub’s workspace (backend) where the repository is stored and can be edited; and 3) discussion forum where users communicate needs, evidence, justifications, decisions, and other such information with each other. The account names appear in these spaces which can then be traced to the user account pages which reveal other information shared by users.

Community guidelines and policies
There are two levels of guidelines users must abide by when contributing on GitHub. The first are guidelines about ensuring open collaboration to build a stronger community. These guidelines include what must be done in case of offensive language, what language is allowed and considered appropriate, what happens if someone breaks rules, and so on.

The second level of guidelines is established by the repository owners. For example, in this descriptive case, the repository is owned by Microsoft. The company sets guidelines for its users on who is allowed to contribute and what steps need to be taken to ensure appropriate collaboration practices. The second level also determines the style of writing, language, and other principles which are specific to the company.

The constant moderation of the feedback system provides oversight capabilities while also establishing strong protocols for developing a community that shares trust and feels accountable for validity and accuracy of content developed by and for the community as a whole.

Mediated potential #2: Wiki revision
A different kind of infrastructure is seen in wiki-based documentation projects, such as that for a 3D imaging technology: Imager. Although the documentation for this software has since moved to GitHub, it originally existed on a wiki. As the developers added seed topics to the wiki, end users and developers added information regarding functions and use scenarios. One example is the development of an “Annotations” page, on which the developers started a list of the software’s originally-designed annotation capabilities. Partly as a result of conversations happening on the software’s email list, new annotations were developed, and old ones were changed, in response to foreseen and unforeseen user needs. The annotations wiki page illustrates how the infrastructure of an email list plus the wiki platform shapes the kind of rhetorical inaction that users and developers alike can have.

As with the GitHub case, the documentation for Imager was placed on a wiki to allow users to contribute to its development. Although the software was designed for medical diagnostic work, it became apparent soon afterward that professionals in other fields were finding uses for the tool as well (e.g., dentistry, geology, anesthesiology). Consequently, writing the documentation to fit both the intended use case and other viable use cases needed to fall on the broader community whose rhetorical contributions to the documentation project both made the documentation useful across use cases while also influencing the software’s functional development.

Information production
Like other wikis, the Imager wiki supports a simple model of information production. Users who are logged into the wiki space navigate to pages containing topics of interest. Once on a topic, users can choose among the “discussion,” “view source,” “history,” and “edit” tabs. Those who wish to make changes to the documentation may open the “edit” tab, which will take them to a word processor interface containing minimally formatted contents of the page, including special characters showing the sections to which users can make contributions. Users can either delete, change, or add new content to the wiki page and style it. Having direct edit access for each account-holding contributor allowed for ready adaptation or supplementation of the content to accommodate their experiences or use cases.

Once a page is saved, the new version becomes live and a record of the change is generated in the “history” tab. The “history” tab
shows a record of all changes made to the wiki from the start of the seed page. Each history record will show a visual depiction of the changes between the current and immediately previous versions. In different wiki platforms, the changes will be highlighted. At the same time, the change (or addition of a new page) is added to a site-wide list of recent changes. The historical record acts as a feedback channel and a mechanism for oversight. The highlighted edits differentiate new contributions from the old and make the work and its contributors visible and accountable for their contributions.

An alternative route to making a contribution on the Imager wiki is to utilize both the discussion forum (once an email list and now an interactive Google Group) to introduce topics of interest and concern. The discussion group is frequented by the software developers, the communication team, and end users. Discussion topics introduced in the group are often refined throughout the course of a conversation. Points are clarified. Suggestions are taken and sometimes developed into changes in the software. Once discussion has taken place online, users may incorporate the result onto the appropriate wiki page. The wiki itself also supports discussion of changes, but it is infrequently used. The discussion forum is an important part of the user community if only because it is a place in which one establishes a commitment to the community by discussing changes. Users who contribute willingly or who are redirected to the discussion forum build the necessary connections to establish the trust and accountability necessary to make changes that will stick in the documentation. Making changes is easy. Making them persist requires building social capital that is afforded by the discussion forum.

**Information curation**

On the surface, a wiki page shows only the latest version of a topic. It reflects current thinking or currently proposed thinking. However, beneath the surface, in the “history” tab, is an archeological record of the changes that led to the current version. Investigation of the changes can reveal the evolution of the topic as well as iteration of content as users have come into contact with it. Sometimes these additions and changes may be accompanied by notes explaining the reasoning, but often they are not. Furthermore, the feedback record provided by the version history will also show implemented and reverted changes, sometimes revealing a level of adaptation that users would like to see in the software. Even if those changes do not persist, they may support dialogue that results in other changes to the documentation or changes in the software product itself.

On the Imager wiki, the contents of some pages (e.g., Annotations) show the evolution of the software but also a collection of end user experiences that end up in the documentation. Conversation from the email list has reflected a growing community of end users within the medical field but also from across other fields that benefit from 3D imaging. The contribution of those experiences and case scenarios is, of course, preserved in the email records, but also in the history of changes on wiki pages. As use scenarios are raised and discussed, they are sometimes integrated into changes in the wiki, either by direct reference to the use scenario or through the development and documentation of new features that reference those scenarios (Gentle, 2012). The revision feedback, especially when monitored by developers or the community, provides a level of oversight and accountability that can lead to productive discussions about developing the documentation or the software product itself.

**Information integration**

Changes made to the wiki space are integrated automatically, which supports spontaneous adaptation of the content, even if only temporarily. Unlike collaborative platforms, where supervision and oversight occur prior to publication, a wiki makes new content live immediately. For wikis that are actively used or at least actively monitored, changes will be noticed either because the wiki notifies site owners or because readers will notice a change in frequented topics. Review is then retrospective. If any user decides that the content is either inaccurate, inappropriate, or unnecessary, the change can be reverted to the previous version. Changes that are accepted or allowed to stand await scrutiny of the next reader. Eventually, successive changes are layered upon other changes, burying some changes below others. The process is one by which facts or more stable forms of knowledge are created by pushing attention away from the moment of their creation and by giving legitimacy by building upon those contributions through acts of trust building, like reciprocating help given and being available and accountable for discussion of changes (Swarts, 2018a). Content that is rejected for contribution to the wiki page may generate a call for discussion. The issue may also work its way back to the discussion group if additional input is sought for evaluating a contribution.

**Identification**

The importance of identification may vary across wiki sites, but most offer functionality for creating a profile through which to add or edit content. Even wiki sites that allow anonymous editing still record IP addresses so that some level of accountability is present. Often users are identified by a name and any contact information supplied. Profiles of users may provide only biographical content, but other wiki sites may show a summary of contributions made across the site: pages edited, new pages created, which is a record of feedback about a contributor. For profiles that show a person’s record of site activity, the details may give a sense of the person’s longevity in the community and their level of commitment to the joint enterprise of building the wiki site.

In the Imager wiki, users are required to identify themselves in the process of enrolling on the site. Anonymous editing is not allowed. The profiles require biographical information of 50 words or more, and although there are no requirements of what to include, many contributors provide institutional affiliations that reveal their professional connection to the software, as well as their professional context for utilizing it. Prospective wiki editors are also asked to provide an explanation of why they want to edit the content of the site, but this information is not included as part of their public identity.

**Community guidelines and policies**

Wikis can vary in the degree of specificity of their community standards for participation. However, one implicit consideration is that community members need to be respectful of the community effort to create knowledge. No vandalism or intentional efforts at generating misinformation is allowed. A wiki is a resource shared and maintained by a community of practice whose members buy into the project of building a knowledge base because those efforts build social capital for all members (Pan, Shen, & Feng, 2017). The community is built on a sense of trust that members are acting in the best interests of the group and trusting that the efforts any individual makes to the overall project are reciprocated, if not directly then in general, by supplying information about questions yet to be asked or are by providing oversight to ensure the accuracy.
and currency of the information available.

More generally, there is another implicit expectation that changes to the content of the wiki should obtain community acceptance in order to stand. When it comes to making changes to content that has been previously added, one must remember that changes are adaptations of contributions made by others. In a way, this ability to adapt one another’s contributions directly, instead of directing all contributions through site owners, as obligatory passage points, is a significant affordance of a collaborative platform like a wiki. Out of respect for the original contributor, but also for the broader community, all contributors are expected to engage with the community and be accountable for what is offered as knowledge.

It is worth noting all the circumstances for participatory knowledge afforded by GitHub and wikis to understand that they are only made possible through the design of their infrastructures and the constant participation of users. The next section summarizes details about the socio-technical infrastructure’s capacity for inventing mediated potential and simultaneously recording users’ individual needs and characteristics. Observing these collaborative platforms closely across the aforementioned infrastructural framework will help us design infrastructures that increase users’ potential for action while being receptive to their individual needs.

**MEDIATED POTENTIAL IN GITHUB AND THE WIKI**

GitHub and Wiki are both examples of infrastructures where mediated action is initiated through the interfacing of users and the infrastructure that contributes not only to information development, but also to fostering community alliances aligned by common goals of solving content problems and keeping the content up-to-date. Both examples demonstrate that users on these platforms are not simply producing information; rather, their actions are mediated by using tools, artifacts, and cultural devices afforded to them by the infrastructures.

**Oversight**

Oversight helps in the overall conceptualization of tasks carried on the two content development platforms. Because these are both large projects, individuals are better able to control when contributions can be easily reviewed.

The GitHub space is shared by writers, editors, technical communicators, testers, developers, end users, support employees and so on. Their actions are mediated through the spaces impacted by the contributions they make, for example, focusing attention on each PR created and expecting a merge, as well as on each issue that requires closure, etc. The infrastructure relies on (temporary or permanent) coalitions among users and other stakeholders where each of them assumes roles that help them contribute toward a commonly shared list of predefined goals.

The Imager wiki is highly driven by organizational structures. User roles are predefined while goals are determined by content contributors and the team of moderators reviewing any content change. While edits are accepted immediately, they are reviewable by the entire community enabling an error detection system.

Both GitHub and wiki rely on temporary coalitions (between users and site admins) which are made to publish a content change and end in content publication. The infrastructures’ designs act as mediating tools to enable users to continue the revision process even after the change is published.

**Feedback**

While feedback systems such as like/dislike do not really convey the message of whether content was useful for the user or not, converting the feedback into data is important.

GitHub gives the users an opportunity to convey their feedback by converting it to actual content that can be embedded within the existing documentation topic, or as comments in the form of messages in discussion spaces. Such feedback becomes accessible to other stakeholders as well, and all participants can collaboratively incorporate it into the content system supported by the infrastructure. Contributors not only control the content in the feedback communication, but also the arrangement and delivery (Ranade & Swarts, 2019).

Pull requests are a form of feedback that are relative to the content. Users create pull requests by making content-specific modifications and writing what they need in their own words. They use the style guide provided to them by the corresponding organization. Contributors also receive feedback through the content that users add in the discussion posts to either justify their pull requests, also known as ‘commit messages’, or replies to exciting messages posted in the forum. These messages are formatted in a communicative style usually directed to the author or humans in the knowledge network who are visible on the discussion platform. The discussion fields on GitHub are a space in which pull requests are either accepted or challenged or revised. In this sense, the conversation happening in those spaces provides feedback by which a contributor can see how their contribution, as envisioned, was taken up or not taken up. If the contribution did not bring about the difference intended, the shortfall is often clear or can be clarified. This feedback and oversight function helps ensure the development of skilled contributors.

The Imager wiki also solicits feedback in two similar ways. The first is where users can make the change into the wiki directly. However, unlike GitHub the change is directly reflected in the public facing content, and moderation is retrospective. The wiki provides feedback about the changes made and specifically shows what was added and deleted so that others can review and accept or revert. As with the GitHub space, the wiki space also provides some feedback when changes are reverted, but only if the person making the revision chooses to comment on it. The Imager discussion forums and history pages associated with a topic can provide a detailed picture of how the content was developed and how it evolved. In fact, the richness and immediacy of feedback in the email discussions shows how potential changes to the Imager wiki project are taken up by constituent audiences (e.g., developers, end users). The conversations show what contributions may be valued and provide some feedback about how the community would perceive those changes, all of which helps an individual contributor to be more sure of their contributions.

Since feedback systems allow users to get insights on how other users think, process information, and their expectations from content, it leads to real-time adaptation (Ranade, 2020) of their own goals and methods of processing information.

**Adaptation**

Adaptation often happens after feedback is received and while it is being integrated into existing content. Infrastructures can either force adaptation or recommend it through community guidelines.
or similar protocols. In the case of GitHub, adaptation of approved changes to the documentation project depends on contributors informing themselves of how to make changes suitable for integration. Adherence to organizational stylistic standards is a must and links to corporate style guides provide some support for contributors. Editors and repository owners provide other support by either adapting the content for integration or pushing back to the contributor with guidance for improving the content. Actual integration of the pushed changes to the documentation is handled by the GitHub software.

The negotiations that can take place in the process are a key byproduct of the feedback-integration process. GitHub allows such negotiations to happen through a direct communication channel between users and other stakeholders through the discussion forum and commit request comments. In the Imager wiki, adaptation of the content is the default. The word processing interface and the embedded user support for including special characters for formatting contributions ensures that any individual contributor is away from what technical criteria must be met for successful adaptation. Adaptations to the content then go live and await engagement by the community or the site owners who scrutinize the content. Those adaptations that are deemed appropriate will hold, but those too, many eventually change as the software develops. But the wiki platform also provides the means for users to challenge an adaptation or contribute to an adaptation provided by others, and this level of equal access to the means of adaptation as well as the relatively easy ability to undo adaptation supports both individual and community-mediated contributions.

The back-and-forth communication channels provided by both these platforms ensures clear communication. Stakeholder access to communication channels ensures the validity of negotiations. Since technical writers are part of the same infrastructure, they make it possible for the change suggested by the user to be accepted for publication.

Trust and Accountability

While direct communication channels reinforce trust and accountability among stakeholders, mediation and the transparent process of executing the publication process is a major strength of both GitHub and the wiki.

Like other information media, GitHub and Imager wiki are also information delivery platforms, but unlike others, GitHub and Imager wiki are also the tools of content development. Therefore, users can participate in content development, provide feedback, understand whether and why the feedback was accepted or rejected, and also interact with the ones handling their feedback and without long waits. This process is called a continuous development/continuous integration (CI/CD) model which makes GitHub and Imager wiki powerful infrastructures.

GitHub and Imager wiki seem to demonstrate a flat hierarchy, where all users can contribute to edits and provide feedback for the existing content, view content updates and discuss inclusion and exclusion of content, but the platforms have an embedded hierarchy where certain users such as official content developers appointed by corresponding organizations (in the case of GitHub) and software developers (in the case of wiki) have more access. Rather than limiting users' access to the editing space, users' interactions are managed through a smart interface design allowing oversight.

The structure and visibility of the GitHub and Imager wiki communities also contribute to how individual contributors can both know their place in the community, identify community norms and expectations, and participate peripherally as they work toward more meaningful and direct contributions. Such scaffolded development and integration of a community or rhetorical situation is never a given. The delineation of access mediated by infrastructure helps users establish trust in the platform and builds harmony among the coalitions. Content revisions that take place persist because of coalitions built with the community through feedback cycles.

Distributed content platforms, and open feedback systems such as GitHub and wikis modify the role of technical communicators making them content organizers and content moderators (Swarts, 2018b), data analysts and project managers (Ranade, 2021). This research shows that they can also get involved with ensuring the rhetorical role of infrastructures to support user contributions and thus promote a model of users as engaged rhetorical actors. In addition to content development, technical communicators can contribute to the content design and make informed decisions about its supporting infrastructure.

CONCLUSION

The rhetorical situation presented by these large documentation projects and, indeed, other project management endeavors is at a level of complexity that individuals would have a difficult time identifying how to make a legitimate contribution. The work of information production, curation, and integration are so tied to issues of contributor identity and community acceptance that the technological infrastructures become necessities for people to take any kind of action. By applying this infrastructural framework to different rhetorical situations, one can see users in a different light, as engaged rhetorical agents who participate in acts of interpretation and content creation by utilizing the rhetorical potential afforded to them by socio-technical infrastructure.

The main limitation here is that only two descriptive cases are used. However, the cases picked for this research are based on what can be considered “typical” in the field of technical communication, likely to achieve generalizable findings. The findings of this research will contribute to theory building about infrastructures, audience participation, coalition building, and role of technical communicators in analyzing other concrete situations engaged in knowledge building.

Although our descriptive cases make the argument that infrastructure and mediated potential help us understand collaborative, open-feedback systems like GitHub and wikis, the applicability of these concepts is broader. GitHub and the Imager wiki allowed us to show examples of designed and visible infrastructural environments that encourage users to be engaged participants in the rhetorical construction of meaning. The GitHub and wiki infrastructures afford forms of rhetorical interaction. However, affordances apply to users in other infrastructural settings as well. Consider the earlier example of a field technician troubleshooting a fiber optic connection in a business part. That technician’s socio-technical infrastructure was far different than GitHub or a wiki. For one thing, the technician was not altering the content of the documentation being used, but the technician did rely on both the documentation and the broader socio-technical infrastructure in order to engage in the work. In that situation, the object of the work was to make sense...
of the documentation on site, given the peculiarities of the fiber optic set up, the needs of clients, and the expectations of the home office. Meeting all of those demands requires a user whose potential to engage in the work is mediated and enhanced by infrastructure, and it is best to update our understanding of users by considering their engagement with infrastructure.

One implication of this proposed method for analyzing the act of technical communication and work supported by the products of technical communication is to recognize that users are not uncomplicated, passive consumers. Users are situated within socio-technical infrastructures that make different demands on the kind of work they are trying to accomplish. Users rely on infrastructure to support that work, which suggests that designers of technical communication solutions should cultivate a way of anticipating and analyzing both the user’s work demands, limitations, and affordances of the local and networked infrastructures supporting that work. We can design better communication products when we understand how those products fit within an infrastructure and become part of it.

ACKNOWLEDGEMENTS
We would like to thank the journal editor Derek G. Ross, and guest editors Jordan Frith and Sarah Read for helping to advance the state of knowledge in this domain through this special collection of articles. We also appreciate the contributions of our reviewers, for their insightful suggestions.

NOTES
1. Although the term ‘master’ has been used for technical accuracy, we do not sanction the master-slave terminology of GitHub. GitHub has updated these terms in 2020, however, since the repository used as the case study here was developed before the change, the name of the main branch remains to be “master” in this discussion.

2. Software name and wiki site name are pseudonyms, in accordance with IRB approval.

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Automated Infrastructures: Participation’s Changing Role in Postindustrial Work

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ABSTRACT
As artificial intelligence (AI) automates technical and dialogic processes, technical communicators produce value through articulating complex problems, facilitating new forms of participation, and managing user-generated content via experience architecture. Automated and intelligent agents are least able to grasp the context of experiences, requiring human input/feedback for maximum performance. The examples we trace both prepare communities to embrace AI as part of the available information infrastructure and create an automated infrastructure of intelligent augmented action. Following Star’s anthropological investigation of infrastructure, we analyze organizational examples where rhetoric entangles AI, automation, generative design, additive manufacturing, gift labor, and assembly lines.

CCS Concepts
Information systems

Keywords
AI, automation, technical communication, participatory design, experience architecture

INTRODUCTION
Robots and other assistive technologies have become part of human-machine teams, valued as collaborators. No technology yet simulates users’ input in design. However, several emerging technologies discussed in this essay allow for greater automation of input, altering participation. This automation is part of the infrastructure of postindustrial work. Attention to crucial areas where authentic encounters (Sullivan, 2017) offer the biggest reward to work teams will continue to differentiate rhetorical labor from other forms of symbolic-analytic work. Simultaneously, user participation animates academic inquiry by development of research methods and reveals automated infrastructure in which processes, technical partners, and institutional cultures support and resist action by organizations and their stakeholders.

A user-centered orientation to technical and professional communication (TPC) provides a durable foundation for research and practice. Dialogue with people, our messy and expensive human encounters and engagements, are the point. While resource intensive, there is no replacement: artificial intelligence, statistical modelling, and representative personae may augment and enhance communicative practice, but such modeling does not replace authentic interaction between designers and users, authors, and audience.

Modeling may be used after interaction, or the model will not replicate human input. Authenticity remains an important locus for discussions of the continued identity of the field as a cohesive program of research and teaching. Determining the extent of user participation and the role of audience become fodder for interaction rather than problems to solve. For example, expert photographer Pye Jirsa discusses elements of the image creation process recognizable as automated infrastructure.

To paraphrase Jirsa (2021), the transition from analog to digital photography displaces technical expertise that had previously been a barrier to entry. Jirsa asserts photographers were always more than technical experts: automation of cameras, lighting, and processing allows non-experts the ability to create technically
proficient photos. Ready access to online tutorials and training make it easier to go beyond technical proficiency. In response, Jirsa asserts that professional photographers are not just selling photos, but rather “selling the ability to understand client values and needs and translate that into a photograph” (17:20). Jirsa subsequently raises an important rhetorical question, “What AI could sit across from me asking the right question, understanding what I want to communicate, and then translate that into the photograph?”(18:40). Dialogue is the process of photography.

Jirsa recognizes that high-quality photos can be produced with ubiquitous tools—our phones—and the process of editing is accessible because of advances in interface and automation. The rise of DIY content production across a range of industries—in which producers create custom and personalized products, performances, and services—coincides with increased technical accessibility and automation. When technically sound content can be produced by casual users, what is sold is an experience, guidance and insight provided by an expert. As Jirsa points out, “if you’re leaning on the photograph as being that thing that you’re selling, then you’re always going to be beholden to the person who can do it cheaper in every situation” (19:01). Process is participatory.

Jirsa does not discount that professional photographers continue to be technical experts and artists. Part of selling a good client experience is being technically competent with a camera and understanding the fundamentals of photography. Practice, along with automation, makes the technical parts seem easy and allows the photographer to center the rhetorically complex task of satisfying clients. Every camera can still take bad pictures, whether it’s a film camera or an AI-supported smartphone. But when starting a photography business requires only a camera, memory card, computer, and minimal training, Jirsa’s premise is that being good at taking pictures is not enough to sustain a career. This echoes Robert Johnson’s argument that the ability to document technical expertise through writing is insufficient to sustain the field of technical communication (1998).

Participatory design is value added as it is woven into the content creation process. This relationship between the professional and the client is significant precisely because technical communicators have long been defined by their ability to communicate between subject-matter experts and other stakeholders. Woven into such processes, user participation is central to professional engagement, even if the role of the professional is diluted, as in Faber’s (2018) analysis. Increasingly, content producers act as technical communicators when they “[ask] the right question... and then translate that into the [product].” While we agree with Kimball (2017) that we have access to tools, most do not have access to the expert’s trained eye. That expertise still lends value. Rhetorically complex tasks are not yet automated. Embedding infrastructure for expert decision-making, as Jirsa describes, is what we assert makes automated infrastructure central to continued user experience and expert engagement. Participation is infrastructure.

Value is produced through participation when systems are designed for user collaboration. Participatory approaches assume the end result extends beyond any individual’s capacity. By this same principle, exosuits, generative design software, and the management of volunteers enhance paid human labor, and vice versa. These technologies do not demand that lineworkers precisely repeat fine movements over long work shifts, that designers imagine the best possible component, or that volunteers offer perfect solutions that can be immediately incorporated into a product line. Rather, all these user-involved processes improve outcomes in advanced organizations through infrastructure for participation. High technology workplaces utilize user participation as the default means of getting work done. New technologies and practices emerge through participatory processes situated as automated infrastructure, ranging from personalizing a t-shirt, to “high tech” examples of 3D scans and semi-automated design tools, and the challenges of organizing and yoking gift/volunteer labor.

We acknowledge user participation as a new default and trace examples that transform our understanding of user-generated content communities. The argument traces evolving trends in participatory design, drawing from emergent practices in software design and development, advanced manufacturing and rapid prototyping, robotics and assistive technologies. Some of these automate or even simulate users’ role(s), obscuring source(s) of participation. As such, we ask two primary research questions:

1. How do we as technical communicators continue to add value to new generations of increasingly automated processes built on, but no longer directly engaging, participants?

2. Can such next-generation processes be considered user-centered?

Our conclusion recognizes that these developments will likely alter user research and methods of data gathering, but we focus here on design processes and roles that users play, as well as attitudes towards users. Finally, these novel design practices should still be understood as developments of user-centered and user-participatory methods. To reach this conclusion, we start from a definition of infrastructure informed by Star & Ruhleder’s foundational work (1996) as well as Sarah Read’s (2019) definitions.

**Defining Automated Infrastructure**

Read examines definitions of infrastructure from fields of “economics, computing, and information science.” Referring to economics, Read explains that “A functional understanding of infrastructure in economics means what that counts as infrastructure is determined not by what kind of thing something is but by what it does for the economy” (p. 239). Similarly, she cites Jeffrey Grable’s (2007) assertion that “infrastructure ‘does work,’” and “must do something” in order to be considered infrastructure. Read explains that “what counts as infrastructure is determined based on its real-time outcomes” (p. 242). Finally, Read also references Malcolm McCullough’s argument that “information technology has become ambient social infrastructure” (p. 240). She goes on to argue “that as computing becomes pervasive, ubiquitous, and part of the social infrastructure, the development and design of computing technologies must become human centered and mimic biological systems” (p. 240).

Becoming human centered does not necessarily mean becoming participatory by default. Ubiquitous computing technologies embedded in what we are defining as automated infrastructure—such as machine learning, cloud computing, Internet of Things connectivity, and artificial intelligence (AI) in various forms—are not inherently user-centered, though they do often depend on user input or user data. We do understand automated infrastructure as experiential though. We draw from Dourish & Bell’s (2007) “experiential reading of infrastructure” (p. 417). Their framing of infrastructure as experiential, “focuses not so much on the ways in
which infrastructures reflect institutional relationships and more on
how they shape individual actions and experience” (p. 417), and
situates infrastructure as a means of experiencing reality.

We also understand infrastructure as the material automation of
process and method. Processes and methods that require repetition
are often ripe for automation, and form the infrastructural foundation
to facilitate comparatively complex work. Theory enables experts
to develop initial novel solutions that later become routinized
and automated. As Jordan Frith (2019) theorizes in A Billion
Little Pieces: RFID and Infrastructures of Identification, this is
a reciprocal relationship. “[Infrastructure] becomes infrastructure
through relationality that involves material (and/or discursive)
structure as well as the practices it shapes” (p. 21).

Given these definitions then, automated infrastructure becomes
infrastructure when it automates participation (via pervasive
computing and management of volunteer labor) to support technical
communicators in creating value through participant experience.
In some instances, participation is highly automated, bearing a
closer resemblance to system-centered design or high-fidelity
personae, and in others human actors primarily facilitate authentic
encounters. It is worth noting that in the former, the value for users
may actually be in minimizing human-to-human interaction and
automating dialogic interactions.

We assert that the value of technical communicators lies in their
ability to solve complex problems while designing systems that
facilitate new forms of participation and user-generated content,
balancing competing needs for interaction with efficiency and
competing constituency demands. As a field, we are documenting
new ways users generate their technologies through automated
processes without losing focus on stakeholders’ expressed
need. User participation and gift labor can be effectively and
economically managed, and contributions from users assessed, as
in the management of volunteer labor where assessment entails
goal setting for the food bank balanced with the experience of
volunteers so they return (see conclusion for an extended example).
While automation and rationalization are changing researchers’ and
communicators’ interactions with users, safeguards are necessary to
avoid returning to systems-centered design and encourage meaningful relationships—what Sullivan named “encounters”
with user populations (Sullivan, 2017). To avoid losing user
input, interaction can be designed into processes, resulting in an
automated infrastructure of participation. Such rearticulation of
user-generated content and user representation, simulation, and
engaged participation envisions participation not as zero-sum—yes
or no—data bits but as points along a continuum of increasing or
decreasing participation and user-centered design.

AI-based decision-making as automated infrastructure supplies
an array of solutions for problems that at first glance appear
wild, or even wicked (Rittel, 1972; Rittel & Horst, 1973) but
have readymade solutions available. We assert that automated
infrastructure assumes participation as the default, applies a logic of
digital media to physical/material objects (see Gershenfeld, 2012),
and extends the labor of human designers and participants through
digital automation, often enhanced by AI and cloud computing.
Much like the digitization and subsequent automation of cameras
and image processing software, advances in the automation of
design and fabrication technologies have similarly made delivering
a technically sound (and often customized) design mundane.
The interfaces and platforms for customization are part of the
infrastructure of widespread AI adoption, creating a landscape
of automated participation. This demands reconfigurations of
work and gift labor, but does not automate institutional change
or guarantee ethical restructuring, as such rhetorically and
institutionally complex tasks remain difficult to automate. And
as Star and Ruhleder point out, determining “Who (or what) is
changer, and who changed?” is not always straightforward (1996,
p. 112). The extent to which participation is invited, automated,
and its resulting impact varies widely as our examples illustrate.
Consistent throughout our examples though, is that the automation
of technical expertise makes otherwise technical tasks more
mundane/accessible, thereby emphasizing the rhetorical expertise
of designers and technical communicators, and the experiences of
users.

METHODS AND GUIDING QUESTIONS

This essay represents theory development and literature analysis
from organizations that are automating manufacturing, managing
gift labor, and inventing additive manufacturing communities.
Following Star’s anthropological investigation of infrastructure
(1999), rhetorical arguments entangle AI with generative design,
additive manufacturing, gift labor, experience architecture, and
configuration of assembly lines.

The included examples demonstrate that automated infrastructure
is not exclusive to robotic and AI-driven systems, but are informed
by a shared rationale: first, saving physical human labor, and
now, rationalizing repetitive elements of knowledge work. We
note examples embedded in workplaces as well as volunteer
organizations. These questions provide a spectrum for comparison:

• To what extent is participation automated by machines
  and/or digital technology? Primarily automatic or mostly
  manual?

• To what extent is designer input automated? And to what
  extent is user input automated?

• What is the transformative potential of user
  participation and input within the system?
  Primarily cosmetic, constrained to individual fit and taste?
  Minor sequential change (i.e., a 1.01 to 1.02 version)?
  Transformative (Changes underlying architecture and/or
  participatory relationship)?

• Could the example be part of an everyday encounter? Or
  part of a process for creating everyday goods and services?
  Examples balanced between everyday encounters and
  specialized industries, as our experiences are informed
  by ongoing fieldwork with advanced manufacturing,
  automated assembly, and DIY communities.

Each example offers a decision architecture that creates the
appearance of customization. End-users perceive their choices as
customization. What is the difference between the perception of
customization and customization itself? Is it distinction without
difference? Early in the development of user-centered design,
the newness of emergent genres, technologies, and interfaces
required extensive direct contact and interaction between users and
designers: distinguishing Norman’s (2002) next bench design from
user-centered technology. As Johnson’s (2010) essay asserts, user-
centered design is everywhere. It is ubiquitous. And it is therefore
not only commonplace and mundane, but it is also a regularized part of the industrial design process (Sharp & Macklin, 2019), if not an assumed part of the generalized design process. What do you do when your insurgent ideas have won the day? What are the minimum requirements to claim a design is human centered? How far does one have to go to encounter an Other in Buber’s sense of the I-thou to avoid making the relationship transactional, or I-It (Salvo, 2004)?

Personae (Usability.gov, 2013) offer one way to represent users in the design process and a potential site for automating infrastructure. Personae methods vary in their inclusion of real user data from deeply informed to less informed to entirely fictionalized, and while all the points on the continuum from deeply informed to fictional provide design guidance, the utility of the representations will vary wildly. The underlying ethical assessment also varies as fictionalized personae can hardly be represented as participatory tools (Friess, 2017). Yet some user representation with minimal participation is better than having no space for design to be impacted by end-user preference.

For example, take Moore & Elliot’s (2015; Moore, 2013) assertion that too many calls for public participation are little more than window dressing: the important decisions have long been made and public participation is collected because it is a legal requirement. Citizens’ statements and concerns have little impact on the final outcome of such projects. In such cases, it seems more ethical that citizens are represented through fictionalized personae rather than given an opportunity to offer feedback that has no impact.

Personae, decision architecture, and participation exist on variable continua, ranging from futile to impactful, fictionalized to direct participation & input, to shallow variables like yes/no decision trees to more complex, dialogic interchange. Decision architecture, participation, and personae are valuable tools that, when utilized effectively and with an eye towards the impact on the project, can both include and represent user feedback as an automated element of design: built into the process of iterative development. As so much around us becomes automated, the invention, arrangements, and deployment of a variety of participatory and user-centered strategies would necessarily themselves become rationalized and representational. Their ethical status, dialogic impact, and ultimately their design effectiveness needs to be assessed on a case-by-case basis.

**UBIQUITY OF/AND PARTICIPATION: EMERGENT PROPERTIES**

A new field of research—critical algorithm studies—has emerged that includes a small library of books that address how algorithms oppress, disenfranchise, and reify unequal distribution of wealth and power (Gillespie & Seaver, 2015; Noble, 2018). Such critiques are essential as the extent of user participation in participatory processes changes; i.e., there is danger in assuming that participation, or semi-automated design processes, “just work” for all users. In infrastructural terms, such an assumption ignores the “installed base” on which automated infrastructure is being built (Star & Ruhleder, 1996, p. 113).

When Johnson declared that we had entered an age of ubiquitous usability (2010), he seems unlikely to be discounting either the utility or importance of usability research. Widespread acceptance of usability presents new problems. Rather than prove the value of the usability-trained technical rhetor, the challenge has become differentiating rhetorical expertise in audience engagement from shallow marketing assertions about value-added user interface design (Dorazio, 1998). With fashionable use of design thinking and similar monikers commonly used to sell technological gadgets of dubious value, having proven the value of usability and user-centered design has brought with it ambiguous rewards: what value does rhetoric add to usability when user-centered design philosophies are, quite literally, everywhere, coded into the fabric of our technological age? Johnson asserts, paradoxically, that we are victims of our own success.

Dialogic interaction is the foundation for usability, user experience design, participatory design, patient-oriented medical communication, personae-building methods, and other digital, medical, industrial, agricultural, and business writing strategies. Dialogic rhetoric offers a meta-theory—a concept from which other theoretical stances are derived—unifying emergent discourses addressing research and practice of TPC with attention to authentic engagement and interaction with the people who will use and be subject to the technological and textual artifacts being designed. This essay asserts a common foundation for many emergent facets of TPC, a techno-rhetorical basis (Johnson, p. 160), for the work of the field and an enduring ethics for dialogic interaction.

The illusion of customization can be powerful. Industrial manufacturing produced numerous identical items while, under the slightly misleading title of mass customization, we currently enjoy an age of choice. The appearance of customization is the result of multiple layers of choices, revealing the impact of concentrating on the process of design and production rather than on outcome. Ordering a t-shirt online layers an A-B choice architecture on the design: white or grey? Arial or Lucida Handwriting? Round neck or V-neck? Nikolaus Franke, Martin Schreier, and Ulrike Kaiser (2009) found participants would pay up to 40% more for a shirt if they designed the graphics themselves, even when the “custom” design replicated a mass-produced shirt (p. 132). Even when participants only chose color, they remained willing to pay more than an off-the-shelf product (p. 137). An ecology of web technologies and just-in-time manufacturing make pseudo-customization commonplace for graphics.

The following sections on generative design trace emergence of automated infrastructure through advances in the measuring and references, design, and a shift from subtractive to additive manufacturing. As emergent automated infrastructure, these technologies allow for the creation of new shapes and structures that would otherwise be impractical to create, and are quickly becoming commonplace. Simultaneously, they alter the relationship between users and designers.

**Automating Design: Generative Design and the Elbo Chair**

In addition to automating the process of measuring existing bodies and objects (Doray, 2015; Gill & Parker, 2017; Javaid et al., 2017; Juhinke et al., 2020; Paquette et al., 2000; Gill et al., 2017; Rajeshkar et al., 2017; Sokolowski, 2020; Sokolowski & Bettencourt, 2020), new technologies have emerged for further automating the design of objects. In particular, generative design and additive manufacturing enable the production of new designs that couldn’t previously be produced with traditional subtractive manufacturing approaches. One such example is the Elbo chair, which relies on generative design.
The Elbo chair is an example of Autodesk’s Project Dreamcatcher, “a generative design system that enables designers to craft a definition of their design problem through goals and constraints” (“Project Dreamcatcher,” 2018). At the risk of oversimplifying, generative design allows designers to imagine part of a chair, and the software fills in details. Generative design follows the advent of parametric modeling, which is similar to responsive web design in that components of a design automatically scale in relation based on designer-defined parameters. For example, a designer might collaborate with a user to define the base shape of the chair, and manually iterate through different parameters for each component of the design (e.g., adjusting how long the legs are, how wide the seat is, how wide or narrow the arm rests are, etc.). In a parametric design, narrowing the width of the seat automatically shortens the distance between the chair legs based on defined constraints.

By comparison, in a generative approach, designers draft a “loose” model of an initial chair with critical features and some defined dimensions and/or constraints. For example, the chair must have a seat that connects to the legs, the back rest, and the arm rests at specific points, and must be of a specified height. The designer essentially creates the 3D modeled equivalent of a stick figure chair, with a few critical elements. The designer can then use this loosely defined mockup to set constraints for iteration, for example, that the chair must be able to support 300lbs of weight, but must use less than 10lbs of material. Given initial critical features and constraints, the generative design software iterates thousands of possible designs using cloud computing and AI to optimize design options.

The designer no longer needs to manually mockup chairs of different widths and heights and simulate use conditions; the software runs through thousands of combinations, optimizing for constraints and presenting a narrowed range of possibilities. By analogy, this process is similar to creating a design challenge with clear constraints and crowdsourcing possibilities. Generative design is more reliable, creating forms that human designers might not consider. The labor of iteration shifts away from designer/user interaction to an automated process, leaving the designer to choose among narrowed range of possibilities meeting specified criteria.

In Aristotelian terms, generative design uses AI to identify available means of meeting goals beyond human capacity. The designer makes choices having invested less labor in the process of iterating through potential means. Additive manufacturing technologies produce complex 3D shapes impossible to realize through subtractive manufacturing. Additive manufacturing includes a range of technologies, but is most often represented by 3D printing. 3D printers create physical objects building up layers of material (additive) rather than removing material from a solid block (subtractive). Imagine building layer by layer with LEGO bricks can produce complex internal structures. Although there are still physical constraints to consider when designing for additive manufacturing, additive makes complexity free (for more on this, see Paulsen, “The 3D Printing ‘Complexity Paradox’”).

The Elbo chair represents generative design and additively manufactured objects. The Elbo chair and its ilk demonstrate the potential impact of these technologies not only on manufacturing but on usability and participatory design. A designer receiving a 3D scan from a user (whether that model is a 3D scan of a tooth’s root, a limb, or a seated pose) can generate a design that is a “perfect” (or near-perfect) physical fit, automating the traditional participatory dialogue. As technical proficiency becomes automated, the nature of the dialog changes. Which parts shift and which remain unchanged (particularly when the user has been precisely and accurately modeled)? Leaving aside technical elements, such as material properties and manufacturing limitations, additive processes enable designers to emphasize rhetorically complex conversation: Should the chair have a more organic feeling? Evoke a trip to the beach? Or perhaps something Cubist? While such conversations happened previously, with automated infrastructure, design expertise takes on new rhetorical heft.

Generative Iteration Design Infrastructure

Although generative design software currently models specific components, the technology is not yet advanced enough to model entire assemblages. Generative design is young, and bears resemblance to creating portraits in studio settings more than taking a selfie. Modeling stationary, non-adjustable chairs is comparatively easy, given simplicity of the design. But modeling an adjustable ergonomic chair amplifies complexity. Each moving part can be generatively designed, but designing complex systems remain outside capacity. This is not to say that more complex models are impossible to generate.

Take a bicycle for example. Generative modelling can offer variations of frames, handlebars, seats, and other parts individually. The software cannot yet generate an entire bike. Project Dreamcatcher shows multiple versions of generative bike frames suited to different uses and styles. Interestingly, Bijker’s (1997) history of bicycle frame design and standardization gets replicated in miniature with emergent designs reflecting current distinctions between cyclocross, road, and touring styles, pertaining to riding position: endurance, speed, and load.

For now, designers will design complex chairs and bicycles, and users will define parameters, particularly for complex models. But when considering fit, function, and interaction, examples like the Elbo chair and bicycles should give technical communicators reason to reflect on future automations. For instance, Pinarello’s use of additive manufacturing and automation optimized weight of a bike by 40% in under a month (Gambini, 2021). Are dialog and participation reduced when processes utilize additive scanning? Situating examples as high-fidelity personae is tempting, and plausible to imagine generative design technologies applied to databases of scanned bodies. Avoiding lengthy, and therefore expensive, dialog is already a goal, yet offers advantages for users. For example, several bra retailers have marketed apps intended to 3D scan users’ bodies (using photogrammetry and user-captured images), promising better fitting bras without the potentially awkward social interaction of measuring and bra fitting (“Bras and Underwear,” 2018; “The Digital Bra,” 2018). The scan itself is participatory and user-centered: photographic and biometric data provide affordances and constraints.

Such situations also reinforce the ethical and security issues associated with creating hyper-accurate and/or realistic personae, especially those based on biometric data, as well as the dangers of recreating or reinforcing existing systemic issues. At the same time, these examples also suggest the possibility of using participatory approaches when addressing problems with greater complexity, rather than when addressing relatively simple fitting processes. In the following section, we examine this distinction in more detail, and provide examples of complex problems related to managing...
process as automation: integrating iteration

Systems based on participation have the potential to transform institutional structures or practices, but may be limited to transforming consumer-as-user experiences. Take for example Lay’s crowdsourcing of new chip flavors. Regardless of how great the new “Deep Dish Pizza” or soy ginger flavor potato chip, it does not transform the management structure of Lay’s. Lay’s is careful not to hold contests for new varieties of snack food that might require changes to equipment or production lines. Participation that does not transform institutional structures or practices can still impact accessibility. For example, such competitions allow Lay’s to produce flavors that are potentially more accessible without having to reimagine the line of chips as an allergen-free snack food. Generative design and crowdsourcing may yield unexpected results (potentially benefiting both users and companies), but they don’t automate the rhetorical work of creating new goals and constraints or reimagining infrastructures (automated or otherwise).

Transforming Infrastructure

Although this example of chip flavors illustrates a change in participatory processes, crowdsourcing flavors is relatively frivolous and risk averse when compared with restructuring a global corporation. The management structure of Lay’s is unlikely to change because a participant suggests a new chip flavor, or even if hundreds of thousands of customers demand boycott a particular flavor. Similarly, if new flavors were created through generative design, rather than crowdsourcing, such reactions would likely only mean tweaking the flavor constraints slightly. Feedback-based crowdsourcing is an outcome of automated infrastructure. Feedback is now available through social media and crowdsourcing channels: now it is someone’s job to figure out how (else) to use gift economy data derived through participation, requiring new infrastructures, at first novel and surprising and then automated and delivered to the social media experts.

Other participatory structures do facilitate institutional or structural changes though. By comparison, participatory structures such as Subaru’s use of kaizen (a process of continual improvement) directly impacts the configuration of Subaru’s manufacturing plants, offers a meaningful reward structure to participants, and creates a mechanism for change over time. At Subaru’s U.S. manufacturing plant in Lafayette, Indiana, workers are offered rewards for suggesting operational improvements.

Depending on the overall impact of the suggestions in terms of cost savings and other factors, workers may be financially rewarded, up to and including a full vehicle for major improvements. Even for minor improvements, such as making office forms more effective, employees can still be rewarded with a candy bar for their suggestions. Nor are the reward structures creating a marketing gimmick of usability (Bawa, 2001). Suggestions need not be grand or radical. They are powerful though, because suggestions can be as simple as a line worker asking, “What if we tried it this way instead?” and encouraged to put forth new ideas with the guarantee that they will be seriously considered. Consequently, the ways that Subaru values and constructs participatory systems are reflected in the design of its assembly lines as well.

Ford vs Subaru

Automation includes the ways workers are asked to interact with artifacts and processes. Ford assembly lines and Subaru assembly lines are visibly different in how they relate to workers. Ford’s assembly lines are linear and centered on the gravitational limitations of assembly lines. Subaru created alternatives, turning the assembly pieces in order to accommodate human bodies. 3-axis presses are infrastructural automations, recognizing how human bodies function, and accommodate workers’ needs (see Salvo, 2018). These two auto manufacturers provide a comparative example of how different approaches to participation reshape institutional structures (or not). More specifically, the companies differ in how they respond to worker mobility during the assembly process, and how they situate workers in relation to the design of the assembly line. Over the past two years, Ford has experimented with using “EksoVests” to augment workers who are required to lift tools upward in order to assemble underbody parts overhead. Unlike Sci-Fi depictions of robotic exosuits that provide workers with super-human strength, the EksoVest is designed as “an endurance enhancer” and provides “five to 15 pounds” of passive arm support, reducing fatigue from repeatedly lifting tools (Baldwin, 2018). Although still in its pilot stages, Ford is considering additional applications for the EksoVest on its assembly lines. By contrast, when facing a similar problem of how to reduce worker fatigue and injury for assembling underbody parts, Subaru made an infrastructural change to the assembly line by utilizing 3-axis presses—and simply rotate vehicles 90 degrees to accommodate human bodies.

In both the Ford and Subaru assembly plants, workers and automated machines collaborate to produce a result that exceeds the individual capacity of either actor, despite the companies implementing different collaborative structures. In the case of Ford, the EksoVest alone cannot assemble parts (though it would be technically possible to design such a robot), and the assembly line workers could not perform at the same level without ill effects from repeated motion. Similarly, humans and robots collaborate in a different configuration, but produce the same result. Further, in all of the examples thus far, whether it is generative design, crowdsourcing, or an exosuit, the systems are driven by participation to varying degrees. They are less dependent on perfect execution by human participants, but they do require participation in order to function.

The systems are designed so as to make participation the point—simply participating is enough, by default, to make the system or final design functional, but often in a way that exceeds the individual capacity of either human or machine. As another recent example of this participatory relationship, DAWN ver.β café in Japan provides a unique context. Starting as short-lived beta test, and now a permanent café (DAWN Avatar Robot Café) thanks to crowdfunding (Steen, 2021), the business is modeled after futuristic anime, “in which robots and humans interact as equals” (Master Blaster, 2018). The café is partially automated via participatory “cobots” (a shortening of collaborative robots), but is unique in that the cobots are remotely controlled by paralyzed operators who work from home (Elejalde-Ruiz, 2018). Although the café could easily run automated without any human workers, this experimental participatory model provides an opportunity for the operators to interact with customers and earn money. In short, this collaboration provides paralyzed employees opportunities for income and human interaction, while also improving customer satisfaction with the cobo.

As these examples demonstrate, automated infrastructure reflects...
Johnson’s “Ubiquity Paradox” in which usability loses some of its specialized value precisely because it is so widespread. Automated infrastructure becomes invisible. Software tools like those marketed by SAP, for example, and tested configurations of automated infrastructure, might be better understood as a metaproduct—a tool used for making other tools, like tap and die work, or robotics and 3D printing—where one process is used to build the tool that constructs the tools used to make products. Companies make and market robots so they can be deployed to make cars, airplanes, and widgets, so a tool-making-tool. Once the meta- and post-prefixes begin stacking up, we enter the realm Baudrillard named \textit{orbits}: the layers of recursion become not only unclear but unnecessary to keep clear.

Martin Buber (2010), Bakhtin (1981), and others, assert components of dialogic rhetoric for those who want to be successful in the post-career gig economy—the automated, robotized, social-media inflected workplace—all collectively, indelibly, marked as TPC by the way its subjects are treated: as possessors of valuable knowledge. Having just embarked on this journey of understanding the user-participant’s contribution to design, it would be devastating to allow our successes in various spheres of work to rename and, finally, tear practice from its rhetorical interests.

Heidegger’s concept of standing reserve (1977) seems an apt reference here, treating the water of the Rhine as a resource waiting to be utilized. Pessimistically (and reductively), a parallel Heideggerian critique would label the marshalling of gift-economy labor as dehumanizing, treating people as standing reserve, as things, as \textit{it}, or a \textit{commodity}, contrary to Buber’s imploring I-Thou encounters. It is important to balance this oft-referenced example with a later Heideggerian interest Stambaugh (1987) articulates more generously and generatively. Stambaugh might count a simplistic standing reserve argument that a gift of labor is more akin to “growing one’s own carrots and peas” which, although highly inefficient, is disproportionately satisfying, and highly valued in the later Heidegger as an expression of human satisfaction (1977, p. 79). The satisfaction volunteers find in their freely-given labor is worth far more than the gains of automation, digitization, and advanced production, and justify the costs of displacement when the drudgery of sweat work is replaced by joyful and meaningful engagement. This is one way to define a future of meaningful work.

\textbf{CONCLUSION}

Decision architecture is one element of experience architecture, defining a trajectory for technical communication expertise. It represents a professional intervention in what the recent 2-volume MIT Press books named \textit{Designing for Emergence} (Pendleton-Jullian et al., 2018a, 2018b). Like the medical interventions promised by an age of genomic medicines, this new age is radically (ubiquitously?) centered on end users and their needs, but the processes by which designers and communicators interacted with and were impacted by users is obscured. Further, the endless A-B choice architecture of customization leaves the designer’s intentions and agency further obscured. Potential behaviors of less common choice combinations, whether creating a custom bicycle or a new snack flavor, are unpredictable and lead to properties unforeseen—those very properties users desire but would have been eliminated had designers retained agency over final artifact production. Designing for emergence means relinquishing control of every possible design permutation while simultaneously assuming responsibility for the endless combinations of alternate versioning choice architecture makes possible.

Deloitte asserts new employment opportunities in supporting emergent configurations of work (Agarwal et al., 2018). Artificial intelligence, robotics, and volunteer labor are the three most potent elements that technical communicators can adapt to rearticulate traditional strengths of core competencies for the new configurations of work. So far, with choice architecture, this essay has allowed examples to tumble out of the literature: human-robot collaboration, support for routine decision-making, automation of repetitious activity, marshalling the gifts of participation culture. But their application in this essay has been abstract and wrapped in the language of futurists with varying degrees of digital automation and AI. Yet the examples are not fully dependent on high-technology alone. If well executed, decision architecture adds value for both user and designer, rewarding a thoughtful choice architecture leading to a sustainable experience architecture via rhetorical effectiveness—the difficult to automate questions as articulated by Jirsa in our opening, organization of gift labor, and attention to complex user needs.

Let us conclude with another example. Students in technical and professional writing majors often take credit-bearing internships near the end of their studies. Bay (2006) presents the internship practicum as a career path for English majors. In Bay’s narrative, students often find themselves working for nonprofit institutions in the college town surrounding the university. One local nonprofit, dependent upon volunteer labor, recognized that volunteer groups were not returning—there was a “one and done” sense that a reservoir of volunteer labor was available but that the organization was not meaningfully engaging volunteers. That is, they were not supplying a meaningful engagement with the organization or its mission: there was no experience for volunteers to take away in reciprocal payment for their time and labor.

The organization, a food pantry, hired a full-time employee under the title of volunteer coordinator to create meaningful volunteer experiences for service organizations, church groups, senior citizen groups, and other community members seeking meaningful engagement. The food pantry recognized the need to create meaning for their volunteers: people offering gifts of time, labor, and expertise, who are dedicated to the organization’s mission, and loyal if they are given reason to return. Repackaging bulk foodstuffs for individual consumption is a regular need at the pantry: for instance, one morning, a truckload of surplus breakfast cereal needed to be repackaged in bags appropriate for an individual family to consume in a reasonable time. Another: frozen pizzas could not be sold because an ingredient was left off the packaging’s ingredient list, drawing attention to the underlying infrastructure of food safety and food packaging. The mistake required that the entire run of pizzas be pulled from grocery store shelves. Rather than discard the perfectly good food, the food pantry accepted the bulk-frozen pizzas. Below, these two examples are described to articulate the important role of automated infrastructure in the mundane work of the volunteer coordinator.

The volunteer coordinator first created an assembly line to repackage the cereal. Huge 10-foot-tall packages—six feet by six feet by 10 foot industrial packages—were systematically opened and portioned into two pound scoops of cereal that needed to be weighed and vacuum-sealed into plastic bags, with a sticker containing product information. Fourteen service organization members accomplished this tedious task, clad in hairnets and
overalls, over two 4-hour sessions during one week. Members expressed satisfaction watching the first 10 foot by six foot by six foot box of surplus food transformed from a waste product into hundreds upon hundreds of individual bags of cereal, ready for families to take home, where smiling children were able to pour (surplus) milk and enjoy a moment of childhood—Saturday morning breakfast cereal—in the volunteers’ imaginations. The volunteer coordinator had transformed a challenge and problem into a rewarding experience for volunteers, usable packaged products for hungry families, and routine throughput for the food pantry.

The pizzas presented another problem. They had to be kept frozen, removed from the inaccurately printed packaging, relabeled with accurate ingredient information, and repackaged for distribution. A church group of some 20 members spent three hours on a Sunday in summer, clad in winter coats and gloves, repackaging frozen pizzas and relabeling them inside a commercial freezer. It seems a simple problem of logistics (Pflugfelder, 2018), but the preparation was the coordinator’s full-time job for two weeks leading up to the repackaging event. Importantly, the church group left laughing and talking about the process of packing, repacking, relabeling pizzas, in their coats in summer. The food pantry was able to make prepared foods available to their clients while meeting the stringent requirements for food labeling and distribution. And clients of the pantry received highly-prized easy-to-prepare foodstuffs that also made the families feel they were participating in the common life of mainstream culture—something so mundane as a frozen pizza to make a family feel they had access to desirable foodstuffs. And in the spirit of Nudge (Thaler & Sunstein, 2009), to also receive a grocery bag of fresh vegetables, dry beans and rice, canned goods, and all the nutritious foods the food pantry has to offer in addition to the desired pizzas.

The volunteer coordinator shares the plans and documents necessary to support the pizza repacking day and cereal repack, gets feedback from the leaders of the church groups and service organizations, and shares a report with other volunteer coordinators at food pantries across the country. Volunteers are engaged and delighted with their experience. Pantries report success, then share their own tweaked planning documents and innovations like volunteer drives and outreach, and the needs of different volunteer groups. Gift labor is made meaningful, human beings are knit into the fabric of the community, and engaged. A new position, volunteer coordinator, is seen as not only valuable but essential for sustaining meaningful use of a newly articulated source of labor: unpaid volunteers.

Infrastructure allows us to address the difficulty of novelty when we encounter challenging problems. First, professionals painstakingly build bespoke solutions. When we encounter series of similar problems, patterns emerge and we work to articulate effective solutions for them. Expertise allows us to routinize challenges, and if we are attentive, we regularize solutions which allow us to continue concentrating on challenging examples. Over time, those regularized solutions become embedded in practices and organizations—they become infrastructure. Ultimately, we have numerous off-the-shelf solutions waiting for appropriate situations. AI helps us match patterns to existing solutions, eventually freeing us from mundane work allowing experts to focus on unique situations and challenging contexts: focusing on moments where work is challenging and rewarding. The volunteer coordinator first faced what seems like a unique challenge, but soon developed a solution. The next answer was a variation on the theme. Once articulating and communicating both the situations and solutions, national and international networks confirmed and redeployed these solutions. These solutions have become part of the toolbox of institutional strategies for utilizing what was at first a unique and slippery resource, resulting in satisfied volunteers and a volunteer coordinator hailed as innovative and effective at her work, based on her reliance on automated infrastructure.

The organization, the food pantry, employed the volunteer coordinator in order to make an available source of work—gift labor—into a usable resource, turning surplus and mislabeled foods into distributable goods. The work required the coordinator to communicate effectively using networked tools, create posters, reports, and communicate over national and local networks, to organize people and plan events, break down complex processes into component parts, and understand the needs of user groups. The organization had to move goods into the hands of citizens. Those citizens wanted to be treated with care and respect—wanted the experience (as end users) to be more like going to the grocery store and less like an institutional intervention. These are infrastructural innovations: work is shifted to the coordinator, who spends her working day creating the context for volunteers’ experience. Finally, volunteers wanted to be rewarded for their gift of time and labor with a satisfactory experience and feeling of having contributed—as stakeholders. Both the cereal and pizza examples demonstrate the important role the user experience continues to play in a workplace augmented by artificial intelligence, aided by automation and robotization, and buoyed with gift labor. While work is changing, human need for connection, relevance, and sustenance remain.

ACKNOWLEDGEMENTS

The authors would like to thank Chapel of the Good Shepherd Episcopal Campus Ministry and Food Finders Food Bank.

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https://doi.org/10.1177/15419312004403811


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Building Ethical Distributed Teams Through Sustained Attention to Infrastructure

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ABSTRACT
Building sustainable infrastructure is a core principle of Constructive Distributed Work (CDW), an integrated approach to project management and team building. In this article, we explain the origins of CDW and describe the theory of sustainable infrastructure that underpins our approach to training, supporting, and coordinating work across a diverse and distributed team. We illustrate how mapping strategies can help us make infrastructure more visible, and therefore more available for reflection and iteration, and demonstrate how a participatory approach to developing and sustaining infrastructure helps our team maintain its commitment to more ethical and inclusive research practices.

CCS Concepts
Information systems

Keywords
mentoring; assessment; project management; communication mapping; infrastructure

INTRODUCTION
The Corpus and Repository of Writing (Crow) is a web-based interface that combines a corpus of student texts with the pedagogical materials teachers designed for those students (crow.corporaproject.org). This web interface serves as both a research and pedagogical tool (Staples & Dilger, 2020). Crow is not only the interface, but also a group of dedicated faculty and student researchers, a team that collaborates across multiple institutions to further develop and maintain the web interface while also mentoring and training graduate and undergraduate students to achieve their professional goals through research, development, grant writing, and project management (writecrow.org). The complex assemblage of people, locations and tools that make up the Crow research team began with eight researchers—two faculty and six graduate students at one university—and has grown over seven years to encompass scholar-teachers at more than eight institutions, including both domestic and international partners. This diverse and distributed team thrives in part because of our early commitment to sustainable infrastructure and our continued attention to keeping that infrastructure visible and open to negotiation.

Long-term research and development projects face a variety of pressures: the shifting responsibilities and resources of primary investigators, the transience of student researchers, and the institutional demands of funding, to name only a few. Furthermore, systemic inequalities and barriers to learning and engagement persist in research teams, and addressing these often invisible barriers is key to how all Crow researchers understand sustainability. Our commitment to iteration and flexible design requires internal assessment that helps our team develop feedback loops among Crow researchers, and also through outreach and publication, with a wider audience of researchers and administrators interested in building more ethical, inclusive and sustainable research teams.

Our name for this assessment is constructive distributed work (CDW). It’s a multi-dimensional, data-driven approach to reflective assessment and iterative design that guides the administration and development of Crow and helps us attend to the professional development and well-being of all Crow researchers. CDW helps...
CROW CENTER SUSTAINABLE INFRASTRUCTURE, WHILE ALSO ENSURING THAT INFRASTRUCTURE ADAPTS TO MEET THE NEEDS OF OUR DIVERSE DISTRIBUTED TEAM. IN THIS ARTICLE, WE PRESENT A CASE STUDY THAT ILLUSTRATES HOW MAPPING INTERACTIONS BETWEEN CROW RESEARCHERS AND OUR INFRASTRUCTURE OVER TIME CAN HELP US REFINING OUR METHODS FOR EXPOSING AND ASSESSING THAT INFRASTRUCTURE, WHILE SUPPORTING OTHER CORE ELEMENTS OF CDW, SUCH AS HELPING TEAM MEMBERS DEVELOP RHETORICAL CONFIDENCE AND BUILD NETWORKS OF MENTORING.

THIS CASE STUDY ILLUSTRATES HOW MAPPING CAN BE A USEFUL TOOL AS WE FURTHER DEVELOP INTERNAL ASSESSMENTS THAT INTERROGATE OUR OWN PRACTICES AND REVEAL OPPORTUNITIES TO ACT ON POTENTIAL GAPS OR PROBLEMS. WE OUTLINE HOW INFRASTRUCTURE THEORY INFORMS OUR WORK, DESCRIBE HOW OUR INFRASTRUCTURE EMERGED AND CONTINUES TO SHAPE CDW PRACTICES, AND EXPLAIN HOW MAPPING ENRICHES THE USER-CENTERED APPROACH WE TAKE TO CDW RESEARCH AND ASSESSMENT. WE HOPE THAT SHARING THIS CASE STUDY AND THE TOOLS WE ARE CREATING TO ASSESS OUR OWN APPROACH TO SUSTAINABLE INFRASTRUCTURE WILL CREATE SPACES FOR FEEDBACK AND OPPORTUNITIES FOR OTHER RESEARCH TEAMS TO CONSIDER HOW THEY MIGHT IMPROVE THEIR OWN INTERNAL PRACTICES.

CROW IS A CORPUS, REPOSITORY, AND INTERFACE BUILT BY A TEAM

FOR US “CROW” MEANS MORE THAN ONE THING. IT REFERS TO BOTH THE RESOURCE WE DELIVER AND THE TEAM WE HAVE ASSEMBLED TO GROW AND MAINTAIN THAT RESOURCE. IN THIS SECTION, WE OFFER SOME BACKGROUND EXPLANATION OF CROW AS A RESOURCE AND CROW AS A TEAM. AFTER SEVEN YEARS OF DEVELOPMENT AND RESEARCH, OUR TEAM HAS BUILT A CORPUS, REPOSITORY, AND THE WEB-BASED INTERFACE THAT ALLOWS STUDENTS, RESEARCHERS, AND TEACHERS TO ACCESS AND USE THE DATA WE HAVE COLLECTED. OUR CORPUS INCLUDES OVER 11,000 SAMPLES OF COLLEGE WRITING, CONTAINING NARLY 11,000,000 WORDS. THESE TEXTS REPRESENT STUDENTS FROM 58 COUNTRIES AT THREE INSTITUTIONS (UNIVERSITY OF ARIZONA, PURDUE UNIVERSITY, AND NORTHERN ARIZONA UNIVERSITY) AND INCLUDE 32 GENRES OF WRITING. THE REPOSITORY IS A COLLECTION OF PEDAGOGICAL MATERIALS USED IN THE SAME COURSES FROM WHICH WE COLLECT CORPUS TEXTS. BOTH CORPUS (STUDENT TEXTS) AND REPOSITORY (PEDAGOGICAL MATERIALS) ENTRIES ARE GATHERED AND PROCESSED, WHICH INCLUDES DE-IDENTIFICATION AND ADDING METADATA ABOUT THE STUDENTS AND COURSES INVOLVED, BY OUR TEAM AND THEN ADDED TO THE WEB INTERFACE. WHEN POSSIBLE, TEXTS IN THE CORPUS ARE LINKED TO PEDAGOGICAL MATERIALS IN THE REPOSITORY—THE SYLLABUS, ASSIGNMENTS, LESSON PLANS, ACTIVITIES, AND HANDOUTS THAT GUIDE STUDENTS’ WRITING—ALLOWING FOR A WIDE VARIETY OF APPLICATIONS FOR RESEARCH, TEACHING, AND PROFESSIONAL DEVELOPMENT. USERS CAN IDENTIFY TEXTS USING SEARCHES, FILTERING THE RESULTS BASED ON DEMOGRAPHIC INFORMATION AND METADATA RELATED TO STUDENT WRITING OR TEACHING MATERIALS.

SUSTAINING THE CORPUS, REPOSITORY, AND THE WEB INTERFACE REQUIRE MANY DIFFERENT KINDS OF WORK WHERE DIFFERENT EXPERTISE IS FOREGROUNDED. ONE WAY WE MANAGE THE DEMANDS OF A GROWING RESEARCH PROJECT IS BY DEVELOPING MULTIPLE TEAMS RESPONSIBLE FOR DIFFERENT ASPECTS OF CROW. FOR EXAMPLE, WE HAVE A DEVELOPMENT TEAM THAT WORKS ON EXPANDING CORPUS TOOLS INCLUDING THE DEVELOPMENT OF THE CIABATTA TOOLKIT (WRITECROW.ORG/CIABATTA/), WHICH PROVIDES BOTH TRAINING AND OPEN ACCESS CODE TO HELP OTHERS BUILD CORPORA FOR THEIR OWN PROJECTS (STAPLES ET AL., 2021). THE DE-IDENTIFICATION TEAM PROCESSES DATA TO ADD TO THE CORPUS AND REPOSITORY. OUR GRANT WRITING TEAM FOCUSES ON FUNDING STRATEGIES TO PROVIDE MATERIAL SUPPORT TO RESEARCHERS, FUND DEVELOPMENT AND SPONSOR OUTREACH TO INCREASE THE DIVERSITY OF USERS AND TEXTS INCLUDED IN THE CORPUS. THE CDW TEAM DEVELOPS PROCESSES FOR MENTORING, ONBOARDING COLLABORATION, AND COORDINATION. THE CDW TEAM WHO LED THE RESEARCH PRESENTED IN THIS ARTICLE INCLUDES FACULTY, GRADUATE, AND UNDERGRADUATE RESEARCHERS WITH SPECIALTIES IN APPLIED LINGUISTICS, SECOND LANGUAGE STUDIES, TECHNICAL COMMUNICATION, AND WRITING PROGRAM ADMINISTRATION. CROW RESEARCHERS AT EVERY LEVEL, FROM TENURED FACULTY TO UNDERGRADUATE RESEARCHERS, MOVE BETWEEN THESE TEAMS AS THEY WORK ON DIFFERENT TASKS.

CASE STUDY: GRANT WRITING AS INFRASTRUCTURAL ACTIVITY

IN PREVIOUS PUBLICATIONS, WE HAVE HIGHLIGHTED HOW WE FACILITATE NETWORKED MENTORING AND BUILD RHETORICAL CONFIDENCE TEAM-WIDE THROUGH OUR METHODS FOR GRANT WRITING (BANAT ET AL., 2020). BECAUSE GRANTS FUND OUR PROJECT, GRANT WRITING REQUIRE COORDINATION ACROSS EVERY TEAM, AND MOST CROW RESEARCHERS WORK ON A GRANT WRITING TEAM AT SOME POINT IN THEIR ASSOCIATION WITH CROW. ALONGSIDE OUR GRANT STRATEGY FOR FUNDING CROW, WE ENCOURAGE AND SUPPORT RESEARCHERS’ INDIVIDUAL EFFORTS TO Pursue GRANTS AND FELLOWSHIPS THAT WILL FURTHER THEIR INDIVIDUAL GOALS. BECAUSE GRANT WRITING IS SO CENTRAL TO OUR WORK AND OUR APPROACH TO PROFESSIONAL DEVELOPMENT, IT IS A USEFUL LENS FOR APPLYING THE CDW HEURISTIC TO EXAMINE HOW OUR PRACTICES ALIGN WITH OUR INTENTIONS. MAPPING THE INFRASTRUCTURAL INTERACTIONS OF A CROW RESEARCHER WORKING ON THE GRANTS TEAM HELPS US TO SEE HOW INDIVIDUAL EXPERIENCE AND KNOWLEDGE MIGHT SHAPE INTERACTIONS WITH CROW INFRASTRUCTURE.

FOR THIS CASE STUDY, WE DREW ON THE FOLLOWING USER STORY, GENERATED USING A PERSONA DEVELOPED FROM EARLIER RESEARCH (BANAT ET AL., 2020) TO SHOW THE DISTRIBUTED NATURE OF CROW WORK, AND THE COMPLEX ASSEMBLAGE OF INFRASTRUCTURES THAT RESEARCHERS NAVIGATE.

Noor Fares is a graduate student new to the Crow team. As part of their onboarding to Crow, they were introduced to the team communication platform, Basecamp, and asked to read and comment on the Crow best practices document that describes our approach to Basecamp, Google Docs, and our cultural approach to visibility and collaboration. After reviewing their interests for the semester on the matrix with the PI at their home institution, Noor was added to the grants team. The faculty PI that led the grants team asked Noor to review an annotated draft of a previous winning grant. This familiarized them with some Crow history, and the vocabulary Crow uses to describe research. Noor participated in Zoom meetings with the team, which has members located at multiple institutions.

After the meeting, Noor met with a graduate student who worked on the previous winning grant to discuss their questions, and to offer feedback about building on the
Develop rhetorical confidence, approaches that inform our writing that mediates essential sustainability, and inclusion requires project leaders to always diversify teams in ways that prioritize ethics, interdisciplinarity, and orientations to work as deeply related and interactive. Managing managers and administrators to see core principles, best practices, we advocate for a three-dimensional approach that asks project management and team building. This framework has evolved over time, and continued reflection and iteration are baked into the way we do CDW. In a previous article (McMullin & Dilger, 2021) we outline the three dimensions of CDW:

- **Core principles:** Develop rhetorical confidence, facilitate networked mentoring, and build sustainable infrastructure. Infrastructure influences all of these interactions: both the material, digital aspects of collaborative work and the best practices and tacit knowledge needed to communicate and work effectively. Attention to sustainability requires that Crow researchers uncover and keep visible the many intersections of experience, technology, and coordination needed to conduct their daily work. The upheaval of the COVID-19 pandemic and its rapid shift to work-from-home in all sectors of our lives have taught us in multiple ways a fundamental truth: infrastructure is most visible when it’s broken (Star, 1999). Research teams have had to think quickly about how to work in distributed and digital spaces. The Crow team has had a jumpstart on this process, as we collaborate across disciplines and institutions. Over seven years of development, as our team has grown and our networks of institutions have expanded, we have iteratively refined the theoretical frameworks that support our project. Our understanding of sustainable infrastructure has grown as we incorporate new research and theory about infrastructure.

As noted above, sustainable infrastructure is one of the three core principles through which CDW functions as an integrated heuristic for project management and team building. This framework has evolved over time, and continued reflection and iteration are baked into the way we do CDW. In a previous article (McMullin & Dilger, 2021) we outline the three dimensions of CDW:

1. **Core principles:** Develop rhetorical confidence, facilitate networked mentoring, and build sustainable infrastructure.
2. **Best practices:** Confront rhetorical challenges, coordinate distributed work, teach collaborative writing, help team members establish cohesive professional identities, prioritize individual learning, and reflect carefully when adapting practices from software development.
3. **Orientations to work:** Approaches that inform our choices, activities we carry out in daily work, and outcomes that benefit individual researchers and the team.

We advocate for a three-dimensional approach that asks project managers and administrators to see core principles, best practices, and orientations to work as deeply related and interactive. Managing diverse teams in ways that prioritize ethics, interdisciplinarity, sustainability, and inclusion requires project leaders to always think about multiple things at once. The CDW heuristic is our way of giving shape to that multi-dimensional thinking such that teams can better understand where they apply attention and focus tasks at hand. The CDW heuristic iteratively evolves as we assess the experience and needs of our team.

### A THEORETICAL FRAME FOR SUSTAINABLE INFRASTRUCTURE

As we continue to refine our theoretical approach to developing CDW, four characteristics have guided our definition of sustainable infrastructure. Sustainability requires that our infrastructure is:

- **Reflective:** We attend to the connections, processes, and networks that make up the complex assemblages in which we work.
- **Iterative:** We adapt to changing conditions, and use feedback to address gaps, inequities, and opportunities for growth. This requires short and long-term thinking focused on capacity building for our project and for individual team members.
- **Participatory:** We invite questions, feedback, and center the well-being of our team and their success. We understand that different members of our team experience working with Crow differently. We value the complexity of multiple knowledges and experiences.
- **Visible:** Infrastructure, by nature, fades into the background, and is built on tacit knowledge and institutional memory. Tracing infrastructures, and naming the processes, tools, and capacities embedded in infrastructure helps to keep the assemblage visible and open to negotiation.

The following literature review guides our thinking and identifies the actions we take to build sustainable infrastructure.

#### Fostering Reflective Iteration

Drawing extensively on technical communication and infrastructure studies, Read (2019) developed a four-part framework for theorizing infrastructure, which Frith (2020) proposed extending to highlight the rhetorical, writing-focused nature of her work:

1. **Inclusiveness:** a broad scope for what counts as writing;
2. **Relationally defined:** a focus on what writing does for something or someone;
3. **Alliance brokering:** writing that mediates essential alliances;
4. **Mission critical:** writing that is essential to the operations of an organization (Read, p. 237).
5. **Embeddedness:** writing that disappears into infrastructures such that it becomes invisible in day-to-day use (Frith, p. 408)

This frame is incredibly useful in helping organizations—in our case a research team—to uncover the tacit knowledge and kinds of writing essential for both daily operations and the growth and well-being of an ongoing research project. Understanding infrastructure as relational—an assemblage of activities that includes people, digital artifacts, and material tools—reveals the orientation to infrastructure that underpins our work. Like Read and Frith, we are...
invested in understanding the infrastructural functions of writing in our organization (Read, 2019, p. 260). Making those often-invisible elements of our infrastructure more visible can help us to acknowledge the labor inherent in infrastructural writing and attempt to address the barriers to inclusion and collaboration often embedded in institutional research models.

These five elements of infrastructure help us to articulate aspects of Crow’s approach to sustainability. As Noor Fares’s user story suggests, we take an inclusive approach to what counts as writing. Small messages in team communication platforms, comments on drafts, and agenda notes are often more significant to our understanding of infrastructure than the more formal products (like research papers and presentations) more easily recognized as scholarly writing. This inclusive approach also helps us to articulate the embeddedness of writing in our infrastructure. Procedures for data processing, conversations about development, and mentoring conversations facilitated by agendas and planning documents shape the way our team functions, and are constantly authored and revised, even though team members may not think of their interactions with these documents as writing tasks or infrastructure building.

We are concerned with what writing does for the sustainability of the Crow corpus, repository, and web interface and for the growth and development of our team. CDW research and project management is designed to uncover the roadblocks team members experience when infrastructural practice is tacit, invisible, and exclusive. As we develop iterative research and iterative practices to support sustainable infrastructure, we pay attention to the relational nature of writing—how the documentation we produce across a variety of platforms facilitates work. Our outreach goals (JoEtta & Picoral, 2021) highlight how alliance brokering shapes our infrastructure. We seek to build relationships with institutions, researchers, administrators, and funders that improve our capacities to support student researchers, and to create opportunities for sponsored pedagogy and research opportunities that foster a diverse network of scholar-teachers. Two areas of infrastructure theory help us understand the mission critical aspects of our writing infrastructure: participation and multiplicity.

Inviting Everyone to Participate in Sustaining Infrastructure

As noted above, Star (1999) describes two characteristics now foundational to contemporary thinking about visible infrastructure: first, infrastructure is most visible when it is broken. Second, infrastructure is built in layers, accreted over time and across systems. “Changes take time and negotiation, and adjustment with other aspects of the systems involved. Nobody is really in charge of infrastructure.” (p. 382). Working actively to keep infrastructure visible can help researchers to see through those layers of accretion and respond locally to the complications and ethical challenges of collaboration. Importantly, with CDW, the Crow team takes responsibility for the ways we design, intervene, and negotiate to address infrastructural problems. Institutional infrastructures, even those we have a hand in building, can be seen as monolithic, beyond our capacities for response, but we have the capacity to seek change through local, situated, and intentional action that invites participation from all members of our team. Lauren (2018, p. 40) suggests “participatory project management” as a way to address power imbalances and institutional roadblocks. Indeed, CDW researchers are committed to designing methods that help us iteratively negotiate the infrastructural systems within which we are embedded (Hart-Davidson & Grabill, 2011; Porter et al., 2000). Technical communication has a long history of reinforcing systemic inequality by making systems invisible (Longo, 2000; Walton et al., 2019). However, attention to researchers’ experiences, and their social and technical interactions, can help researchers enact local, specific interventions that address the systemic problems of access, inclusion, and sustainability present in institutional research and development.

If we think of inclusiveness both in terms of what counts as writing and how differences in experience mean team members engage differently with writing infrastructures, it becomes more apparent why our attention to sustainable infrastructure also requires attention to the other core principles of CDW (networked mentoring and building rhetorical confidence). Like other scholars studying the relationship between mentoring and inclusion (Mckoy et al., 2019; Melonçon & Potts, 2020; Montgomery, 2017), we have seen that inviting participation can help to build networks for mentoring. By insisting our collaborations include a listening infrastructure that invites dialogue (Moore & Elliott, 2016), we can help team members develop rhetorical confidence as we enact the transparency and create the dialogue necessary to remove barriers and amplify diverse voices across our team.

Making Multiple Experiences Visible

Read’s theoretical framework suggests that an ontological approach to infrastructure must account for differences in how researchers interact with the infrastructures they seek to sustain. Similarly, Mol (2003) draws attention to material realities of multiplicity. In her studies of medical practice, patients, doctors, diagnosticians, and technicians experience disease not from relative positions, but from multiple and layered realities that interact differently with the institutional infrastructures of medical practice. Uncovering and interrogating these layered realities can, Mol suggests, help us respond better to the realities of practitioners and patients. Attention and iterative action mean that we must be conscious of how we experience infrastructure differently. It’s not a matter of perspective, but a difference in the realities of identifying and navigating systems of power and institutional bias. As diverse researchers from a variety of disciplines, including writing studies, data science, linguistics, and technical communication, Crow researchers build and sustain infrastructure with a variety of knowledges, as well as multiple discursive and cultural practices and from differing positions of power. We are finding that integrating the user experience approach that initially informed our software development keeps these differences visible and helps us see changes over time—for example, by using personas for professional development, and by shaping project goals in relation to usability evaluation of the Crow web interface.

Because our Crow research team includes international and multiply marginalized scholars, and because we are committed to further addressing the institutional barriers and biases they experience, we have to commit to a robust theory of infrastructure that considers more than differences in perspective. Differences in lived experience mean that our team members perform Crow work in multiple realities, and their encounters with power and discrimination are not always immediately visible. Disclosing those realities can also be difficult as inherent discrimination and unexamined biases from PIs and other colleagues can make team members feel unsafe. Interrogating the ways we incorporate multiplicity as a practice of listening, gathering information, and creating ways for all team members to speak to their experiences.
is necessary as we seek to build a theory of infrastructure that supports and sustains both Crow work and Crow researchers. CDW, is by nature, always a work in progress. This case study, like other research we have published, continues our commitment to sharing that work in progress, making arguments for ethical and sustainable work, inviting others to engage these methods, and staying accountable and open to feedback as Crow continues to grow.

METHODS
The descriptive case analysis we share here is thus framed through our own experiences: as participant researchers in Crow, as developers of documentation, and as the team members who carried out user experience research at different time periods through the lifespan of the project. This analysis allows us to draw implications informed by our research and development progress—building patterns (Yin, 2009) instead of making assertions (Stake, 1995). As Creswell (2013) argues, these patterns are lessons learned from researching and studying a particular case of interest. These lessons can be applied to inform our development, progress, and learning in Crow, and can also be applied to other research contexts and communities seeking to build sustainable infrastructure in collaborative teams.

We approach this analysis through communication mapping (Angeli, 2017) and spatial technical mapping (Read & Swarts, 2015) to make sense of the distributed infrastructure embedded in our work and to learn how communication and coordination move through that infrastructure. Angeli identifies “stakeholders, communication channels, power dynamics, and shared values among stakeholders” as the components making up her assemblage maps (p. 237). She argues that the “components of an assemblage interact dynamically with communication acting as a stabilizing force” (p. 238). Angeli’s communication mapping shows that spatial relationships and pathways are central to understanding how assemblages interact. Similarly, Read and Swarts demonstrate how spatial and social mapping can make assemblages more visible and open for revision and iteration. We argue that CDW acts as a stabilizing force that designs and facilitates workflow in research teams. In the following sections of this article, mapping is a research and assessment method that allows us to examine how infrastructures interact and helps us draw relationships and unpack messy connections between material and social infrastructures.

By developing a case study based on the user story we shared at the beginning of this article, then mapping the emergence of CDW as a guiding heuristic with both that case study and the interactions of current researchers in mind, we can address the following research questions:

1. How does mapping emerging infrastructure help us demonstrate the CDW heuristic, and how does its integration support inclusive project management?
2. How can mapping interactions with infrastructure help us to make infrastructure more visible, and facilitate conversations about iterative design when it comes to mission critical writing?

MAPPING THE EMERGENCE OF CDW
CDW emerged as a methodology and practice grounded in building a sustainable and ethical research team. The infrastructures that support Crow work formed as a situated response to building software and building a team simultaneously. Because software design is central to our project, like Hart-Davidson and Grabill (2011), we seek to make explicit connections to software development not only for methods, but also because “the development of information and software tools is a deliverable of our research” (p. 161). Indeed, the poor sustainability and inconsistent attention to usability we saw as major barriers to success in other web-based writing research projects convinced us to seek ways to embed continual user-centering in our project at multiple levels. Hart-Davidson and Grabill suggest that technical communicators recognize the rhetorical activity inherent in distributed knowledge work and actively seek to shape and understand it through research and attention to infrastructure. Likewise, the CDW team makes conscious choices linking user experience design, writing research, and technical communication research because we see these different facets of our work as entangled. By making those connections not only explicit, but foundational, we nurture human, digital, and material infrastructures that make our team successful—both internally, in building infrastructure that helps the Crow team, and externally, in creating software tools broadly usable by diverse scholar-teachers.

Mapping infrastructure formation highlights the feedback loops embedded in development, research, and team-building processes, which helps our team understand where we naturally look for feedback, and it helps us to assess where adjustment is needed. Our first map includes the physical spaces, meeting sites, and mission-critical documents embedded in Crow infrastructure from early design brainstorming and development phases of both the Crow web interface and the makeup of our research team.

The map shown in Figure 1 is a part timeline, part geo-spatial digital map. Both the Crow team and our goals for research, development, and mentoring changed significantly in the two-year period this map describes. In 2017, Shelley Staples, one of the founders of Crow, moved from Purdue University to the University of Arizona, and Crow won a Humanities Without Walls grant (Dilger et. al., 2016) that included Michigan State University, significantly speeding up our timeline for inter-institutional collaboration. Two additional research sites, now staffed with grant-supported undergraduate and graduate personnel dedicated to mentoring, meant we rapidly expanded the number of students and faculty working on interface development and student-led research using the corpus. This map shows a big picture view of the resultant interactions of infrastructure attempting to link our labs, digital meeting places, and sites for face-to-face collaboration within a distributed team. For example, at Computers & Writing 2016, we attended a workshop that helped shape the Crow web interface (Omizo & Hart-Davidson, 2016) and discussed the possibility of collaboration with Michigan State with Bill Hart-Davidson. In the rest of this section, we use the timeline map to reflect on how infrastructure often built in the moment helped Crow respond to specific time sensitive problems or questions, then became part of the enduring infrastructure that now sustains our work. We consider how continued attention to our interactions with this infrastructure invites iteration and negotiation when existing tools create bottlenecks in workflows or when current practices leave team members feeling unsupported or excluded in decision-making or collaboration.
Environmental Scans Shaped Material and Social Infrastructures of Crow

To build visible infrastructure and design a user-centered platform in Crow, our early work focused on environmental scans of similar projects. In 2016, we conducted environmental scans (Donaldson & Franck, 2016) of Pedagogy Toolkit, BYU COCA, DRAW, Lextutor, MICUSP, Sketch Engine, and Talk Bank. Through team discussion and an initial examination of these websites, we developed uniform criteria to conduct these environmental scans and created documentation for sharing our findings with the team. These criteria prioritized metadata about each project, targeted audience and purpose, user experience considerations, and design principles. Environmental scans were analyzed collaboratively and helped us determine the design principles and components we would prioritize for the Crow interface. This collaborative, design-oriented process informed other Crow work habits. Negotiating criteria for environmental scans and establishing strategic priorities for our web interface design became models for the processes we used to identify initial research questions and directions for Crow project direction overall. As both process and product, these environmental scans also created a better understanding of user-centered design approaches across our interdisciplinary team.

Collaborating on knowledge sharing and documentation through discussion, both face-to-face and in Google Docs comments, increased the visibility of these artifacts and helped to build rhetorical confidence among team members. By distributing work among Crow researchers, we were gradually creating cohorts and sub-teams, thus building Crow’s social infrastructure. Coming to agreement on scanning protocols and criteria engaged collaborative brainstorming and negotiation, which was easier when Crow was a smaller team with fewer sites. The limited number of Crow researchers at the onset of the project was a pragmatic decision to balance mentoring capacity with creating social infrastructures needed to facilitate effective collaboration. That is, as we thought of capacity building, we kept long-term sustainability as our primary goal. We asked what people had time for and what we could do effectively, recognizing, for example, that faculty PIs had external responsibilities and that graduate and undergraduate student researchers had commitments to coursework and their own individual research projects. The questions that guided this initial design work continue to inform Crow development: How do environmental scans help us think of backend problems? What kind of capacity do we need to build to sustain the Crow interface? How do changing circumstances and conditions influence our decisions to expand or limit capacity building?

Research Questions Emerged through Collaborative Road-mapping

By conducting environmental scans, Crow researchers imagined early on what Crow as a corpus, repository, and interface might look like. The way we performed and analyzed these scans also helped to shape the framework for how Crow functions as a team. All Crow team members contributed research questions that we might pursue through Crow development. We created a research question matrix in Google Docs, a document we actively consulted as we brainstormed our approach to developing the web interface and building the capacities of the Crow team. This matrix was revised extensively as we considered possible developments in the project. The interests and expertise of Crow researchers helped us prioritize our research and development choices. Because the document was shared, and comments and questions were both encouraged and preserved through Google Docs features, this process encouraged a mindset of iteration and reflexivity. We sought to make an inclusive, equitable, ethical research community by engaging...
researchers at every level of the team with our design and research road-mapping, providing the mentoring needed to invite access and build the confidence necessary to contribute. This process helped us to establish a flatter approach to project management where the concerns and interests of student researchers are considered and included with the same weight of the faculty PIs on the project. We also identified facilitating networked mentoring and building rhetorical confidence among team members as core principles of Crow work.

As our team has expanded to multiple institutions including new members, we have revisited our environmental scans adding new projects and documenting how others faded or simply vanished. Thus, sustainability continues to be a prime consideration for Crow project development. Staples’s relocation to Arizona and doctoral students finishing their studies and moving to accept faculty positions required us to prioritize modifying our infrastructure to support an inter-institutional team. Our original practices of mentoring (for example, common research meetings in the same physical space) had to evolve as partners’ roles changed and expanded to various institutions, in different geographical spaces, across multiple time zones, and with more demanding schedules.

The Matrix Developed as a Tool for Collaborative Planning and Mentorship

As we moved beyond initial brainstorming and planning into interface design, we needed a more sustainable and reflexive way to assess professional development across our distributed team, while establishing leadership roles for project teams. Over time, we developed “the matrix,” an internal document, visible to all Crow researchers, where each member of the team shares information about current projects, research interests, and professional development goals. Everyone is encouraged to consider their entire identity, not just their Crow interests in filling out the matrix (McMullin, Banat, et al., 2021). For example, teaching load, publications in process, administrative appointments, and individual research obligations are all included. The matrix functions as both visible infrastructure and the operationalization of our mentoring best practices. It serves five purposes critical for CDW:

1. Encouraging team members to explore their own professional growth;
2. Supporting assessment of individual capacity and commitment, explicitly considering overwork and burnout;
3. Facilitating formation and rotation of interdisciplinary sub-teams within Crow;
4. Highlighting leadership opportunities for team members across both institutions and career roles;
5. Illuminating changing circumstances and evolution of roles, interests, and expertise over time.

The visibility and accessibility of the matrix help us make this activity collaborative. Framing the matrix within CDW helped us learn how to consider orientations to work (approaches, activities, and outcomes) in public conversation, demonstrating how we enact the core principles that ground Crow work. For example, we have designed specific “how-to” explainers targeting important tasks related to our research, like participant recruitment, deidentification, and grant budgeting. These explainers also support mentoring new members who are executing tasks and activities integral to project development. After these team members have developed expertise in these areas, their positionality and engagement in new projects can grow. The continuous interaction between the matrix, documentation, and research activity demonstrates that material and social infrastructures are in constant interaction and influx with permeable boundaries. Such interactions, as facilitated by the matrix, promote inclusive participation of all team members, flatten hierarchy, help us assess and sustain interdisciplinarity, and keep us accountable.

Our Team Communication Platform Becomes Distributed Homebase

As our team expanded to include not just multiple sites, but multiple teams that were simultaneously engaged in different parts of Crow research and development, we needed a central hub to coordinate work. Technical communication scholarship (Hart-Davidson et al., 2012; Pigg, 2014; Slattery, 2007) underscores the value of coordination, the continuous effort that builds and sustains the assemblages and networks inherent to distributed work, and suggested integrating and curating our use of a team communication platform. It’s not enough to choose a tool; it’s necessary to assess and then shape how that tool supports the collaborative infrastructure needed for distributed work.

To organize synchronous and asynchronous collaboration, we chose Basecamp as our team communication platform. To use it effectively, Crow researchers had to experiment with its affordances, tools, and functions, including how to use different elements like calendars, to-do lists, message boards, the general chat thread “Campfire,” and direct message “Pings.” Basecamp connects the multiple platforms we use in Crow (Google Drive, the Crow interface, writecrow.org, and GitHub). The most prominent affordance of Basecamp is coordinating the social interactivity that accompanies collaboration. Our early use of the platform also made clear the need for best practices and guidelines that would encourage Crow researchers to Basecamp use, while adapting as the Basecamp platform developed over time. For example, we needed to designate clearly which kinds of information should be documented in the different areas of Basecamp. Campfire is useful for quick announcements, reminders, and celebrations of team success. To-dos are useful for documenting conversations related to specific tasks; message boards support broader sustained discussion or requests for input from the whole team. One early change was to outline expectations for keeping discussion about work visible:
that is, to conduct discussions, including brainstorming, conflicts, and negotiation in public threads rather than in “Pings” invisible to the rest of the team. When Basecamp added a “boost” feature that allows users to react to posts with emojis like a “thumbs up” or clap, or brief phrases like “Got it” or even “Not sure,” we had to consider how these new avenues for response allowed for participation and coordination that was not as visible as comments in a-to-do thread.

Crow best practices have had a positive impact on existing Crow researchers, improving their workflows and communication practices in Google Docs and Basecamp and helping new Crow researchers join and build upon the prior work of peers. Best practices also facilitated the onboarding of additional Crow researchers. With the expansion of the team to more institutional contexts and with new researchers joining the project, Crow started operating in smaller sub-teams. The graduate lab practice, as a centralized space for daily project operations, ceased to be a possibility despite its valuable contributions to the project. Today, we operate from multiple sites where PIs, graduate, and undergraduate researchers interact synchronously and asynchronously. These interactions are not always smooth. Multiple barriers like power and expertise imbalances require continued attention to how our best practices grow out of core principles and are reflected in our orientations to work. The CDW heuristic helps us to make visible to the wider Crow team how our daily interactions work and where our priorities are focused so that as a team, we can assess, reflect, and iterate as we continue to build infrastructures that help facilitate more inclusive and ethical work.

For example, as our inter-institutional expansion took hold, Crow activities diversified considerably, and we realized we needed best practices for the team leads that distribute and organize work within subteams. The team lead best practices prioritize the following:

- Asking for help from Crow leadership when needed;
- Supporting and engaging all team members within smaller units;
- Delegating meaningfully, but maintaining participation in project work;
- Reporting regularly to all Crow researchers to enhance transparency; and
- Identifying and tracking specific responsibilities publicly and constructively.

These guiding principles mentor Crow researchers as they transition into leadership roles and serve as another way to operationalize the three-dimensional CDW heuristic and its active shaping of Crow infrastructure.

**User-Centered Methods for Assessing Visible Infrastructure**

Tracing the evolution of the CDW heuristic helps to identify the mission critical writing infrastructures that sustain Crow work. We can begin to see where participation occurs most often and is most likely to be informed by tacit knowledge, or hampered by barriers to communication or interaction that our particular experiences as
PIs, administrators and/or mentors might not make immediately visible. In other words, mapping helps us to understand how theory informs our practice as we keep infrastructure visible, and make constructive decisions about where to focus our questions as we assess and iterate on existing infrastructure. As we develop research tools for assessment, keeping in mind the participatory and multiple nature of a dynamic team, we draw on user-centered research methods, like the data-informed persona and user story we introduced in the beginning of this article. Mapping gives us another tool for triangulating the data behind user personas and offers us another method for listening to team members and incorporating feedback as we share maps and ask others to comment on and iterate maps.

As we were designing our methods for assessment, we once again leaned on software development and user experience design methods to build reflective personas from interviews with various Crow researchers (McMullin, Weech, et al., 2021). We formed three personas: the undergraduate, graduate, and early career faculty researchers. Through interviews focusing on interactions with infrastructure, we developed a better understanding of how team members used documentation and the platforms that facilitated or impeded collaboration and progress. We asked:

1. How team members identified the social, spatial, and technological contexts where Crow infrastructures are situated, i.e., how they understood the relationship between documentation and the platforms we use (team communication platform, the Crow web interface itself, Crow website, GitHub) as well as the relationship between Crow fieldwork (research lab work, data collection and processing, outreach, summits and conferences) and Crow’s infrastructures.

2. How team members identified the boundaries, limitations, and affordances of different types of infrastructure in Crow, i.e., the types of infrastructure that facilitated their progress/development and the types that created confusion or hesitation.

The data we collected helped us improve our existing documentation and build new documentation that bridges gaps and loopholes. For example, we learned from our personas that new team members who engage in collaborative writing in Crow would benefit from specific asks and directions during collaborative writing and from clearer task assignments in Basecamp buildouts for a range of projects. This led to clearer directions when inviting team members to contribute to work in progress. Persona research also showed how the process of onboarding has changed with the expansion of the team to new institutions and the addition of new researchers from the institutions in our expanding network. To coordinate onboarding across sites and various levels of expertise (incoming and former team members), we are developing an onboarding explainer and checklist. User experience research is leading us to create documentation that facilitates more effective use of Crow’s infrastructures and thus helps networked mentoring become more inclusive and equitable as we account for differences in expertise. The relationship between user experience research and creating documentation further highlights the reflexive process of assessment and demonstrates the interactivity between the social and material infrastructures in Crow. By layering what we learned from persona development with what we are learning by mapping the emergence

Figure 4: Onboarding of Noor Fares to the Crow Grants Team. Map shows interactions between people (hexagons), mission-critical documentation (squares) and our team communication platform (pentagons). Green solid arrows trace contributions to infrastructure. Blue dotted lines map “read and comment” writing tasks.
of existing Crow infrastructure, we are getting a better sense of how our infrastructure works in practice and learning where we need to further iterate in order to support the current needs of our team.

MAPPING SPECIFIC INTERACTIONS USING PERSONAS

The timeline map helps us to understand how our user experience approach has evolved, and how that approach led to the development of the CDW heuristic. The reflective nature of timeline mapping is important, both for our own internal assessment, and as an opportunity to invite feedback from a wider audience of scholars, researchers, and professionals outside our team. This look back, however, doesn’t really provide an opportunity to assess individual experiences, or to identify emergent or still hidden aspects of mission critical infrastructure. The map in Figure 3 attempts to capture the user story we share at the beginning of this article in a more granular way by focusing on one researcher, and their contributions to documentation—meaning ways researchers add to or build content into existing infrastructures. Contribution here indicates authorship, whether that’s adding information to a document like the matrix, contributing to threads or tasks in Basecamp, or designing buildouts for specific projects.

While grant writing isn’t the only task we could map in this way, it is a useful starting place because nearly every member of the team touches a grant writing project while working with Crow, and because the cycle of grant writing is more easily generalizable to a wider audience than other aspects of our research and design life cycles. This map begins with the onboarding process and includes the start of a new grant writing cycle in which Noor Fares joins the grants team and is tasked with creating the Basecamp buildout for a grant application. To make the infrastructure required for a researcher to complete this task visible, we map their interactions with the material and social infrastructure of the Crow team. This map begins with onboarding because the networked mentoring approach we take to orienting new Crow researchers is foundational to how researchers experience and interact with Crow infrastructures.

Originally, we planned to only include the graduate student persona Noor Fares, but mapping the scenario completely had to include the other members of the team with whom Noor collaborated. Adding faculty, team leads, and other members of the grants team helped us see better where opportunities for facilitating networked mentoring and building rhetorical confidence show up in our infrastructure. Green, solid arrows on the map trace sites of contribution to infrastructure, where mostly informal writing becomes a permanent contribution to built infrastructure. For example, all Crow team members, from undergraduate researchers to senior faculty, contribute to the same version of the matrix. This helps with transparency, but also modeling. Conversations between faculty leadership and Crow researchers often begin with the matrix, and new researchers can review previous iterations to understand how to contribute to the document. Basecamp coordinates nearly all Crow work, and every researcher contributes notes, comments, ideas, and updates that become a relatively permanent and public record of Crow work. Our best practices help orient new researchers on how to use different areas of the team communication platform, and how to interact with others in that space. As part of onboarding, new researchers are encouraged to look at in progress as well as archived projects to better understand how we use Basecamp.

The blue dotted lines on this map indicate “read and comment” writing. Because of the distributed nature of Crow work, collaborators often work asynchronously on projects. Further, because our work is interdisciplinary, “read and comment” tasks are often assigned as a way to gather a wider range of experience and expertise. The first “read and comment” assignment given to Crow researchers is to comment on the Crow best practices document. Because this is a living document, there are nearly always open comments, suggestions for revision, notes to resolve or update changes visible on our best practices. Asking researchers to not just read but read and comment on best practices orients new researchers to the way our infrastructure evolves, and is open for questioning, critique, and suggestion. It also helps to build rhetorical confidence by asking researchers to practice a mode of writing that is foundational, but can often be invisible, or feel inaccessible to new researchers. As the map in figure two makes clear, “read and comment” tasks are carried out by every member of Crow and involve nearly every iteration of writing. Because we are collaborators, we invite a lot of discussion. Because we are asynchronous collaborators, discussion often happens in comments on work in progress.

Unlike the contributions which end up as more permanent infrastructure, read and comment writing often disappears as documents are finalized. This genre of writing is infrastructural, but it is either scaffolding or building material that fades away as questions and tasks are resolved or comments are incorporated into draft text in the writing process. The prevalence of “read and comment” tasks on this map help us to triangulate information that has surfaced in other aspects of our assessment. For example, a key takeaway from our persona development project was that being asked to read and comment on a project already in process can be intimidating—especially as a new researcher. Without clear instructions or a specific task, it can be difficult to see how and where to jump into an ongoing conversation taking place in the comments or suggested revisions of a collaborative project. Similarly, when we share CDW with colleagues outside of Crow, we are often asked how researchers develop the skill of “reading through the changes” in a collaborative document where many voices are present. This map helps us to confirm that “read and comment” writing is a mission critical aspect of Crow work, and one where we have opportunities to improve our onboarding and mentoring. Thinking about this ubiquitous but often invisible practice can inform a wider understanding of inclusive collaborative writing.

KEY TAKEAWAYS: MORE MAPS AND MORE MAP MAKERS

Mapping how we came to develop the CDQ heuristic opens up possibilities for sharing CDW methods with new teams and invites feedback that will inform future development. The maps in this case study helped us to articulate sustainable infrastructure as a core principle of CDW and helped us to further understand the “read and comment pass” as an emergent genre of mission critical Crow writing that is valuable to our team, and potentially to the wider research community. It is important to note that the CDW heuristic emerged from practice and is not meant to be a template that can be applied without reflection, user-centered listening, and careful consideration of disciplinary and contextual influences. This case study further illuminates how mapping might be useful, not only as an opportunity for assessment, discussion, and iteration within our team, but also as a tool to help new research teams identify
the core principles, best practices, and orientations to work that are central to their infrastructure. Mapping can create a collective of communal reflection and assessment of infrastructure.

Multiple approaches to mapping also help us to show how sustainable infrastructure operates as a core principle of the CDW heuristic, and how it is integrated into our attention to other core principles, best practices, and the activities, approaches, and outcomes of day-to-day work. Like infrastructure, the three-dimensional nature of CDW as a project management approach can be difficult to see at first glance. Even across the Crow team, where attention to infrastructure has been part of the conversation since the beginning, how the CDW framework guides our work isn’t consistently visible to everyone, and the best practices and orientations to work we employ can still fade into the background. Both new and veteran researchers are always developing their own methods for navigating interactions within the team. The mapping we showcase here doesn’t necessarily represent the experience or understanding of every member of the Crow team. Maps are always a snapshot and are always informed by the experiences of the mapmakers. In outlining a method for using personas as a basis for mapping interactions within our infrastructure, we have added a tool for assessment to the CDW heuristic. However, maps can only account for participation and multiplicity if we map multiple interactions, from multiple perspectives, and read those maps through and across one another to build more effective and transparent infrastructure that supports all members of our team.

As the CDW team gathers data and develops methods for understanding how our approaches, activities, and outcomes interact with our core principles and best practices, our next steps include asking more members of the entire Crow team to discuss what they see in these persona-informed interaction maps and inviting them to revise or reimagine those maps based on their own experiences. These complex conversations, facilitated by mapping, can help us be more accountable for how our infrastructure affects our team, and how bias, power, and positionality might still be creating barriers for members of our own team. More broadly, we hope the methods we share here will help other research teams interested in how CDW might support and amplify their own work.

ACKNOWLEDGEMENTS
Special thanks to Dr. Aleksandra Swatek and Anuj Gupta for their contributions to this article, and to the Crow team members who participated in earlier research discussed in this article. The Crow project was supported by the American Council of Learned Societies and the Humanities Without Walls consortium.

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Writing Infrastructure with The Fabric of Digital Life Platform

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ABSTRACT
Teaching writing involves helping students develop as critical communicators who use writing to question often-unseen systems of power enabled by infrastructures, including digital spaces and technologies. This article uses Walton, Moore, and Jones’ (2019) 3Ps Framework—positionality, privilege, and power—to explore how, through assignments we developed incorporating the Fabric of Digital Life digital archive, instructors can make visible to students the invisible layers of infrastructure. Using the 3Ps framework, we illustrate how our pedagogical approach encourages students to use writing to interrogate digital infrastructure and the ways it is entangled with positionality, privilege, and power.

CCS Concepts
Information systems

digital writing infrastructure; socially just digital literacy; critical writing pedagogy

INTRODUCTION
Teaching writing involves helping students develop as critical communicators who use writing to question often-unseen systems of power embedded in infrastructures. Infrastructures are defined in part by their level of visibility. Star (1999) issues a call to study infrastructure, which is “by definition invisible, part of the background for other kinds of work” (p. 380). As infrastructure, digital platforms may “often downplay, obfuscate, and/or black box” decisions (Edwards & Gelms, 2018, p. 3). Yet not all platforms “black box” decision-making. The Fabric of Digital Life (Fabric), a digital archive, is particularly concerned with the visibility of embodied technologies. Inspired by Weiser’s (1991) prediction that “profound technologies … weave themselves into the fabric of everyday life,” Fabric tracks the emergence of technologies through collections of artifacts such as video clips, news articles, marketing materials, and other texts. As a digital archive and platform, Fabric is an infrastructure that is used to archive, study, and illuminate other infrastructures.

Infrastructure is relationally defined by the communities, technologies, and approaches that it brings together to support organized activities and practices (Star & Ruhleder, 1996). Infrastructure emerges in situ (Star & Ruhleder, 1996), or in the real-life contexts of these integrating agents. Infrastructure has largely been discussed in scholarship on organizational information systems that support workforce collaboration, particularly for geographically dispersed communities (Star & Ruhleder, 1996; Star, 1999). Read (2019) expands the concept of infrastructure by applying it to communication and writing artifacts to articulate how writing products, activities, and processes underwrite organizational life in technical organizations. Read (2019) developed criteria for identifying communication infrastructures, which adhere to Star and Ruhleder (1996) notion that infrastructure and writing are relatively defined. Frith (2020) added criteria to Read’s (2019) communication infrastructure framework to articulate the invisible nature of writing in an organization. Discussing writing as infrastructure, Read (2019) suggests that “developing methodologies to make invisible writing visible enables us to make arguments for its value in scholarship, teaching, and industry” (pp.
To help in making the invisible visible, we apply Read’s (2019) and Frith’s (2020) elements of infrastructure as an analytic tool for examining how infrastructure and writing are relationally defined in our work toward building digital literacy with Fabric. Infrastructure serves a function for certain organizations, objects, or systems; as Read (2019) writes, we must identify “for what or for whom writing functions as infrastructure” (p. 252). Fabric acts as infrastructure by providing a digital platform for cataloging artifacts about technologies, promoting certain discourses or ways of seeing technologies through its collections, and providing opportunities to participate in building the platform, its collections, and its artifacts. Our Building Digital Literacy (BDL) research group incorporates Fabric into writing classrooms by having students analyze, create, or contribute to collections. The BDL team, begun in 2019, is an international group of instructor-scholars formed to build a strong community for collective intention surrounding digital literacy understanding and student digital literacy development (Duin et al., 2021).

In our analysis, we use Walton et al.’s (2019) 3Ps Framework—positionality, privilege, and power—to explore how, through assignments we have developed that incorporate Fabric, students make visible the invisible layers of infrastructure. By examining the relationship between Fabric’s infrastructure and the 3Ps, we interrogate how positionality and privilege influence how we talk about technologies and how power is used, misused, and distributed through and across infrastructures in ways that are often invisible. The 3Ps framework helps us understand how our pedagogical approach might encourage students to use writing to interrogate infrastructure and the ways it is entangled with positionality, privilege, and power. We analyzed three datasets: assignment prompts; published collection descriptions contributed by students; and our collaborative autoethnographic reflections on this work. We demonstrate how assignments that involve working with Fabric can help students unearth a complex web of rhetorical agencies embedded in digital infrastructure. For example, assignments asking students to take on the role of curator help to reveal how curators occupy a certain space of privilege and exert a level of power through rhetorical choices about metadata and collection themes. We demonstrate how Fabric is an infrastructure that, unlike most digital infrastructures, holds within it the power to contribute to social justice work within the TPC discipline, and provide methods for incorporating Fabric in the classroom to encourage critical awareness of infrastructure, including “for what or for whom” infrastructure is operating. Ultimately, we aim to articulate how attending to the 3Ps in the context of infrastructure and building digital literacy can support socially just writing pedagogy.

BACKGROUND: THE FABRIC OF DIGITAL LIFE
The Fabric of Digital Life (refer to Figure 1) is a public cultural analytics database and digital repository used for the organization, storage, research, publicization, and preservation of artifacts on the emergence of embodied technologies (Pedersen & Baarbé, 2013; Iliadis & Pedersen, 2018; Pedersen & Iliadis, 2020).

Created by Dr. Pedersen and members of Decimal Lab, a critical media collective at Ontario Tech University, Fabric addresses the issue that technologies are not fundamentally neutral; that is, they are designed, developed, and adopted according to the values, biases, ideologies, and cultures within which they thrive (Haas, 2012; Noble, 2018; Walton et al., 2019). One of Fabric’s objectives is to reveal motives inherent to embodied technologies through the diverse artifacts that contribute to their rise and societies’ adoption of them. Growing since 2013, Fabric hosts a collaborative community of researchers who contribute content, metadata, collections, and pedagogical resources for instructors to use. The BDL group is one cluster of researchers (Duin & Pedersen, 2020; Duin et al., 2021; Tham et al., 2021; Iliadis et al., 2021). For sake of content scope, Fabric follows embodied technologies that are ambient, carryable, wearable, implantable, ingestible, embeddable, and robotic. However, these kinds of inventions function in rich ecosystems with other emergent technology such as Artificial Intelligence (AI), smart homes, social media, internet of things, cryptocurrencies, AI assistants, biotech and so many other contextualizing technologies. (Fabric of Digital Life, 2021, para. 4)

As a database, Fabric is constituted by several pre-existing “discursive infrastructures” (Frith, 2020, p. 402) developed by organizations external to it. First, Fabric is structured according to the Dublin Core metadata standard, which is an element set for describing a range of networked resources. Beginning in 2001, “The semantics of Dublin Core have been established by an international, cross-disciplinary group of professionals from librarianship, computer science, text encoding, the museum community, and other related fields of scholarship and practice” (Dublin Core Metadata Initiative, 2005, para. 7). Metadata is defined as “a structured set of named attributes with associated values used to describe data” (Kubik & Kwicień, 2021, p. 5). However, another way to understand metadata is data about other data (Metadata Basics, 2021). As such, Dublin Core is sometimes referred to as “small language for making a particular class of statements about resources,” with a “grammar” used for the “task of expressing complex relationships or concepts” (Dublin Core Metadata Initiative, 2005, para. 8).

A second data infrastructure for Fabric is its database, which provides public access to its web interfaces and closed access to its archival pages for the editorial team. Fabric is built upon an open-source collections management and presentation software called CollectiveAccess developed by a company called Whirl-i-Gig. CollectiveAccess is pre-loaded with metadata standards including Dublin Core and a range of other meta schema to help organizations make digital collections accessible without extensive programming. Finally, Fabric’s original development team, archivists, editors, and community have developed practices geared...
for the study of the cultural emergence of embodied technologies, a dynamically evolving phenomenon. While data standards and database software may constrain Fabric, they also enable research stakeholders the ability not only to review Fabric’s content but also contribute to it through many points of entry.

**INFRASTRUCTURE, DIGITAL LITERACY, AND THE 3PS**

Infrastructure permeates most activities of daily life while, by definition, remaining mostly or completely invisible. Frith (2020) and Read (2019) highlight both the invisibility and pervasiveness of infrastructure in daily life, from objects like highways and power plants to texts like software documentation and Tag Data Standards. Frith argues that “infrastructures matter … [t]hey are not just neutral substrates that support other practices. Instead, they shape those practices; they exert agency over everything from how we communicate to how bodies move” (2020, p. 406). The invisible but omnipresent nature of digital infrastructure in large part drives our work on building students’ digital literacy. Further, because of the power of infrastructure, and those who design infrastructure, to shape human experience, we deploy the 3Ps Framework (Walton et al., 2019) as a methodology that serves as a critical lens on infrastructure and digital literacy. In the remainder of this section, we first expand on how we apply Read (2019) and Frith’s (2020) elements of infrastructure, then discuss digital literacy, and lastly, expand on the 3Ps Framework.

**Infrastructure**

We adopted Read’s (2019) four-part framework for infrastructure—Inclusiveness, relationally defined, alliance brokering, and mission critical—and the fifth part that Frith (2020) argued was an essential addition: embeddedness. Drawing on their work, we developed the following operational definitions that we used throughout the project, including for coding data:

- **Inclusiveness**: A broad scope for what counts as writing, making visible “the types of writing that … might not be conventionally or culturally visible as writing” (Read, 2019, p. 247).

- **Relationally Defined**: A focus on “for what or whom the writing functions as infrastructural” (Read, 2019, p. 251) embedded within social and material structures of organizational context.

- **Alliance Brokering**: Writing mediates essential alliances “with actors who are essential to an organization’s existence and operations … [and] not always with actors who are human” (Read, 2019, pp. 254-255).

- **Mission Critical**: Writing is essential to the operations of an organization and involves “learning to look closely at technologies and arrangements that, by design and by habit, tend to fade into the wood-work (sometimes literally)” (p. 34)” (Bowker & Star, 1999, as cited in Read, 2019, p. 258).

- **Embeddedness**: Writing gets built into objects and erases itself as the objects go out into the world. Frith elaborated that “documents such as standards become infrastructure when their guidelines become embedded inside objects and are rendered invisible to people who actually use those objects” (Frith, 2020, p. 408).

These five elements of infrastructure are not mutually exclusive; they interact, overlap, and rely on each other as key characteristics of what it means for writing to function as infrastructure.

**Fabric as Infrastructure**

In Fabric, infrastructure is multi-layered. Because Fabric archives information about embodied digital technologies, it foregrounds those technologies as infrastructures. Correspondingly, Fabric is a platform that serves as an infrastructure by housing data in a CollectiveAccess database and digital platform, which is cataloged and archived according to the Dublin Core metadata standard and specific metadata guides developed by and for Fabric archivists and collaborators. In addition to being an archival infrastructure, Fabric functions as writing infrastructure: it takes an inclusive approach to artifacts; its focus on rhetorical effects highlights relations among artifacts and between artifacts and users; it actively engages both readers and artifacts in alliances using metadata; its written descriptions and metadata are essential to its function; and its written existence is obscured by its archival responsibilities. The multilayered nature of infrastructure aligns with the BDL team’s understanding of digital literacy as multilayered and multifaceted.

**Digital Literacy**

The BDL team has worked over the last three years to build student digital literacy by incorporating Fabric into writing classrooms. In our discussions, we have noted how technical and professional communication (TPC) scholars have primarily focused on technological literacy and, most recently, code literacy (Duin & Tham, 2018). Hovde and Renguette (2017), drawing on the work of scholars who have addressed technological literacy (Breuch, 2002; Brumberger et al., 2013; Cargile Cook, 2002; Northcut & Brumberger, 2010; Selber, 2004; Turnley, 2007) consolidate this scholarship into functional, conceptual, evaluative, and critical levels of technological literacy. After reviewing a number of digital literacy frameworks and beyond TPC, the BDL team developed a common language for building digital literacy, namely, that digital literacy is concerned with the rhetorical situation. Attending to the rhetorical situation facilitates consideration of context and the ways that literacies operate in “living, learning, and working in a digital society” (Joint Information Systems Committee, 2018, para. 1).

Vee (2013) argued that literacies are infrastructural, or a fundamental part of daily communication practices. Vee explained:

[A] determination of whether or not a system of skills is a literacy depends on its societal context. One can be skilled at leveraging specific technologies to communicate, but a literacy leverages infrastructural symbolic technologies and is necessary for everyday life. (p. 45, emphasis original).

In other words, literacies are an internal human infrastructure necessary for navigating other, external infrastructures. As Read (2019) says, “in Vee’s work, literacy, technology, and infrastructure enjoy a recursive definitional relationship that depends on their relation to broader society” (p. 241).

Importantly, infrastructure and technology are not neutral; they represent the biases of dominant social groups and thus often reify and replicate systemic oppression and inequity (Haas, 2012; Noble, 2018; Walton et al., 2019). This is especially pernicious with infrastructure as it means that oppression and inequity are embedded in invisible ways in the tools, systems, and material objects we interact with and rely on in daily life. Walton et al.’s
Positionality—"the location(s) of identities—and privilege—the advantages attached to specific identities—determine what kind of power can be enacted in different situations (Walton et al., 2019). Thus, positionality and privilege are woven together in specific ways that enable or constrain power. Positionality highlights the complexities of identities and the way that these identities are shaped by social context; positionality allows for understanding what different identity markers mean as they are located in particular social structures (Walton et al., 2019). However, identities are not essential or determined by society, but are "fluid and contextual," shifting with changing circumstances (Walton et al., 2019, p. 63).

Specific combinations of identity markers may place individuals into precarious social locations. In bringing awareness to intersectional identities and context, positionality is helpful for asking questions about the "who" of infrastructure—who is creating, maintaining, and perhaps resisting certain systems? As a result, who is being erased, hidden, or represented in biased ways? And how do our identities change the ways we view these systems? Asking these questions is critical work as infrastructures are made to sink into the background, along with those that uphold them or are rendered invisible because of them.

Privilege

Inherently connected to positionality, privilege builds from conceptions of identity as intersectional, fluid, contradictory, and contextual to emphasize what identities are centered within society and how this centering takes place. Privilege involves "receiving unearned social, cultural, economic, and political advantages" as part of one’s "specific sociocultural identity markers" (Walton et al., 2019, p. 83). Like positionality, privilege does ask about who is involved, but with a focus on who is valued, centered, and characterized as the norm against which those at the margins are judged (Walton et al., 2019). Occupying a position of privilege means that social structures are constructed to align with a certain normative perspective, while those at the margins are ultimately rendered different and ill-fitting for those same structures. In regard to infrastructure, recognizing privilege not only foregrounds the dominant paradigms and norms embedded within them, it also involves considering how it feels to be repeatedly judged against those norms.

Power

Together, positionality and privilege determine if and how power is enacted in certain situations. An individual’s identities and the social benefits attached to those identities indicate what paths to power are available. Though power has been theorized in TPC, these theories fall short in articulating power as a concept that can motivate action against oppression, as Walton et al. (2019) argue. Instead, a theory of power must acknowledge the role power plays in oppression, and in turn, the lived experience of those being oppressed and marginalized. Failing to account for these lived experiences can situate power as a neutral, abstract force separate from those who wield it and are affected by it. Walton et al. (2019) conceptualize power "as a dialectical system where individuals and groups can enact change and as a relational, shifting system of positionality and privilege" (p. 115). In this view, power is dynamic, shifting locations as situations change; the power available to groups is not the same in every context, and different elements of an individual’s identities render them more or less powerful as they move through various situations. Walton et al. (2019) explicitly discuss how infrastructure works to hide power from view, which aligns with Frith (2020) and Read’s (2019) explanation of infrastructures as agentic, invisible, and relational. Although many infrastructural systems are meant to be invisible as they become deeply embedded in daily life (Star, 1999), this means that power relations that govern these systems may also become invisible. Further, infrastructures themselves exert power in shaping action, and how that power is felt will shift depending on who a person is and what their goals are. It is critical to identify the more invisible and tacit infrastructures, including power relations, that govern our lives. This articulation of power motivates us to ask more questions about who wields power, who does not, and how oppression is implicated in these interactions.

Our project builds upon experiential knowledge and productive ambiguity (Davis et al., 2021) to demonstrate how Fabric is an infrastructure that, unlike many technological infrastructures, holds within it the power to contribute to social justice work within the TPC discipline. Fabric uses metadata to create collections of technological discourse, which may help TPC instructors articulate how the 3Ps circulate within infrastructures and how inclusive writing or communication practices can support socially just infrastructure development. Read (2019) argues that one of the purposes of theorizing writing as infrastructure is to "point the way..."
to pedagogical practices that will improve the teaching of technical writing to future professionals” (p. 237). To this, we would add that critical engagement of infrastructure through the lens offered by the 3Ps can promote digital literacy pedagogy.

**METHODS**

In this section, we describe our data collection methods, our use of Read’s (2019) and Frith’s (2020) elements of infrastructure for coding our collected data, and our application of Walton et al.’s (2019) 3Ps Framework to analyze coded data.

**Data Collection**

We analyzed three different collections of text for this study:

1. **Assignment prompts** incorporating Fabric that the authors used in their classrooms;
2. **Collection descriptions** collaboratively written by the authors and their students; and
3. **Collaborative autoethnography reflections** on the authors’ use of Fabric for classroom assignments.

We placed text from assignment prompts, collections, and reflections into three separate documents for analysis. We included assignments, descriptions, and reflections for analysis to identify infrastructural characteristics across three different writing purposes surrounding our instructional uses of Fabric: pedagogical approaches using assignment prompts, knowledge creation using collection descriptions, and ethnographic detail using reflections. Coding these three sets of texts using the same framework enabled us to identify elements of infrastructure running through all three types and purposes of writing in our dataset.

**Assignment Prompts**

As part of our work with the BDL team, we integrated Fabric into classroom assignments. Three assignment types were developed by initial BDL collaborators and made available to collaborators to incorporate into their classes, which we have described elsewhere (Davis et al., 2021). The three assignment types are:

1. Examine: Learn to explore existing content through artifacts.
2. Contribute: Learn to archive single items (media representations) and understand existing keywords and metadata.
3. Curate: Learn to archive collections of media representations related to a theme.

For this research project, the specific assignment prompts included in our dataset are described in detail in Table 1. The collection of assignment prompts comprised about 5,000 words for coding.

**Collection Descriptions**

In assignments where Fabric collections were curated, curators had to compose a collection introduction and a description of each artifact. These assignments required students and instructors to collaboratively write the introduction and required each student to write a description and create metadata for the artifact they selected for inclusion. Collection introductions and artifact descriptions for three class-curated collections (Carey et al., 2019; Hocutt et al., 2021; Stambler et al., 2019) were included for analysis. The collection of descriptions comprised about 2,000 words for coding.

**Collaborative Autoethnography Reflections**

During the Spring 2020 semester, Duin led BDL team members in a guided set of collaborative autoethnography (CAE) reflections as a means to explore our collective work. CAE, according to Chang et al. (2013), “focuses on self-interrogation but does so collectively and cooperatively within a team of researchers” (p. 21). CAE is “a qualitative research method in which researchers work in community to collect their autobiographical materials and to analyze and interpret their data collectively to gain a meaningful understanding of sociocultural phenomena reflected in their autobiographical data” (Chang et al., 2013, pp. 23–24). Chang et al. emphasize that “in CAE, each participant contributes … in his or her distinct and independent voice. The combination of multiple voices to interrogate a social phenomenon creates a unique synergy and harmony” (p. 24).

The use of CAE was an intentional strategy to flatten differential power structures inherent in the BDL team. Collaborators include senior and junior faculty, tenure-track and contingent faculty, students and instructors, and multiply marginalized and BIPOC scholars and white participants. According to Tham et al. (2020), CAE is “a critical methodology that promotes multivocal, democratic, and human-centered practices” (p. 354); this conclusion is built on work by Hernandez et al. (2017), who note that collaborative autoethnography allows for power-sharing, “inviting people who might otherwise be in hierarchical relationships to become part of a mutually enriching process” (p. 253). Campbell, Duin, Hocutt, and Stambler contributed three CAE reflections each. One additional reflection that was not part of the original CAE project was included in our data for this project: Pedersen’s reflection as Fabric archivist on the ways BDL has influenced archiving practices; and a student’s reflection on encountering Fabric in a curation assignment. The collection of reflections comprised about 16,000 words for coding.

**Coding**

Once we collected our data into documents—one each for assignments, collections, and reflections—we used the five elements of infrastructure from Read (2019) and Frith’s (2020) framework, described above, as a schema for coding evidence of infrastructure in the data (Creswell, 2015). Table 2 includes our codes, code definitions, and samples of coded text.

For each type of text in our dataset, at least three of the authors coded the text. Coding was done simultaneously (Saldaña, 2016), meaning that any given piece of data could be coded for the presence of more than one element of infrastructure. This aligns
with Read’s (2019) and Frith’s (2020) description of infrastructure being able to perform multiple functions simultaneously. While Fabric’s infrastructural elements are integral to its archiving activities, it was not clear that students and instructors were addressing the infrastructural aspects of digital literacy through their written assignments, collections, and reflections. By coding our data using these elements of infrastructure, we were able to reveal specific areas where infrastructure was implicitly and explicitly addressed in our study of digital literacy. Coding allowed us to isolate passages focused on each element of infrastructure for analysis using the 3Ps framework.

After coding, we applied Walton et al.’s (2019) 3Ps Framework as a methodology. In contrast with our coding stage, in this stage we employed the 3Ps as a lens for understanding our coded data, rather than coding specifically for the 3Ps in chunks of text. To conduct our analysis, we extracted data coded for each element of infrastructure and combined them in five code-based documents, one each for: inclusiveness; relationally defined; alliance brokering; mission critical; and embeddedness.

We reviewed and analyzed each code-based document. We carefully read the coded content to identify ways that the content reflected or represented elements of the 3Ps Framework. Afterwards, we wrote summary memos in which we identified the themes we saw, and then reflected on themes and coded content in terms of how the 3Ps framework was operationalized by students and instructors.

**RESULTS AND DISCUSSION**

Our purpose for surfacing the 3Ps in coded elements of infrastructure was to identify ways that instructors could frame infrastructures as facilitating and foreclosing certain ways of using, understanding, and talking about technology, at times with harmful or oppressive effects. We seek to ensure that our BDL work is firmly embedded in a framework for social justice, recognizing ways that infrastructural aspects of digital literacy may need to be foregrounded and addressed. Importantly, we see the five elements of infrastructure as deeply tied to positionality, privilege, and power. Infrastructure exerts often-invisible influence in our lives. Digital infrastructure can both enable and constrain access to information, determining what information can be engaged, who gets to engage it, and who gets a voice and where they can use it. Such infrastructure emerges from the work, decisions, and writing of people: people whose positionality and privilege gives them power.

In the remainder of this section, we present the results of our analysis, discussing how the five elements of infrastructure emerged in our dataset of assignments, collections, and reflections related to using Fabric in the classroom through the analytic lens of the 3Ps Framework.

**Inclusiveness**

During our coding, we defined inclusiveness as a broad scope for what counts as writing. One goal for many instructors using Fabric in the classroom was to foreground for students an inclusive vision of writing, especially in TPC contexts. We aimed not only to draw their attention to the infrastructural writing behind the scenes as writing—metadata, interfaces, algorithms—but also to think through with them how infrastructural writing influences our daily lives and interactions with embodied technologies.

Fabric requires selectivity in determining what does and can—and does not and cannot—be archived. As we identified what could be included, we necessarily demarcated boundaries between what could and could not be part of a collection or of Fabric as an archive. In most cases, the language used was positive, referring to examples of what could be or was included, rather than negative, referring to examples of what could not be or was not included. For example, as captured in one instructor’s CAE reflection, a student commented on the wide-open availability of Fabric as a digital archive:

> My artifact, for example, has an author, a creator, a copyright. But it is always available and always free to access. Much like a lot of the epic stories from the
Table 2: Infrastructure Codes, Definitions, and Samples of Coded Text

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition</th>
<th>Assignment Prompt</th>
<th>Collection Description</th>
<th>Reflection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inclusiveness</td>
<td>A broad scope for what counts as writing.</td>
<td>Assignment Prompt: As curators, you and I will compose this introduction collectively (see tasks below). What counts as an object in this collection? A physical product, a website about a product, a news story/article/video about a product, a case study on the use of a product... all of these count as an object for the purpose of this assignment.</td>
<td>Collection Description: Because we are witnessing a revolution in communication and composing practices, techniques, modes, media, and tools, this collection responds with representations of tools that are unlikely to be placed together elsewhere. Educational tools like these, from resources for teachers to resources for students, have become part of the fabric of teacher and student digital lives.</td>
<td>Reflection: I was glad to see that there were different types of artifacts, too, including scholarly articles, web articles, etc. This is good for different types of learners and students at different academic levels.</td>
</tr>
<tr>
<td>Relationally</td>
<td>A focus on what writing does for something or someone, embedded within social and material structures of organizational context.</td>
<td>Assignment Prompt: Who is the intended audience? In what context is it or was it delivered to them? Do you think it is usable or not for that particular audience? In what ways is the technology discussed or used that shape your understanding of it or interpretation of it?</td>
<td>Collection Description: As technology evolves, it is becoming smaller, more portable, and more efficient. Many of our collected objects feature products that improve efficiency of communication which is necessary as daily life is becoming increasingly fast-paced.</td>
<td>Reflection: I am pleased to see that students recognize the activity of archiving as a rhetoric activity, especially when considered in terms of agency and power.</td>
</tr>
<tr>
<td>Defined Relationally</td>
<td></td>
<td>Assignment Prompt: Your goal is to identify these factors and make the appropriate accommodations in your technical communication that support the target user’s (or audience’s) goals for use. Ideally, the purpose of your technical communication matches the audience’s goals for use.</td>
<td>Collection Description: Each application included in the collection influences hiring processes through programmed and automated procedures.</td>
<td>Reflection: One of the themes emerging from the semester is the realization that asking work to be completed outside of class that requires collaboration is challenging.</td>
</tr>
<tr>
<td>Alliance</td>
<td>Writing mediates essential alliances.</td>
<td>Assignment Prompt: Your goal is to identify these factors and make the appropriate accommodations in your technical communication that support the target user’s (or audience’s) goals for use. Ideally, the purpose of your technical communication matches the audience’s goals for use.</td>
<td>Collection Description: Each application included in the collection influences hiring processes through programmed and automated procedures.</td>
<td>Reflection: One of the themes emerging from the semester is the realization that asking work to be completed outside of class that requires collaboration is challenging.</td>
</tr>
<tr>
<td>Brokering</td>
<td></td>
<td>Assignment Prompt: Your goal is to identify these factors and make the appropriate accommodations in your technical communication that support the target user’s (or audience’s) goals for use. Ideally, the purpose of your technical communication matches the audience’s goals for use.</td>
<td>Collection Description: Each application included in the collection influences hiring processes through programmed and automated procedures.</td>
<td>Reflection: One of the themes emerging from the semester is the realization that asking work to be completed outside of class that requires collaboration is challenging.</td>
</tr>
<tr>
<td>Mission Critical</td>
<td>Writing is essential to the operations of an organization.</td>
<td>Assignment Prompt: Read the resources on archiving as a scholarly activity and research activity. Pay attention to archival actions like naming an artifact, assigning metadata, writing descriptions, etc.</td>
<td>Collection Description: The app is software that hospitals are implementing to streamline communication between departments regarding a patient's information and history. The app eliminates the need for outdated technology like pagers, fax machines, and even email in some situations.</td>
<td>Reflection: The quarantine of professors and students, and of institutional staffs and faculties, has revealed how woefully illiterate we really are, and how hard it is to develop literacy that creates new knowledge through these tools. Our crash course in digital literacy reveals the extent of the problem — and Ann’s right, it’s a crisis.</td>
</tr>
<tr>
<td>Embeddedness</td>
<td>Writing gets built into objects and erases itself as the objects go out into the world.</td>
<td>Assignment Prompt: Pay attention to archival actions like naming an object, assigning tags, writing descriptions, etc.</td>
<td>Collection Description: Educational tools like these, from resources for teachers to resources for students, have become part of the fabric of teacher and student digital lives.</td>
<td>Reflection: This led us to recognize that the collection may more accurately depict the embodied classroom, identifying technologies that are used in the embedded classroom.</td>
</tr>
</tbody>
</table>
We delineated the relationally defined function of infrastructure as Relationally Defined equivalency relations, as in synergy and synchrony. relations—not differential relations, as in power dynamics, but of artifacts together opens doors to creative constructions and to each other as well, highlighting how the 3Ps operate in non-their own positionality, but the positionality of artifacts in relation to each other. Role playing was a strategy often used in assignments asking students to simulate different positions in the rhetorical situation, which helps to highlight how behind-the-scenes roles combine positionality and privilege into the power of naming and describing artifacts, foregrounding how such invisible, infrastructural writing work shapes issues of access, inclusion, and equity. By identifying various roles, such as the analyst, curator, collection editor, and collection archivist, the relationship between these roles was made explicit and who does what or who has the power to do what was recognized as students simulated a role themselves. In other words, using Fabric, we worked to make visible to students the ways that invisible infrastructure is relationally defined by what it does for something or someone alongside surfacing critical inquiry into how those relationships are delineated and by whom.

Additionally, instructors were required to negotiate their roles as both an instructor to the students and a contributor to Fabric. Instructors collaborated with students to work through productive ambiguity in order to identify audiences, technologies, and the best way to represent embodied technologies in Fabric. Instructors’ desire to have students engage the rhetorical situation and see the interconnectedness of technologies clashed with the requirement for students to adhere to the curatorial model set forth by Fabric. As one instructor reflected, “I am not confident [my students] provided the best, most accurate, or complete information, but I didn’t question it — I was not looking for ‘accuracy,’ only adherence to the guidelines and constraints built into the [curation] spreadsheet.”

A common thread in many of the instructor reflections in our dataset was the notion that society is a multilayered, multidimensional network of actors and technologies with varying degrees of agency and that interacting in such an infrastructure is messy, wavering, and requires complex digital literacies. As instructors try to help students develop digital literacy skills, it is clear that we constantly reflect on our processes and grapple with knowing that digital literacy is a privileged skill. Digital literacy may only be accessible to students who are in privileged positions, like pursuing a college degree, and even then, other aspects of positionality may create barriers. As instructors, we did our best to meet students where they were and then to foster the improvement of their digital literacies.

Further, as we argued earlier, literacies themselves are internal human infrastructure necessary for navigating other, external infrastructure. Digital literacy requires attention to the rhetorical situation, context, and ways of “living, learning, and working in a digital society” (Joint Information Systems Committee, 2018, para. 1). Literacies, technologies, and infrastructure are relationally defined at a high level with each other, and then each of them also contains layers of infrastructure that are further relationally

Middle Ages, the availability and shareability of it makes it almost as if it belongs to everyone. Of course, I guess that is also the point of the archive at all.

This emphasis on availability, expressed in terms of shareability into the future, represents the inclusive character of infrastructure and its relationship to writing while also representing an innovative approach to power; power can be shared among Fabric’s curators, contributors, and creators. An instructor’s assignment prompt revealed a similarly inclusive approach to the curating assignment: “Because we are witnessing a revolution in communication and composing practices, techniques, modes, media, and tools, this collection responds with representations of tools that are unlikely to be placed together elsewhere.” While descriptions of Fabric assignments and collections necessarily address the power of an archive to exclude, the language used overwhelmingly represents that power as inclusive rather than exclusive. Perhaps this represents an approach to power that focuses on the power of inclusiveness over exclusion.

Closely related to, but distinct from, inclusion was a theme in the data of overcoming boundaries to cross thresholds of counting: what “counts” as an artifact when creating a collection, or assessing why something has been included, or counted, as an artifact in an existing collection. Distinct boundaries are inferred in assignments that clarify what students should consider when identifying an artifact to include in a collection. For example, in a curation assignment, the guidelines specify criteria for including an artifact in the collection: “Any artifact you choose to add in this collection must be justified as a tool or technology that facilitates technical communication and fits within the scope of our collection.” In a different assignment, additional requirements for inclusion are outlined relative to the infrastructure and discoverability of the archive: “Contributors must select a technology, compose a proposal to the collection archivist, and compose metadata for the technology in order for it to be added and be able to be discovered in Google searches.” In these examples, an unspoken threshold of what counts in the archive exists but may not be clearly articulated. These boundaries highlight the way that privilege operates: privilege is inherent to counting, and through their work with Fabric, students and instructors had to consider the privilege they occupied as curators along with considering who did not have that privilege.

Walton et al. (2019) describe positionality as “fluid and contextual” wherein “social contexts and constraints do not create an identity which a person then discovers but rather form a position from which a person can craft meaning and use as a point of departure for action” (p. 63). This suggests that when foregrounded through the right environment and activities, instructors can help students understand their positionality as a starting point for work toward understanding and acting toward social justice. As instructors and students grappled with collective work building and analyzing collections of disparate artifacts, they thought through not only their own positionality, but the positionality of artifacts in relation to each other as well, highlighting how the 3Ps operate in non-human, infrastructural spaces. In this way, Fabric’s placement of artifacts together opens doors to creative constructions and relations—not differential relations, as in power dynamics, but equivalency relations, as in synergy and synchrony.

Relationally Defined

We delineated the relationally defined function of infrastructure as a focus on what writing does for something or someone, embedded within social and material structures of organizational context. In assignments, students were asked to critically interrogate existing Fabric collections to unpack the rhetorical situation around the technologies that had been archived, the arguments that collections and their archivists were making, and, indirectly, to consider issues of how positionality and privilege acted to shape representations of technology and who does or does not have access.

As writers and curators, students and instructors worked together simultaneously as agents involved in the rhetorical situation of creating and contributing content to Fabric while also thinking critically about how to describe artifacts, attribute metadata to them, and articulate their relationship to each other. Role playing was a strategy often used in assignments asking students to simulate different positions in the rhetorical situation, which helps to highlight how behind-the-scenes roles combine positionality and privilege into the power of naming and describing artifacts, foregrounding how such invisible, infrastructural writing work shapes issues of access, inclusion, and equity. By identifying various roles, such as the analyst, curator, collection editor, and collection archivist, the relationship between these roles was made explicit and who does what or who has the power to do what was recognized as students simulated a role themselves. In other words, using Fabric, we worked to make visible to students the ways that invisible infrastructure is relationally defined by what it does for something or someone alongside surfacing critical inquiry into how those relationships are delineated and by whom.
defined. The roles of positionality and privilege, and the power they afford, are deeply embedded in these relational definitions, as power emerges in context in specific situations and networks. And, in the case of digital infrastructure, the end result of that power, of those relational definitions, shapes our everyday interactions with the ubiquitous tools in our digital society.

**Alliance Brokering**

Building on Read (2019), we defined alliance brokering as writing that mediates essential alliances. A recurring theme across our datasets was that Fabric called attention to the various roles individuals played in the building, creating, and shaping of the collections.

![Figure 2: Essential alliances for use of Fabric.](image)

As shown in Figure 2, instructors were positioned to broker assignments that emphasized specific roles in relation to working with Fabric, and students were asked to collaborate with each other to critically analyze Fabric and understand the rhetorical situation. As students assumed the roles of analyzers and contributors, they were required to create alliances with each other, the instructor, and the Fabric curators. Writing products and activities mediate alliances with actors essential to the objective of such activities. Through collaboration, critical analyses, and writing technologies, students essentially became allies, despite challenges, and were able to work and write together to achieve a shared goal. Fabric’s relationship with other institutions and their position as contributors made visible the various positions operating within Fabric and how power is distributed. The infrastructure of each assignment was developed by the instructor who introduced the collection, provided a structure, formed the collaborative teams, and provided safety as the work proceeded. Additionally, assignments focused on the class’ infrastructure with the suggestion to build alliances (groups, collaborations) as part of the course structure.

The large box in Figure 2 is intended to illustrate Fabric’s depth of infrastructure managed by its researchers and archivists. Fabric and its team of researchers and archivists are in control of the platform, including its scope, interfaces, and metadata scheme, and the forms and methods for collaborators contributing to the archive. The BDL instructors (large oval in Figure 2) broker with the Fabric team in order to continually tweak the platform to better serve users. In the classroom, the instructor is in control, positioned as developer and broker of the assignment infrastructure, implementation, and use of the Fabric infrastructure. Note that this circle extends beyond the Fabric infrastructure; in other words, instructors may envision uses of Fabric that extend beyond its intended scope and infrastructure.

The smaller circles in Figure 2 represent what students learn about the Fabric infrastructure, largely based on the instructor’s guidance and willingness to broker alliances with Fabric; again, this understanding may fall beyond Fabric’s intended scope and infrastructure. The instructor is positioned at the center of Fabric use as alliances with understanding embodiment, building digital literacy, and collaborating with other students and other institutions come down to the instructor who designs the assignment infrastructure and implementation. We already know that this holds privilege and power as well as responsibility and accountability for student success.

Through developing and expanding digital literacy awareness, through confronting the productive ambiguity involved in use of the Fabric in the classroom, we have the opportunity to broker, to share agency with students, so that we and they might lay bare the rhetorical, agentive nature of infrastructure. Fabric openly shares its agency with instructors and students; through greater understanding of metadata, we can begin to identify how an alliance with Fabric offers the opportunity, the privilege, to begin to understand and witness the power of Fabric as an infrastructure for building conceptual understanding, for resisting “right or wrong” answer thinking, for creativity, for crossing the threshold to acquire a new level of skills for novel situations. However, the bottom line is that the privilege and power of doing so begins with positionality.

Ultimately, alliance brokering is a key part of the BDL team’s work on multiple levels: we are working internationally, cross-institutionally, and longitudinally as scholar-teachers; we are brokering with Fabric as its team considers and adopts changes to better meet our needs as researchers and instructors; we are brokering alliances with our classes through our assignments; and we are illuminating the ways in which alliance brokering is a key part of infrastructure through our assignments and our efforts to build digital literacy.

**Mission Critical**

The mission critical element of infrastructure centers how writing is essential to the operations of an organization. Read (2019) discusses the mission critical element as deeply tied to three other elements of infrastructure: inclusiveness, relationally defined, and alliance brokering. In other words, understanding writing as mission-critical infrastructure requires delineating what counts as writing inclusively, understanding how it is relationally defined, and how writing helps broker alliances.

Similar to the other infrastructural elements of Fabric, we saw mission critical as multilayered. Within Fabric, the mission related to the overall aims of Fabric as a platform as well as the parameters of individual collections. For example, in one collection, students created an introduction discussing applicant tracking systems, platforms that are critical to managing job applicants and facilitating relationships between them and organizations. In writing this introduction and curating the collection, students were also creating infrastructure that was mission critical to Fabric as an archival platform. Layered on that was the mission of the assignment: in terms of contributing or curating a collection, students were tasked with goals of Fabric, the instructor, and the students themselves. Additionally, because the BDL developed our assignments to help foster digital literacy, the mission of student literacy development was at play as well.

Ultimately, we saw mission critical as closely tied to making visible...
how invisible things are critical to certain goals or outcomes and also to the roles of positionality, privilege, and power in shaping those goals and outcomes. This suggests that centering how some invisible or low-visibility technologies are critical to different parts of our society may be a key element of fostering social justice and digital literacy simultaneously. In turn, this means making the 3Ps more visible to instructors by encouraging students to look for how subjectivities and overlapping identities are constructing technologies; how those occupying certain identities are advantaged or disadvantaged to different degrees when it comes to technology use; and how power is enacted based on these identities and privileges associated with them. In our data, we saw our assignment prompts and collections pushing students to try to uncover the mission critical nature of some of the technologies and infrastructures with which they engaged. Further, our reflections largely surfaced the theme of visibility/invisibility in terms of thinking through our experiences with developing student digital literacy, which we see as being mission critical to their success as communicators and thoughtful contributors to discourse and use of technology in a digital society.

**Embeddedness**

Embeddedness was, like mission critical, somewhat difficult to identify. By definition, embeddedness refers to how writing gets built into objects and erases itself as the objects go out into the world. The ‘baked-in’ nature of digital infrastructure in the tools we use every day can complicate making it visible: it is just how things work. That said, working with our Fabric assignments and reflections in the BDL team helped us identify ways to approach making visible the invisible. In analyzing data coded for embeddedness, we saw assignment instructions designed to engage students with understanding, using, and creating metadata. Fabric’s metadata decisions have a trickle-down effect. Whereas the Fabric team has the power to create the overall metadata scheme for its specific type of artifact, it is constrained by the Dublin Core metadata standard and the CollectiveAccess database software. Individual contributors and collaborative archiving teams, like students in our classrooms, must work within that metadata scheme and through the Fabric platform to complete their tasks. Positionality, privilege, and power operate at every level and shape the entire experience of contributing, managing, and archiving on Fabric, and are embedded in the infrastructure itself. The people who created and maintain Dublin Core shape what metadata can look like, then CollectiveAccess further shapes it by delineating how the database works and how it can display to users. On the front-end, then the Fabric team determines what specific metadata fields to collect and what standardized keywords or terms might be used in that metadata. Lastly, at the contributor/collector level, people choose the metadata for each artifact and collection and how to curate a set of artifacts around a theme or argument. In this way, the embedded infrastructure of writing operates at multiple, intersectional levels with the 3Ps. Just as the people who write the algorithms that drive Google searches help decide what we get to see and not see when we search for things, the people who add metadata to objects in databases like Fabric make decisions about the identity of specific artifacts (through naming and categorization practices). The ways people’s positionality, privilege, and power operate in the construction of specific metadata can enable and constrain the questions we can ask of data and the answers we can get from it.

Through our efforts to build digital literacy using activities like metadata development paired with metacognitive reflections, we defamiliarize the familiar by asking students to look at everyday activities like digital searches from a new perspective: that of content creator and of decision-maker. In our CAE reflection data, we captured a student commenting that “it had not occurred to me to not trust the nature of the language with which we speak.” Here again, in using Fabric to help build digital literacy, and, in the case of embeddedness, we make visible hidden infrastructure in our digital world for students to both see and hopefully critically engage.

### 3Ps, Infrastructure, and Socially Just Pedagogies for Digital Literacy

In revealing infrastructure and the work it does, we have the opportunity to ask students to think critically about the 3Ps of the people who created the infrastructure: the people who created metadata frameworks/standards for Fabric, themselves as student archivists, and perhaps, by extension, that of the people who created embedded infrastructural writing in the pervasive digital tools and artifacts we use in our daily lives. In Table 3, we present a heuristic for understanding each of the five elements of infrastructure through each of the 3Ps.

Foregrounding the 3Ps across all five elements of infrastructure can thus be applied as a heuristic for developing assignment prompts that work toward building socially just digital literacy among students. Further, as a collaborative group, our ongoing autoethnographic and classroom-based research serves the purpose of making the invisible visible for us as researchers too, as we encounter and grapple with the productive ambiguity we have lauded (Davis et al., 2021) in terms of students’ engagement. Metadata is a great example of embedded infrastructure as it is rendered invisible to people who use databases like Fabric; by instructing students to engage metadata overtly, we are, in essence, making visible a type of hidden or embedded infrastructure. Once visible, we can work with students to interrogate how positionality, privilege, and power shape metadata, and in turn writing infrastructures, our engagement with them, and the knowledge-making work happening through them. We are disrupting or defamiliarizing the familiar and asking students to see it in new and critical ways, which we suggest will help to foster their own digital literacy and critical engagement with everyday digital tools.

### CONCLUSION

By engaging with Fabric, we and our students were able to critically analyze a digital writing infrastructure and examine the relationship between that infrastructure and the 3Ps. Doing so enabled us to foster digital literacy and develop a social justice-aware approach to engaging in a digital world. We found that assignments involving Fabric enabled us to collaboratively interrogate with students how power is used, misused, and distributed in society in ways that are often invisible. Therefore, we suggest that critical analysis of writing infrastructure is an effective social justice pedagogy. By asking students to engage in activities like metadata assessment or development for Fabric, we can help students understand how metadata and search algorithms shape engagement with information and knowledge-making in infrastructures more broadly. Importantly, some of these infrastructures have been shown to perpetuate or replicate racism and oppression in often subtle and insidious ways (Noble, 2018), and surfacing the 3Ps during classroom examinations of infrastructure facilitates...
Our uses of Fabric in the classroom, as seen in our data analysis, contributed to more than just building digital literacy. Through engagement with and metacognition about metadata, roles, and the ways that digital infrastructure is developed and influences our lives, we engaged students in thinking critically about infrastructure itself. We made visible the invisible functions of writing as creator, curator, and user of digital technologies. Further, we engaged students in thinking about social justice through consideration of the ways that infrastructure and positionality, privilege, and power are interconnected and mutually constitutive. We have discussed in more depth elsewhere (Davis et al., 2021) our assignments and how we operationalized them in the classroom. We argue that instructors can use assignments involving Fabric to help students identify how positionality, privilege, and power all play a role in infrastructure by making infrastructural elements and actors (human and non-human) apparent. We suggest that Fabric is an excellent tool for building digital literacy and fostering social justice thinking in the classroom. TPC instructors can use similar assignments that ask students to rhetorically analyze databases and/or create metadata to examine the ways that infrastructure and the 3Ps shape our engagement with digital technologies.

In addition to the 3Ps, instructors might consider how their assignments can contribute to expanding student digital literacy and critical awareness of infrastructures through assessing what actions assignments accomplish. The 3Ps Framework is part of Walton et al.’s larger goal to promote “coalitional action” against oppression by forming allyships with others, particularly those at the margins (2019, p. 134). To support this goal, they offer the 4Rs heuristic—recognize, reveal, reject, and replace—as a guide for addressing injustices. Identifying where and how positionality, privilege, and power are functioning, and with what implications, is an act of recognition. However, the 4Rs heuristic encourages action beyond simply recognizing where oppression exists. Instructors might ask themselves how they envision their work with students, and perhaps other instructors or community and industry partners, as a way to build coalitions in support of social justice and digital literacy. The assignments we presented here task students with engaging the 4Rs. For example, students who rhetorically analyzed collections on Fabric did the work of recognizing and revealing, or making visible, how technology is constructed in different and, at times, unjust ways, such as when virtual reality is framed as enhancing progress in cultural awareness without considering how culture is represented or how those within a culture feel about these technologies. In curation assignments, students moved from revealing towards rejecting and replacing by crafting collections of artifacts that resisted notions that technologies are neutral tools, and by interrogating how their own positionality and privilege impact their infrastructural work as curators. In sum, instructors might ask how their assignments are designed to facilitate actions needed to confront systemic social issues.

Read argues that “[d]eveloping methodologies to make invisible writing visible enables us to make arguments for its value in scholarship, teaching, and industry” (2019, pp. 245–246). Using Fabric for assignments encourages students to use writing to interrogate virtual and discursive infrastructures on multiple levels, and the ways that these infrastructures are entangled with positionality, privilege, and power. Further, working with Fabric collections as and about infrastructure enables us to surface for students the ways that arrangement and description of artifacts as collections creates specific narratives about technologies, narratives that may potentially perpetuate or ameliorate reductive or harmful thinking.

ACKNOWLEDGEMENTS

The authors would like to thank Dr. Isabel Pedersen, Sharon Caldwell, and others at The Decimal Lab for their openness to collaboration as well as their interest in developing new pedagogical and scholarly uses for Fabric. The authors also thank our students for their willingness to navigate “productive ambiguity” throughout their coursework with Fabric.

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Alternate Histories and Conflicting Futures: 
Git Version Control as Software Development Infrastructure

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ABSTRACT
Despite their central importance to a variety of endeavors and despite widespread use in both industry and academia, version control systems (software for tracking versions of files) have not been extensively studied in fields related to technical communication, rhetoric, and communication design. Git, by far the most dominant version control system today, is largely absent. This study theorizes Git as boundary infrastructure—infrastructure used to facilitate collaboration across disciplines and domains. The unique characteristics of boundary infrastructure explain how something as prominent as Git can be so invisible and help identify dangers posed by boundary infrastructure. Drawing on modes of resistance developed in feminist rhetorics, this article concludes with suggestions to ameliorate the negatives effects such infrastructure might have on collaborative knowledge work.

CCS Concepts
Information systems

Keywords
boundary studies; infrastructure; version control; source management; Git; GitHub

I really never wanted to do source control management at all and felt that it was just about the least interesting thing in the computing world (with the possible exception of databases ;^), . . . . Sadly . . . none of them did it remotely well . . . so I ended up just deciding to write my own.

—Linus Torvalds, creator of Git

[Git] kind of is like time travel—and as anyone who has seen Back to the Future Part II can attest, time travel is complicated business.

—David Demaree, Git for Humans

INTRODUCTION
Version control systems are vital but underappreciated creative technologies. Although it’s tempting to see them as “the least interesting thing in the computing world” (“10 Years,” 2015, para. 4), as Linus Torvalds, the creator of Git, currently the most popular of such systems, says in the epigraph, this is belied by the fact that version control has been part of software development from its earliest days. Ruparelia (2010), for example, dates the first complete system to 1972 (p. 6). Unsurprisingly, software authors, like any authors, must contend with problems surrounding the management of different versions of texts, especially when multiple people are involved. Some system is necessary; whether it’s as simple as a version number in the file name or as complicated as Git, it must reliably maintain the integrity of the work throughout its evolution, which is a challenging task to begin with and only becomes more challenging as more people participate. While perhaps less interesting on its surface than things like augmented reality, crypto, or AI, the humble tools of version control are nevertheless instrumental to each of these examples and many others. Version control is a critical component of so many collaborative projects because of the scope of actions it enables; encompassing projects of all kinds and running the entire length of their lifetimes, version control systems such as Git allow collaborators to depend on a single source of truth, to resolve contradictory changes, to turn back the clock to a time when things were working better, and to
explore different possible futures where things might work better still.

The open-source version control system invented for developing the Linux kernel, named Git by its creator, has rapidly become the most dominant tool used in software development industry and beyond (Stack Exchange Inc., 2019). GitHub, Git’s free hosting platform, has become the largest code repository in the world (Ousios et al., 2014), hosting more than 226 million separate projects (GitHub Search), of which more than 38 million are open source and public (GitHub Search Public). While Git and version control systems have been studied in computer science, human-computer interaction and related fields, typically from a narrowly technical perspective, they’ve received far less attention in technical and professional communication, design discourse, and digital rhetoric. Perhaps this is due to their identity as programming tools; however, while created for that purpose, they are used more widely. GitHub is even used as a kind of social media to maintain a personal and professional profile of contributions, a networks of followers and followings, as well as for a variety of activities such as training courses (“Project Based Learning,” 2021), “awesome” lists of various kinds (Sorhus, 2021), collections of programming proverbs (Januska, 2021), podcast recommendations (Dutra, 2021), archives of free books (EBook Foundation, 2021), not to mention hosting the code and often the content for nearly every major open source application of significance. If something can be represented in a primarily textual form, even just hyperlinks, and especially if people can collaborate on it, it can make use of Git to manage and track its evolution.

Despite such extensive reach, while a survey of the more technical literature finds dozens of articles on Git, version control, source control, and related terms in fields like software engineering, human computer interaction, information systems and even biology and medicine (Ram, 2013), a search for similar terms in journals devoted to rhetoric, computers and writing, and the digital humanities returns few results, the only salient one from Communication Design Quarterly by Pierce (2002), which was published before Git was invented, on using multiple versions of documentation source files for better technical communication. More critical attention needs to be directed at the vital role version control plays in the production of a wide variety of creative projects and in shaping the design and digital communication industries. While the fields listed above are well suited to, for example, measuring performance improvements in Git’s newer features or tracking its userbase over time, few disciplines are better equipped than ours for contextualizing this technology and critiquing its effects.

This study provides such contextualization and critique. Building on the ecological approach to collaboration presented by Star and Griesemer (1989) and the characteristics of infrastructure enumerated by Star and Ruhleder (1996), which were ultimately developed into the boundary infrastructure of Bowker and Star (1999), I conceptualize Git (the application) and GitHub (the code host) as boundary infrastructure, fundamental to modern software development and collaborative knowledge-making of various kinds. The concept of boundary objects, with their primary characteristic of interpretive flexibility, has become important to many fields concerned with knowledge work, from engineering to sociology to design, precisely because it helps explain how diverse groups of people with different expertise, perspectives and values can collaborate in the “absence of consensus” (Star, 2010, p. 604).

The interpretive flexibility that boundary objects possess allows members of different groups to describe the object to different audiences, enabling it to gain traction in multiple domains. Some boundary objects become so successful they evolve into standards, and some eventually become infrastructure.

Perhaps the most important characteristic of infrastructure, as Star and Ruhleder (1996) explain, is its transparency. Rather than drawing attention to itself, it supports work and only becomes visible when absent or disabled. The transparency of infrastructure has been noted by several scholars, for example Mara and Hawk (2009), Parks (2013), and Plantin et al. (2018). Just as importantly, in my opinion, is that the knowledge of how to use infrastructure is learned as part of membership in a group (Star and Ruhleder 1996, p. 111). As York and Johnson-Eilola (2020) note in their study of novice and expert design spaces, infrastructure not only enables work in this way, but in doing so serves to transport the standards, norms, conventions, values, and methods of a community into the boundary spaces where collaboration happens (p. 2). As a result, infrastructure “can serve an important gatekeeping function” (p. 5) and thus lead either to inclusion in or exclusion from the community of practice. Due to this invisible power to include and exclude, infrastructure can exert an outsized influence on collaborative work, often determining who can participate, under what terms, and ultimately which voices matter.

Theorizing Git as boundary infrastructure not only explains how it has come to dominate so thoroughly while remaining largely understudied, but also allows an important critique. The near-total dominance of Git, coupled with its invisibility, ought to be recognized as a subtle but significant warning. When a technology of any kind becomes both endemic and invisible, it creates a potential for hegemony. Even though Git itself is a free and open-source application, it isn’t potentially less dangerous: corporations have not cornered the market on hegemony, and other organizations and bodies are just as likely to perpetuate it. Furthermore, during the course of writing this article, GitHub, the hosting platform powered by Git, was acquired by the Microsoft Corporation in a nearly 10-billion-dollar deal. Microsoft has pledged that the platform will remain free in perpetuity, but who knows? Regardless, the fact that a massive company like Microsoft can acquire and privatize critical pieces of infrastructure should be concerning. This study attempts to conclude, on a hopeful note, that the unique characteristics of boundary infrastructure can themselves be leveraged to provide a remedy for the dangers posed by ubiquitous and (often) invisible infrastructure—whether proprietary or not.

After explaining what Git is and how it works, I outline the scope and reach of the technology and I use results from a prominent industry survey, historical anecdotes, and selected public repositories from the Top 25 most active projects (as reported by GitHub) to briefly explain its role in software development and its applicability to other fields. Within this context, I establish a definitional understanding of Git and GitHub as boundary infrastructure and analyze their most important characteristics: transparency, tendency to embed disciplinary value, and naturalizing function, all of which combine to enable powers of inclusion and exclusion. With these theoretical pieces in place, I develop a critique based on threats to diversity, collaboration, and creativity posed by the gatekeeping function. Finally, I describe how modes of resistance inspired by feminist rhetorics, such as those found in Gloria Anzaldua’s borderlands and embodied by Donna Haraway’s cyborg, can be used to ameliorate the dangers of hegemony posed by the uncritical adoption of

Communication Design Quarterly, 10.2 2022
technological infrastructure in research and pedagogy.

WHAT IS GIT AND HOW DOES IT WORK?

Even if you’ve never heard of Git, you probably know enough to understand how it works. Imagine you are using Track Changes in Microsoft Word to co-author an article with a colleague. After submitting a draft, the journal editor sends it to reviewers who each make comments, then the editor makes their comments and merges all of them into a single version before sending it back, asking you and your co-author to keep Track Changes enabled while you make the revisions. Even in this simplified situation, we already have at least five people making changes to at least two distinct drafts. Now imagine an additional co-author or two, or a second editor or a third reviewer, and a third round of revisions and it should be clear that a relatively robust system is needed to keep track of the status and provenance of changes.

Now imagine not working with two other authors and a handful of reviewers on a couple of drafts, but with hundreds, even thousands of people on tens of millions of lines over the course of years or even decades. You can begin to get a sense of the scale of the problems that Git was created to solve. Add to this that if a revision doesn’t get made, or is poorly or incorrectly made, then it’s not just an error in a journal article, but the program fails to compile or breaks in use. This isn’t hyperbole; development of the Linux kernel has seen more than a million distinct contributions from more than 20,000 unique contributors (Linux Foundation, 2020, p. 4) coming from at least 1,500 different companies (Corbett and Kroah-Hartman, 2017). Since the release of 0.01 in 1991, it’s grown from “88 files and 10,239 lines of code” to, in the v.5.8 release, an unimaginable “69,325 files and 28,442,673 lines of code” (Linux Foundation, 2020, p. 4). To put it in perspective, this is over 10 trillion “tokens” (if lines of code are the sentences, then tokens are words), which is roughly 18,000 times the length of Tolstoy’s War and Peace. In 2019 alone, there were over 82,000 commits (collections of changes) made by more than 4,200 unique contributors (“Kernel,” 2020, p. 4) which is on average 11 commits per hour. Git allows us to track every single contribution, creating what may be the most complete record of collaborative writing in history.

Whether deserved or not, Git has a reputation for difficulty. In his introduction to a Google Tech Talk in 2007, Andrew Keith Paul Morton, one of the lead developers of Linux, said Git was “expressly designed to make you feel less intelligent than you thought you were” (0m 23s) and that Tovalds wrote “a software tool which only he is smart enough to know how to use” (0m 46s). As Demaree (2016), author of a book on Git for the popular A Book Apart series, wrote, “some days it feels like you can’t turn around without bumping into someone complaining that Git makes no goddamned sense” (p. 2). Even the venerable webcomic xkcd has a couple entries on Git, one of which, with its trademark in-group style of humor, jokes about Git’s reputed difficulty.

In the comic, the team leader requires team members to use Git without understanding how it works, and the solution to “save your work elsewhere” puts everyone right back where they were before Git: reliant on file names, the most primitive kind of version control. If Git is known for being inscrutable and if its difficulty is literally a running joke in the programming community, why is it that, as Demaree (2016) wrote, “it seems like we have to use it, despite fearing that we cannot confidently use it” and a little later “[y]ou cannot escape Git if you want to participate in the new platform-y web. At some point you’ll need to contend with it” (p. 2)? Demaree answered the question with a tautology: “Git is difficult because Git is difficult” (p. 2), and as he does in the epigraph, likens it to time travel. However, this doesn’t really explain Git’s reputation for difficulty nor its complicated place in the modern software development ecosystem.

![Figure 1: “Git” by Randall Munro. From https://xkcd.com, October 30, 2015. Published under a Creative Commons Attribution-Noncommercial 2.5 license. Permanent link: https://xkcd.com/1597](https://xkcd.com/1597)

Despite its reputation, and perhaps because of the extreme conditions imposed by kernel development, Git must be highly reliable and at least somewhat simple to use, or else it would fail too often. Git is able to accomplish what it can because of a series of intellectual achievements that make it fundamentally different from the systems that preceded it. Like the second-generation version control systems that came before, Git is distributed and there’s no central repository of code (everyone gets their own version), but Git improves upon second generation tools in several ways. In older version control systems, only a single user could “check out” a file and no one else could make changes while that file was checked out. This was to prevent conflicts. However, in Git, there is no need to check out files because, instead, each user has their own copy and changes are automatically merged by the system.

In a nutshell, it works like this: when Git is initialized in a project, it creates a database inside the project directory that watches for any changes to the files. The project directory becomes a repository. When a developer wants to work on the files, he or she downloads...
a copy of the repository (from a source called the origin), which includes all the project files plus the full history of changes. The developer is free to make whatever edits are necessary in their own local repository, and in doing so to add to the change history, and all of these changes are logged and timestamped. After a while, the developer may want to update the origin, so the changes are staged, inspected, documented, and then, finally, committed. When changes have been committed, they can then be ‘pushed’ to the remote origin. Depending on what permissions the developer has, these changes are then merged in some fashion with the original files and now anyone who copies the source files will also have the new changes, plus the complete history.

This system may sound cumbersome, and it is; but it’s also entirely necessary when working with a non-trivial number of other people on a non-trivial amount of code. Without such a system, collaborative editing quickly becomes too confusing. Git’s innovation is to make this cumbersome process simpler through a series of ingenious solutions. Probably the most important of these innovations are: 1) the concept of storing diffs (differences, deltas, changes); 2) the commit hash; and the 3) branch merging process. If you had to store every version of every word in every file forever, the database within which this information was stored would become larger and more unwieldy every time a change was logged until it inevitably ground to a halt. This isn’t usually a problem with Word documents, which is one reason Track Changes can function as it does, but even just editing a document myself eventually becomes too difficult as all the edits add up and cancel each other out in a mess of red underlines, strikethrough marks, and insertions.

By contrast, Git works by keeping a single snapshot of the full project and otherwise stores only the diffs, or changes, from that original snapshot. This allows Git to dynamically manage the structure of the data model representing the project and store it efficiently. Git also makes it so that each commit (a set of changes) is referenced by a unique hash (a long identification number), so that developers can instantaneously compare any one commit with any other, allowing a time-travel like ability. Finally, when two developers are working on the same section of the code simultaneously, Git’s structure allows them to easily create different versions (or ‘branches’) and, more importantly, to merge these branches back together to avoid conflicts. Together, these innovations made Git the first of the so-called third generation of version control systems. Since its relatively rapid inception in 2005, Git has become the most dominant version control system globally, gobbling up developer market-share at an unprecedented pace.

Despite the reputation for difficulty, it’s my belief as someone who uses Git on a daily basis and has for many years now, the system is fairly straightforward almost all of the time. When I’m setting up a new project, I fire up my terminal app and type in `git init path/to/project/folder and hit enter. Then, I type git remote add origin https://file/github/url and hit enter. That’s it. When I want to save my changes, I usually just have to type git add *, then: git commit -m “a brief message” and finally: git push. Typically, these are the only commands I need to use. Sometimes I might need git pull. More rarely, I might need to git log, git revert, or git blame, but I almost never have to use any of the more obscure commands (and there aren’t very many anyway, relatively speaking). Only on one or two memorable occasions, when different branches of the program’s history can’t be automatically combined, have I gotten

the dreaded merge failure error, but fixing the problem just requires looking through the code at the places that Git has helpfully flagged and deciding which versions to keep.

After learning the basic commands, what they do, and how that differs from whatever mental model was in place before Git, the software itself is pretty easy to use—no more difficult than most and easier than some. I teach it from day one in my introduction to coding course and, while my students, as one would expect, occasionally struggle, it typically takes only a demonstration or two to address their challenges. The only problems I have when teaching Git to intro-level students arise when multiple students must work together on the same repositories—and this is our clue to the mystery of what makes Git difficult. Git isn’t difficult because the commands are particularly complicated, nor because it’s actually a form of time travel and we might accidentally erase ourselves from existence. No, Git is difficult for the simple fact that collaboration itself is difficult. In fact, it’s not Git that’s hard to work with at all, it’s other people! The problem is not remembering the right commands or entering them correctly so that some version of the code is saved. The problem is how to decide, in any given moment, whose version of reality is to be preferred.

COLLABORATIONS, BOUNDARIES, AND CROSSINGS

The problem has shifted from Git to the underlying activity it was created to facilitate, and thus the discussion must move away from version control to collaboration, which enjoys more robust study—often in the terms first presented by sociologists of science Star and Griesemer (1989) with their concept of boundary objects. According to Trompette and Vinck (2009), the concept of boundary objects “proposed revisiting the actor-network theory (ANT) within an ecological perspective of collective action and innovation” (p. 3). Star and Griesemer (1989) described the concept as a better approach to the problem of cooperation in science, a more “ecological” approach focused on organic interactions within the network that “does not presuppose an epistemological primacy for any one viewpoint; the viewpoint of the amateurs is not inherently better or worse than that of the professional” (p. 389). Since its inception, the concept of boundary objects has been explicitly about cooperation between different groups that do not necessarily see eye to eye, share the same values, live in the same worlds, use the same practices, or speak the same languages and, although it distinguishes among groups, doesn’t set one above the others.

Most models of cooperation, Star (2010) explained when reflecting on her early work, began with the idea that first consensus must be reached, and only then could cooperation begin. But when engaged in field studies among scientists, she found that cooperation simply didn’t work that way. Instead, she found “the consensus model was untrue. Consensus was rarely reached, and fragile when it was” (p. 604). Consequently, boundary studies have continuously been developed over the intervening decades in a variety of fields, from sociology of science to knowledge management, to aid those studying groups of people working together to better understand the “nature of cooperative work in the absence of consensus” (Star, 2010, p. 604 emphasis added). During this time, the concept of boundary objects was notably added to and expanded upon by Star and Ruhleder (1996) who detailed the related concept of infrastructure, and Bowker and Star (1999) who introduced the idea of boundary infrastructure.
Some of these terms are misleading, as Star (2010) points out when noting: “We are in a sense stuck with using Newtonian language for quantum phenomena” (p. 603). Although it may seem so at first, boundaries are not mere lines, demarcating one zone or sphere of knowledge from another; instead, they are best if conceived as spaces into and out of which people move. “They are n-dimensional,” Star wrote, “a shared space where exactly that sense of here and there are confounded” (p. 603). By the same token, boundary objects themselves are not mere things, defined by their ‘thingness’ but are instead best understood by the actions people direct at them. Like objects in computer programming parlance, a boundary object is “something people . . . act toward or with” (p. 603) and so it’s most helpful to see a boundary object not as an individual thing that you can touch or hold, but rather as “a set of work arrangements that are at once material and processual” and which “resides between social worlds (or communities of practice) where it is ill structured” (p. 604). This view transforms boundary objects from being singular things to being composites or assemblages, more about relationship, and processes than substances.

Perhaps the most studied aspect of boundary objects, what scholars have called “interpretive flexibility,” is the ability of some objects to be interpreted in different ways by different groups. As Star (2010) herself points out (p. 602), this idea is not new, even though it was central to hers and Griesemer’s early work. An object exhibits interpretive flexibility when it is used in different ways by different groups (remember, objects are defined by actions). For example, Star explains how the same map might be used by a hiker to find a good campsite, as well as by a scientist to study wildlife populations. What matters, Star stresses, is the uses to which they are put (p. 602). The hiker uses the map in one domain, travel, while the scientist uses it in another, ecology, and in this way the same map exists equally in two domains as we cannot privilege one above the other. It exists in a boundary space. So, while an interdisciplinary project hosted on GitHub might contain physical objects, for example, documents, videos, etc., its classification as a boundary object derives more from the way people use it than from any particular composition of its parts.

While discussing this fundamental ambiguity, one must be careful, as Star warns, not to mistake this ambiguity for the “the process of tacking back-and-forth between the ill-structured and well-structured aspects of the arrangements” (p. 601) because they are indeed something different. Not only are boundary objects ambiguous because they exist in multiple worlds, but they are also ambiguous to the people who work on them. Within the boundary spaces, Star explained, the arrangements are poorly structured, but outside of the boundary spaces, when viewing the object from the perspective of a particular domain or discipline for example, the object must appear to be well structured. The work arrangements must be messy and ill-structured while inside the boundary spaces to enable those who enter the space to use them; however, when the object is seen from outside the space, it must appear coherent and well ordered. Those who work on the objects must be able to see them both ways: as sensible and organized for in-domain work, while disorganized and poorly structured for in-boundary work.

So, if boundary objects are arrangements of materials and processes, and boundaries themselves are spaces into and out of which people move, what of these people who must cross into the boundaries to work on the objects? Known variously as “brokers, boundary crossers, and boundary workers” (Akkerman and Bakker, 2011, p. 140), these may consist of individuals or groups who face unique challenges in their work. While there are significant benefits to occupying positions that allow them to take part in multiple worlds, they are often seen only as marginal members of the communities they belong to. Boundary brokers, as Akkerman and Bakker explain, “not only act as bridge between worlds but also simultaneously represent the very division of related worlds” (p. 140). Because of this dual habitation, scholars have emphasized the importance of dialogue, both with actors in the different worlds and inner dialogue carried on internally to help boundary workers with maintaining relationships, translating concepts and ideas, and avoiding the possible failure that results when objects “do not fully or rightfully capture multiple meanings and perspectives” (p. 141). For this reason, the commenting function of Git is central to how it operates. Each commit is accompanied by commentary from collaborators—a record of the internal and external dialogue.

**INFRASTRUCTURE AND BOUNDARY INFRASTRUCTURE**

The interpretive flexibility of boundary objects and the crossings performed by boundary workers are vital to help translate concepts from multiple worlds into forms that are useful for both interdisciplinary and non-interdisciplinary work. However, they are not the only actions that allow for cooperation. When objects grow in scale, they become standards and eventually infrastructure. Standards and infrastructure, although less well treated (Star, 2010, p. 605) than boundary objects are equally essential to the study of collaboration because they provide important, normalizing functions. Standards ensure a certain level of exactitude and provide a rationale to regularize arrangements, whereas infrastructure provides the benefits of standardization. Once something has been standardized, it can work within infrastructure.

Much as the ecological model brought an equity in perspective—the expert was not set above the novice—so too does the discussion of standards in Star and Ruhleder’s (1996) study of infrastructure. Noting the tension between local customs of use on the one hand and the need for standards and continuity on the other, the authors point out that, while there is no universal order, for example “one person’s standard is in fact another’s chaos,” there is nevertheless a need for some kind of common practice, some kind of coherence, despite the fact that “there is no absolute center from which control and standards flow; as well, no absolute periphery.” The need for coherence is not based on geography, the authors are careful to explain, nor on “simple group-membership parameters” (p. 112), and in fact the whole question of the relationship between organizational change and infrastructure turns many of these assumptions on their heads. Git, for example, is not influenced by changes as much as it drives those changes.

The most important assumption Star and Ruhleder (1996) challenge is the definition of infrastructure. Instead of asking ‘what’ it is, instead they ask “When is Infrastructure” in an effort to highlight the fact that, like boundary objects themselves, infrastructure is not a mere thing defined by the stuff of which it is comprised but is instead constituted by the actions people direct at it. Something becomes infrastructure when people use it as infrastructure—it’s profoundly relational—more about the connections between it and its surrounding set of practices than a particular composition, location, or set of features. While this may seem a simple adjustment of frame, it’s actually a seismic shift. Instead of viewing infrastructure as a “substrate” on which other, more important things run, it’s the very engine of large-
scale change. Because it is so fundamental and at the same time so transparent, it affects everything from daily activity to large-scale sociological movements. As the authors elegantly opine: “substrate becomes substance” (p. 113).

With this in mind, Star and Ruhleder (1996) go on to enumerate the “dimensions” with which infrastructure emerges. Infrastructure 1) is embedded or ‘sunk’ into other structures, 2) transparent to use, 3) has reach or scope beyond a single project, 4) is learned as part of membership of a community of practice, 5) links with community conventions, 6) embodies standards, 7) is built on an installed base, and 8) becomes visible upon breakdown (p. 113). These eight dimensions comprise a rough and ready definition when it comes to the design of large-scale information structures and should serve to establish that Git and the GitHub together constitute infrastructure.

The most important of these dimensions are not the material ones. While it’s tempting to focus on how Git was built on an “installed base” of computer systems and prior version control systems, or on how version control is neigh on invisible until it breaks down and then it becomes a showstopper, such as when BitKeeper pulled the license, or when GitHub crashes unexpectedly (de Simone, 2020), there are other, more crucial issues. As much as these qualities tend to illustrate the infrastructural role of Git, it is the links to community conventions, the embodiment of standards, and the fact that newcomers must learn Git as part of their membership in the community of practice that makes Git so important and so powerful. The concept that unites these most important characteristics is the process of naturalization.

As Bowker and Star (1999) explain, one thing that bureaucracies are very good at is holding things together: people, institutions, governments. The way bureaucracies do this is through a process of naturalization, that is, a process in which newcomers accommodate themselves to the way things are. When something is naturalized across multiple worlds, the examples the authors give are medicine and physiology across much of the West, “They are not then boundary objects, but rather they become standards within and across the multiple worlds in which they are naturalized” (p. 312). Although this may have hidden consequences, such as the “hegemony of patriarchy” (p. 312), the categorization works those bureaucracies perform through the process of naturalizing objects across multiple worlds is also important for holding things together, initiating newcomers, and enabling ongoing boundary work.

The role of the newcomer to a community of practice is vital precisely because, for the newcomer, the various objects have not yet been naturalized. They are still seen in their otherd sense as strange, puzzling, mysterious, and difficult. They may appear foreign or alien and their use may be difficult and problematic. As Bowker and Star (1999) write: “The relationship of the newcomer to the community largely revolves around the nature of the relationship with the objects and not, counterintuitively, directly with the people.” These objects take on such primacy because actions, practices, methods, are always mediated by objects in some way. Actions are taken on objects; practices have relevance only in relation to objects; methods are only valid when the objects are constituted fully. And a newcomer’s status in the group relies on his or her ability to perform because their “acceptance or legitimacy derives from the familiarity of action mediated by member objects” (p. 299). Star and Ruhleder (1996) put it even more bluntly, calling it the “sine qua non of membership in a community of practice,” writing how “Strangers and outsiders encounter infrastructure as a target object to be learned about” while “New participants acquire a naturalized familiarity with its objects as they become members” (p. 113). The primary process then, by which newcomers become members of a community of practice (however low status they are) is the process of naturalization by which infrastructure objects become familiar to new participants while remaining objects to outsiders.

## GIT AS BOUNDARY INFRASTRUCTURE

More complicated informational structures must incorporate different classes of boundary objects as well as serve different communities of practice. This kind of infrastructure Bowker and Star (1999) call “boundary infrastructure” is differentiated from more common, unitary types of infrastructure by the kinds of objects it contains and the kinds of work it does. Noting they are not perfect constructions and this lack of perfection is precisely what allows the kind of flexibility necessary to accommodate different classes of boundary objects, the authors explain that boundary infrastructure allows for “local variation together with sufficient consistent structure” (Bowker and Star, 1999, p. 314) and it is this dual nature, indeed, this profoundly ambiguous nature, which allows them to function effectively and allows boundary workers to extract different types of information according to their various needs. If boundary infrastructures did not exhibit the requisite flexibility, if they instead refused to tolerate ambiguity as more traditional infrastructures do, they would hinder boundary crossing and perhaps damage the boundary objects they are meant to contain.

What differentiates boundary infrastructure then, from regular infrastructure, is “the explicit recognition of the differing constitution of information objects within the diverse communities of practice that share a given infrastructure” (Bowker and Star, 1999, p. 314). In other words, it is not that boundary infrastructure is different in kind, merely in quality. It isn’t so much the structure that is different, but rather the kind of objects the infrastructure can usefully contain. We can see this when it comes to GitHub’s Trending page, for example, which lists the top 25 popular / most-liked repositories (GitHub Trending). Although this list changes often, repositories that were trending at the time of this writing included Marktext, (a markdown editor), developer-roadmap (a list of resources and a guide to becoming a web developer), free-programming-books (a collection of freely available books), awesome (a collection of lists on various topics), oot (a decompilation of the Legend of Zelda game, Ocarina of Time), and snarkOS (an open source operating system), among a variety of more traditional coding projects.

Examining these trending repositories demonstrates the wide variety of objects the infrastructure supports. Of course, many contain code, comments, and more arcane programming assets; however, they also contain a wide variety of other objects ranging from .pdfs of books, to simple software, from guides and tutorials, to lists of cool things and archives of videos, as a few examples. These repositories and an uncountable number of others like them show the huge variety of objects the Git infrastructure enables. Git handles images, audio, video, icons, fonts, hypertext, plaintext, as well as all programming languages. Contributors can enter and access various objects, and users can extract them for a variety of uses. Some users will simply use the collections, while other users will contribute to them, while still other users will curate and maintain them, showing variety not only in the types of content, but also how people interact with them.
Made up of different kinds of objects and constituted by different kinds of actions, together the objects and the actions comprise the boundary infrastructure that is Git and GitHub. As Bowker and Star write, boundary infrastructure “must bring into play stable regimes of boundary objects such that any given community practice can interface with the information system and pull out the kinds of information objects it needs” (p. 313) and indeed this is the case. Together, Git and GitHub form just such a stable regime of boundary objects: it manages to contain both the objects and make them accessible.

Aside from meeting Bowker and Star’s definition of boundary infrastructure in this important way, Git and GitHub also exhibit each of the eight dimensions of infrastructure described by Star and Ruhleder (1996), several of which can be mapped onto them straightforwardly. For example, the idea that Git is invisible and transparent to use until it breaks down is fairly indicative of infrastructure status all by itself. When GitHub went down several times in 2020, it made headlines for halting so much work (de Simone, 2020)—an impromptu holiday. Likewise, it’s clear that Git is “‘sunk’ into” (Star & Ruhleder, 1996, p. 113) structures, arrangements, and technologies because Git runs on computers, relies on the internet, and is a prominent part of many developer workflows.

It’s also fairly obvious that Git has reach or scope beyond a single project. Developers don’t use Git just for work on any particular project, but rather for all projects: it is used again and again whenever a project is started. And it’s clear that Git is built on an installed base: whether we are talking about the operating system code that runs the Git software or about the lineage of version control systems preceding it, or even about the optical fibers and the world wide web that enables it, Git is only able to function at all because it both upgrades and works on the technologies that came before it.

Arguably more interesting, however, are the other dimensions of infrastructure which Git exhibits, namely how it is “learned as part of membership,” how it “links to conventions of practice” and how it “embodies standards.” Not only do these latter dimensions show that Git is not merely infrastructure but boundary infrastructure, they are also farther-reaching and more powerful because of how they shape the future. Focusing as they do on newcomers and because of how they affect the way standards come into being and evolve, such large-scale influences can work, as in Git’s case, like a kind of self-fulfilling prophecy that strengthens its position and reinforces its dominance.

Git is perhaps the most powerful way for the community to enforce conventions of practice and evaluate conformity to standards. As a simple example, when a series of changes are made to a repository, it’s the widespread convention that the developer who made the changes explain for others what they do, a practice called commenting the code. This functionality is built into Git at a low level, but not added by default—a programmer must know to do it (use the -m flag), and so very likely must have been taught by someone to do it. There are also conventions about how lengthy such comments need to be (long enough, but not too long), what they need to focus on (strategy, not tactics), and even what voice and tense they should be written in (active voice and present tense preferred). Eventually these conventions become standardized and are used to identify and normalize newcomers who don’t conform. Using the wrong commands, phrasing the pull request incorrectly, even writing the wrong comment could cause a repository manager to deny the commits, preventing participation. It could prevent a newcomer from being allowed to participate in the first place by preventing them from being hired.

According to Stack Overflow’s well-regarded Developer Survey in 2018, Git was the primary version control system, used by over 87% of 101,592 software developers from 183 countries (Stack Overflow, 2018). Stack Overflow stopped asking the question after that year, since almost 9 of every 10 developers in the world used the same application. It had become de facto. Very few applications in the history of computing have become so dominant so quickly. It exceeds Google for searches, YouTube for video-sharing, Amazon for shopping, Netflix for streaming, and Facebook for social media. All of these giants now have significant competitors, while Git has none. Along with this market dominance comes its concomitant importance to the industry and its labor market. As York and Johnson-Eilola (2020) report, C-level administrators (i.e., CEOs, CTOs, CFOs, etc.) view potential hires’ GitHub pages “as significantly more important (30% more) than education, training, or personal brand, ranking below only years of experience, as preferred qualifications for new employees” (p. 5). It is simply remarkable that after only a mere thirteen years in existence, the highest officers in surveyed companies now view their potential employees’ GitHub activity as more important than any other factor except number of years of experience.

As long as GitHub is required to be naturalized for newcomers to earn membership, and as long as it’s used to transport conventions of practice and standards to these newcomers, then its use will continue to be both normalized and normalizing, and Git will remain the version-control system of choice for programmers and other knowledge collaborators. As long as Git remains the system of choice, it will continue to be required for membership, linked to conventions, and to embody standards. In other words, Git is locked into a positive feedback cycle in which its success works to feed its continued success. Indeed, this is the crux of the nearly ten-billion-dollar bet that Microsoft Corporation made when in acquiring the technology. Git has become such foundational infrastructure that other pillars of the tech world have incorporated it.

**CYBORGS, FREAKS AND MONSTERS**

By viewing Git as boundary infrastructure, we can at least partially answer some of the questions raised about why Git has escaped our view, how it has risen so quickly to prominence, and what kinds of theories and models we can bring to bear when studying it and other version control systems. However, this merely raises another set of questions. How should we contend with Git’s dominance? What implications does it have for those who study technologies related to software development or those who teach novice developers? These questions are potentially knottier than the others but also probably have more critical, academic relevance since they are less about the particular instantiation of a boundary infrastructure after the fact of its dominance and rather more about the application of this knowledge and what we can do in the future.

How do we contend with a technology that serves as a powerful gatekeeper of an entire industry? With a tool that is simple and flexible enough that it may credulously contain every single line of code a new programmer might write in her entire career, from her early studies to her pre-employment phases and then in every single job she will ever hold? Is there any other technology that
will remain so essential over such a span of time? Or that allows any of her employers, for example, to look over every single character she has ever written? What kinds of hegemony might such tools enable? Our first pass at addressing these questions will have to suffice for now, as giving them their full due is beyond the scope of this article. However, we would do well to attend to the subversive strand evident across Bowker and Star’s (1999) study of categorization, especially when the authors discuss how the “laws of nature” and the hegemony of the patriarchy both arise out of the naturalization of infrastructure and the standardization of boundary objects.

In highlighting this revolutionary turn, Bowker and Star evoke an entire tradition of subversive resistance endemic to feminist studies. From the cyborgs of Donna Haraway to the borderlands of Gloria Anzaldúa, there are numerous ways to counteract standardizing forces: passing, compartmentalizing, shadowing, fragmenting, code-switching, becoming a nomad (Bowker & Star, 1999, p. 303)—all serve to allow the target of exclusion a method of escape from the standardization imposed by infrastructure. Bowker and Star called those who resist ‘monsters’ and ‘heretics,’ but really, they are Harraway’s cyborgs, in whom humanity and technology are interpenetrated and for whom all notion of purity is excised: these are the hybrids who live in the borderlands and who can themselves exist in many worlds.

Bowker and Star arrive at the key insight that “[w]hen an object becomes naturalized in more than one community of practice, its naturalization gains enormous power to the extent that a basis is formed for dissent to be viewed as madness or heresy” (p. 313). Inasmuch as we feed into narratives of naturalization, we also include those who “believe” and exclude those who don’t. While it may seem desirable, after all who wants to work in the cubicle next to a “mad” person, we must remember that “we are always looking to other communities of practice as sources of validity, and if as far as we look, we find naturalization, then the invisibility layers up and becomes doubly, triply invisible” (p. 313). So, while local eccentricity is perhaps undesirable, some eccentricity is actually necessary as a means to stop the layers of invisibility from forming.

We can implement some of these modes of resistance in our studies, as I hope I have done here, and also, where it might have greater impact, in our pedagogies. In our scholarship we should strive to critique and contextualize infrastructure, especially when it threatens to become invisible or transparent. By using an ecological perspective that doesn’t privilege one view above another, we should focus on the ways infrastructure is used rather than what it consists of, and we can try, in our analyses, to include those data which do not fit our models. In our pedagogy we can always work to resist the impulses of normalization and avoid conveying to our students “this is the natural way,” or “it’s always this way.” Instead, we should focus on strategies based on passing, for example, pretending to be a skilled programmer when writing comments, even if the student is just a novice, and code switching, which is employing the conventions demanded by the community in some contexts, with deliberation, but not in others, to maintain our freer identities.

Remembering that “one person’s standard is another’s chaos” (Star & Ruhleder, 1996, p. 111) and that the core concept of boundary objects is equity in perspective, perhaps the main benefit that the concept of boundary infrastructure provides is the need for feminist-inspired modes of resistance that refuse the branding of madness, rebrand it; that reject a turn to others for validity. Like the African American woman in the sciences described by Bowker and Star (1999), who must “talk black” and “talk white” in a seamless braiding of identity (p. 306), so we must at once naturalize and denaturalize boundary infrastructures and the standardizations they impose if we are to escape the hegemony they threaten. We must preserve the ambiguity of objects and processes and embrace the coherence that standards provide at the same time that we resist the restrictions on identity and the stripping away of ambiguity. We need both the alternate histories and the conflicting futures to counter the hegemony wrought by infrastructure.

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Book Review

_Literacy as Conversation: Learning Networks in Urban and Rural Communities_

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Eli Goldblatt and David A. Jolliffe’s 2020 _Literacy as Conversation: Learning Networks in Urban and Rural Communities_ is to be interpreted as a “book of essays” and, more importantly, as vivid and lived conversations that aim to showcase nearly three decades of friendship between two colleagues concerned about meaningful community participation and literacy. This collection captures their reflections on their participation in community-based projects within the urban neighborhoods of Philadelphia and rural and semirural towns of Arkansas, but also offers an expanded and active understanding of literacy as social practice with complex relationships between sponsors, learning networks, power, and taking place in non-school environments having an access point through conversation and written symbols. Goldblatt and Jolliffe’s endeavor to highlight the social connections and complexity of literacy aligns with their intent to include not just scholars in higher education, but also “everyday folk” or ordinary people including educators, government officials and policy makers, and people from all walks of life. As a scholar of color and teacher of a Hispanic-serving institution and as a community member of a predominantly Hispanic city in Texas, I was immediately intrigued and captured by the authors’ commitment to highlight the stories of people who persevere and design interventions to construct hope and shape themselves and the world into a better place.

In “Part I: How to Read This Book and Why,” Goldblatt and Jolliffe begin by clearly articulating the connection between literacy and action by highlighting the intersection of communities, learning networks, and literacy in action as it unfolds in non-traditional or non-academic environments. Drawing from Deborah Brandt’s (2014) definition of literacy as ongoing conversations to better the world, the authors add to the conversation and define literacy as significant conversations that lead to action and “involve[s] [human beings] with the world of the word, connecting them to intellectual resources sometimes called technology or theory, information or knowledge, insight or wisdom” (p. 7–8). Goldblatt and Jolliffe demonstrate the limits with a perspective that only views literacy embedded in the action of people solving problems. Therefore, their approach provides a wider scope for learning networks to be defined as a “web of public institutions… [that] sponsor activities in which people learn literacy through action and through human interaction” (p. 8). In keeping with these conceptualizations, the authors introduce the framework Literacy Education Audit of Resources and Needs (LEARN) which aims at moving away from the idea of literacy as only a problem-solution process and instead embraces the idea of literacy as a process of “human communication, inquiry, advocacy, and collective identity that is always situated within systems, institutions, and polarities: public and private, nonprofit and business, educational and recreational, oppressive and liberating” (p. 10). A vital element of LEARN is the dialectical relationships that should exist while engaging with meaningful community projects. To advocate for linguistic fluidity, the authors reference Bakhtin’s conceptualization of dialogic use of conversation shaped by centripetal and centrifugal forces that can lead words to specific meanings or force language to become inflexible or rigid. Doing so challenges public educators to know and understand what is happening before building “‘innovative’ curricula or building pedagogical castles” (p. 11). The essays stress that teaching writing and reading is challenging, and that language should take place in action within local practices of communities.

In “Part II: Learning Networks in Philadelphia,” Goldblatt begins the conversation with a reflection of his experience working in out-of-school literacy centers, community arts programs, and urban farms. Goldblatt models the LEARN framework with examples that elaborate on the mission, history, exigence, needs, and potentials of each community-based project such as the Tree House project. For
instance, he quotes the Tree House mission: “to grow and sustain a community of readers, writers, and thinkers in Philadelphia” (p. 69). This mission is later connected to his discussion of literacy resources in Philadelphia and the lack of literacy sponsorship as one of the largest obstacles to overcome for many nonprofits to address their communities. Goldblatt focuses on the relationship that must exist between sponsors and learning networks in order to stretch contributions across these areas and change the narrative of urban life from “deficit, poverty, and hopelessness” to places of “fruitfulness, initiative, and a desire to rise” (p. 126). Similarly, in “Part III: Learning Networks in Arkansas,” Jolliffe recounts his experiences meeting Dr. Steve Collier, a rural health care provider in Augusta, Arkansas, learning with a Latinx youth theater group who call themselves “Stitches,” and composing with the men on death row and members of The Prison Story Project. While reading this section, I could not help but be drawn to Jolliffe’s experiences with the Stitches since their experiences and goals strongly resonated and had a familiarity with my own story as a scholar and teacher in El Paso. A student comments that the name for their theatre youth group came from their “need to stitch their community back together” (p. 147). I can relate to this sentiment since in many ways it has been a driving force for me to overcome ideas of fragmented identity as a Mexican American in the U.S. This mission is made evident in their play, Follow Me@Tio Sam, who centers on a “young would-be politician named Damian who is originally from El Paso but who has moved to Springdale, Arkansas and is now running for elected office” (p. 158). According to Jolliffe, it was precisely the work by the LatinX Theatre Project in this play that shows the dynamic he is trying to write about in this book. These young writers were able to use acts of writing and performing as opportunities that allowed them “to create and understand their identities and their worlds in newly vital ways” (p. 160). As a teacher in El Paso, Texas, I am constantly drawing from my own experiences with identity as a Mexican American and seeking ways to disrupt traditional notions of literacy to develop alternative curricula and more ethical pedagogical practices that can lead students to understand themselves as active and key members of their communities, but also as having unfixed senses of identity that they can use to negotiate the world around them.

Goldblatt and Jolliffe’s work reminds me of the need and importance to continue literacy and community-based work using the LEARN framework or similar approaches, because while it might seem like Hispanic-serving institutions are leading the movement by providing access and a voice to marginalized populations, there is still much to be done not only in terms of learning, but also when it comes to unlearning harmful practices that perpetuate limited notions of literacy, identity, and community-participation. Literacy as Conversation challenges literacy to include practice-oriented approaches in writing and academic writing to be more experience-based without the more conventional need to constantly cite or reference other works and authors. While the book does mention theoretical influences and figures in the earlier sections when explaining the LEARN framework, the rest of the book relies heavily on their own experiences and on modeling the framework through their own work in Philadelphia and Arkansas.

However, given their approach focusing on a wider audience beyond academics, I’m unsure how well the conclusion’s focus on networks, money, and grant writing fits with the rest of their work championing experience. While I understand one of the Goldblatt and Jolliffe’s exigencies is funding the learning networks and the community-based projects they propose, the emphasis on grant writing and cultivating donors might seem like skills mostly associated with academics and not the wider audience scope identified by the authors earlier on. In their conclusion, they draw from Paula Mathieu and Linda Flower’s works on community literacy and add “the work must go on at multiple levels, in multiple frames, in order to foster the greatest number of approaches to pressing problems that are too complicated to have unitary or static solutions” (193). Unfortunately, the approach goes back to using the problem-solution process and it’s difficult to envision the work on multiple levels when it is not fully described or developed and the conclusion centers on grant writing, which is still a traditionally exclusive ability that remains nebulous even for many scholars and ordinary people. This section of the book would be stronger if the authors made it clearer how the very people they argue should invest in the LEARN framework could use it to learn about financing community projects and forming connections with sponsors.

Goldblatt and Jolliffe demonstrate why it is important to recover these connections and opportunities. In Moving Up Without Losing Your Way, Jennifer Morton discusses how social mobility often does not take into consideration “the broken ties with family and friends, the severed connections with former communities, and the loss of identity—faced by students as they strive to earn a successful place in society” (p. 5). As a daughter to immigrant parents, I strive to find alternative messages that indicate to students and members of the community experiences are invaluable assets in an effort to move them away from the idea that social mobility or money as success is the only way to bring about change.

Like so many others in the border town of El Paso, my parents moved to the United States at a young age and worked their entire lives to offer me a chance at a better future. The idea that my future is tied to the American Dream is a motivation but also, as Kenneth Burke would put it, a terministic screen. At the most general level, terministic screens “work to explain the role of symbols in directing attention in certain directions rather than others . . . help us notice certain parts of our experience while encouraging us to neglect others” (Stob, 2008, p. 137). The terministic screen created early in my life led me to understand a ‘better future’ meant finishing school to achieve financial stability and social mobility. However, I now question if these ideals would correlate with living a meaningful life that includes taking into account my experiences and the experiences of others. Goldblatt and Jolliffe’s work reminds educators of the importance of experience, reflection, and conversation that invites all people to hopeful initiatives that are enriched through writing to co-create meaning and lived literacies.

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Book Review

Design Thinking in Technical Communication: Solving Problems through Making and Collaboration

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The use of design thinking (DT) as a pedagogical and problem-solving strategy has been gaining interest in technical and professional communication (TPC) for years, and Jason Tham’s Design Thinking in Technical Communication is the best and most comprehensive statement on this topic that our discipline has created yet. The book first overviews its central concepts (DT and “making”), then illustrates very concretely how those concepts can improve pedagogy, social advocacy, and collaboration in TPC. All the book’s chapters (except the conclusion and first chapter) contain empirical elements, which Tham uses to support his points.

Tham begins with a history and overview of DT, which is unavoidable for a publication like this. Many articles in TPC have made similar efforts (e.g., Bay et al., 2018; Durá et al., 2019; Greenwood et al., 2019; Lane, 2018; Pope-Ruark, 2019; Pellegrini, 2021; Purdy, 2014; Tham, 2021), but Tham distinguishes himself here in important ways. For example, Tham expertly connects DT to a lineage of topics in writing studies (e.g., process pedagogy, multimodality, user experience) and unravels the complicated multidisciplinary origins of DT. Importantly, Tham describes DT as both a non-linear set of strategies that enables designers to solve problems and as a mindset, highlighting the latter as the more important element (p. 8).

The next chapter moves into describing the second main concept of the book: making, which is described as synonymous with the do-it-yourself (DIY) movement (p. 30). Similar to the previous chapter, Tham provides a history of the Maker Movement. Then, he presents three case studies of maker spaces to show the characteristics of these places, highlighting how making can benefit TPC pedagogy. Overall, Tham illustrates “the intertwined relationships between making and design thinking and problem solving in technical communication” (p. 52). I have mixed feelings about how this intertwined relationship of the Maker Movement and DT is presented. On one hand, making is a perfect ideology to be paired with DT. Making is what pushes DT past the theoretical and gives students the experiential learning that Bay et al. (2018) identified as so important. On the other hand, the combination is so perfect that the two concepts already overlap greatly. Meaning, that one could argue “making,” as Tham describes it, is already part of DT, that they do not need to be presented separately then combined. Without making and materiality, DT becomes learning about problems and thinking about solutions with no problem solving. In other words, any DT practitioner and most modern entrepreneurs already create prototypes, which start at low levels of complexity and are made with whatever materials are available, and maker spaces are frequently used to create such prototypes. In my opinion, using one of these spaces to prototype does not necessarily make a person a member of a separate, “grassroots” (p. 31), “fast-growing international movement” (p. 27) with a clearly definable set of beliefs such as “resistance culture” and “antitechnocentrism” (p. 124), which is what Tham seems to imply.

Chapter three “highlights the connections between design thinking and social advocacy” (p. 57). Tham calls this cross section of ideas “social innovation” First, Tham overviews the importance of social justice and ethics overall to TPC. In Tham’s words, “good communication—whether technical or creative—should promote actions toward a good cause” (p. 59). Tham also argues that UX needs to include advocating for users from marginalized groups since design is “never neutral nor objective” (p. 61). Tham then identifies the first step of DT (empathy) as the most important phase of DT where this work takes place and offers a range of highly useful strategies for better understanding users (p. 72–74). To support his claims empirically, Tham offers industry examples which highlight the importance of social innovation and also
provides interviews with industry experts. Overall, Tham makes an argument that is very important and often underrecognized—that DT provides a ready-made framework for solving problems, which could potentially have many social justice-oriented applications within TPC. A strength of using DT to advance a social justice agenda pedagogically is that the wide acceptance of DT in entrepreneurship and business reduces resistance from students who might be politically wary of anything explicitly related to “social justice.” As Tham writes in his pedagogy chapter, “the design challenge prompt did not necessarily steer students into a social justice direction [but] the resulting projects demonstrated awareness toward social responsiveness” (p. 90).

The following chapter details Tham’s pedagogical application of DT, which he presented in an earlier iteration in (Tham, 2021). In my view, this chapter is likely the most important in the book because much of the recent discussion of DT in writing studies speculates on DT-oriented pedagogy (Bay et al., 2018; Lane, 2018; Leverenz, 2014; Pellegrini, 2021). The chapter revolves around a case study of a DT-focused TPC course that Tham taught in Fall 2017, and the methods include “project evaluations, qualitative interviews, and autoethnography” via teaching notes (p. 86). The assignment sequence that Tham presents may feel familiar to TPC instructors: students are asked to research, then propose a solution to a problem on campus (p. 83). But instead of simply writing about a problem, students actually prototype their solution, making use of the full DT process probably in as faithful a manner as is possible for a TPC class. An important point, which should go far to counteract skeptics of a DT-oriented TPC class, is that Tham recognizes that not every class will have access to or ability with advanced manufacturing software and hardware, and therefore, low-fidelity prototypes are completely acceptable. The prototypes that Tham’s students made were mostly made of materials such as “wooden sticks, craft papers, and other up-cycled objects as well as screenshots, digital wireframes, and dummy interfaces” (p. 86). So, instructors do not need to spend large amounts of time learning how to use advanced software and hardware, then teaching that to students. Tham notes that “the point of the design challenge [is] to inspire creative-critical problem solving, not building technology skills, per se” (p. 86).

The penultimate chapter outlines how DT may be applied in TPC to improve collaborations, and the content is intended not only for scholars, instructors, and students, but for practitioners as well. First, Tham provides an overview of scholarship on collaboration within writing studies and TPC, then offers a series of principles which can be used to guide radical collaborations informed by DT (p. 101–103). The empirical element of this chapter is a retrospective look at a collaborative project of Tham’s from 2015 facilitated through collaborative auto-ethnography. Essentially, 10 of the 11 members of the group evaluated their work together in terms of each of the principles of collaboration posited by Tham on a 5-point scale, and they each included qualitative comments as well (p. 106). The case study provides an example of how radical collaboration can occur in academia. Tham finishes the chapter by advocating for radical collaboration in the vein of DT in academia and industry (p. 113) and includes a list of specific strategies for applying each of the principles of radical collaboration at the disciplinary, institutional, and programmatic level (p. 114).

A consistent strength throughout the book is how Tham provides concrete strategies for enacting the ideas that he presents and describes his ideas clearly enough so that someone else could duplicate them. Essentially, Tham just does a great job of following DT principles himself by “showing” rather than “telling” (p. 101). This is true in every chapter since each one ends with a well-designed learning activity, but there are many other examples that should be mentioned. For example, Tham provides a robust list of strategies to better understand users (p. 72–74); he also provides his entire list of assignments for his DT-oriented class (p. 85), a list of DT-oriented in-class activities (p. 95–97), and a heuristic tool for evaluating radical collaboration (p. 116–117). I find this transparency and attention to detail impressive because, especially when discussing DT, it can be tempting to throw around flashy terms like “empathy mapping” or “bodystorming” but be unclear as to what those things actually are. In short, Tham moves far beyond vaguely dropping impressive buzz words and instead really illustrates what those concepts mean and how they can be applied in TPC.

In the conclusion, Tham poses a call for action to use DT and making to create “productive disruption” and change our disciplines for the better. Overall, Tham’s book has much to offer, whether someone is looking for a well-written and comprehensive overview of DT or making, or if they are looking for concrete applications of DT in pedagogy, collaboration, or social innovation.

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