

# Exploring online conversations around science – data practices of informal online knowing spaces

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## Summary

Science and science communication are considered crucial to respond to global crises such as climate change or pandemics. At the same time, debates about the role of online communication in the dissemination of scientific knowledge are fueled by concerns about populist political movements, increased commercialization, and the spread of misinformation.

As public conversations around science move into digital contexts, new actors and mechanisms are shaping the way people talk about science in online “knowing spaces”. While some discussions focus on the risks of dis- and misinformation, others emphasize the encouraging opportunities for professional science communication and for direct exchanges between scientists and members of the public. But both perspectives risk missing important actors and practices: In online spaces, complex sociotechnical systems mediate engagement with science. They involve informal and collective interactions between technical features, social norms, and overlapping communities.

This thesis explores the science communication practices in informal science-oriented online spaces in the context of global crises. The websites of climate movements and discussions of the pandemic on Reddit serve as examples of non-professional actors and practices that recontextualize science communication online. Drawing on Science and Technology Studies, science communication research, and internet research, this dissertation addresses the following research question: In science-oriented online contexts relating to global crises, what traces are visible of ‘behind-the-scenes actants’ shaping conversations about science?

In paper 1, I examined the use of hyperlinks on the websites of two climate movements, Fridays for Future (FFF) and Extinction Rebellion (XR). This paper contributes to a conversation about activists as alternative science communicators. Although both movements emphasize ties to academic science and amplify existing science communication, I saw differences in the sources they refer to and the contexts they reassemble them into.

Paper 2 investigates the data practices (i.e., the social use of technical affordances) in three coronavirus-related subcommunities on the social media platform Reddit. The paper builds on the concept of data practices, showing that data practices differ not only between platforms but also between communities on the same platform.

Paper 3 continues the investigation of coronavirus-related information on Reddit. In this paper, I focused on the role of moderators, the tools they use, and the relationships they maintain with user communities and platform management. I followed three major controversies related to content moderation in the wake of the pandemic. This paper expands on the notion of platform dialectics to distinguish between interactions within communities and interactions across the platform at large, and how they shape coronavirus-related discussions.

My thesis calls for attention to context in science communication. I show how actors informally take on roles as science communicators, and how seemingly similar communities informally engaging with science can develop different collective practices and interactions. While professional science communication efforts still play an influential role in these knowing spaces, the communities mediate and recontextualize them in different ways.

For both practitioners and researchers in science communication, informal recontextualization deserves attention. My thesis shows that work inspired by Science and Technology Studies and internet research can provide the tools to identify and characterize different online contexts, thus contributing to a more nuanced understanding of online conversations around science.



# Table of Contents

Summary .....	3
1 Introduction.....	11
1.1 Aim and research questions .....	12
1.2 Selection of empirical materials .....	13
1.3 A note on Interdisciplinarity.....	15
1.4 Overview of the thesis.....	16
2 Background and theoretical concepts.....	19
2.1 Studying relationships between science, society, and the digital.....	19
2.1.1 Science and Technology Studies (STS).....	19
2.1.2 Internet research (IR) .....	22
2.1.3 Science Communication Research (SCR) .....	26
2.2 Conceptualizing relationships between science, society, and the digital .....	29
2.2.1 Informal science communication .....	30
2.2.2 Online publics .....	32
2.2.3 Data practices .....	33
3 Working with digital materials and methods.....	37
3.1 Studying digital sites.....	37
3.1.1 Found and made data.....	37
3.1.2 Media and societal effects .....	38
3.1.3 Transient and dynamic sites.....	39
3.2 Using digital methods.....	40
3.2.1 Virtual vs natively digital .....	40
3.2.2 Computational vs interpretative .....	41
3.2.3 Digital fieldwork .....	42
3.3 Internet research ethics .....	43
3.3.1 Public, personal, and sensitive data .....	44
3.3.2 User privacy.....	45
3.3.3 Sharing back results.....	46
4 Summary of the articles .....	47
5 Discussion .....	52
5.1 Informal knowing spaces.....	52
5.2 Publics and platform dialectics.....	58
5.3 Local data practices .....	57
6 Conclusion .....	62
References.....	67





## **Appendix**

Paper 1: Experts, influencers, and amplifiers – Exploring climate movements' hyperlinking practices

Paper 2: A tale of three subreddits – community data practices shaping engagement with COVID-19 on Reddit

Paper 3: Moderating an infodemic – Platform dialectics in coronavirus-related knowing spaces on Reddit



## Introduction

This thesis explores how people interact with science in online contexts. Science has close but often indirect ties to people's daily lives. In the face of global challenges, conversations around science become entangled with other issues. Increasingly, arguments are made for the role of science and science communication in addressing for example climate change or pandemics. At the same time, new communication technologies change the way we talk about these issues. In online contexts, distinctions of formal and informal, public and private, and social and technical aspects of our conversations are increasingly blurry. This leads to complex interactions. It changes who and what shapes the conversation, and it can produce disputes about who and what *should* shape the conversation.

So how do people talk about science online? Frequently, both public and academic discussions about online science communication assume that the involved actors are either professionals, or wrong. Either they mention the opportunities for professional science communication, formal outreach and education activities, and increased openness of scientific communication online. Or they focus on ignorant or outright malicious dissemination of false information, anti-intellectual sentiments, and risks associated with commercialization, polarization, and politicization.

However, only a fraction of engagement with science that I observed online would fit neatly into these descriptions as either misinformation or professionally organized. I did not see my own, personal experiences with online science communication fully reflected in these discussions. Similarly, research on the impact or use of science also seemed to prioritize professional and formal contexts over the informal and mundane interactions that I was interested in. As the pandemic unfolded in 2020, discussions about the coronavirus overshadowed other topics online. While much information stemmed from professional science communicators and scientists suddenly becoming publicly visible, the discussions about them were often mediated by other influences. As my personal interest to learn about the pandemic converged with my scholarly interest for informal science communication, I noticed information being treated differently in different contexts. In this dissertation, I describe these different contexts as overlapping *knowing spaces* (Law 2016) with distinct norms and influences that shape diverse spaces for informal engagement with science.

Science communication, understood here as “the social conversation around science” (Bucchi and Trench 2021), occurs in a wide range of online contexts. In this thesis, I investigate sites of informal but scientifically oriented engagement with science. Actors in these contexts subscribe (at least partially) to academic ideals and standards of knowledge production without necessarily being enrolled as academic scholars or professional science communicators. At the same time, a number of social and technical influences mediate the engagement with science, fitting with an understanding of science and science communication *as culture* (Horst and Davies 2021; Davies et al. 2019; Davies and Horst 2016).

My work addresses calls for “making visible the ‘behind-the-scenes’ actants which also shape science communication” (Edwards and Ziegler 2022) and for research on activists as alternative science communicators (Faehnrich, Riedlinger, and Weitkamp 2020). I call for attention to various informal contexts that mediate science communication online, and offer concepts to investigate and describe such differences.

Online contexts are neither completely disconnected from physical and social realities, nor completely representative of them. This confronts social science researchers with the methodological question of whether the object of study is a particular social phenomenon or the media dynamics surrounding it. Following an approach from digital controversy analysis (Marres

2015; Marres and Moats 2015), I take a symmetrical stance to this problem. I traced both *the issue* and *the media effects* and their interrelations in my selected empirical contexts. To bring together the analysis of technical and social aspects conceptually, I used the notion of *data practices* (Weltevrede and Borra 2016) as one of the central concepts in this thesis. Data practices describe the social practices tied to the technical affordances and digital data that characterize different online spaces. I investigate these practices using a combination of computational and interpretative methods.

My dissertation builds on a combination of research interests from Science and Technology Studies (STS), Internet Research (IR), and Science Communication Research (SCR). I present my research in three articles that examine different aspects related to data practices in informal science communication contexts. Paper 1 contributes to the discussion on climate activists as *alternative science communicators* (Faehnrich, Riedlinger, and Weitkamp 2020), focusing on their hyperlinking practices. Paper 2 investigates how users on the social media platform Reddit collectively shaped information related to the coronavirus pandemic. In this paper, I expand the notion of data practices (Weltevrede and Borra 2016) to highlight not only differences between platforms, but also differences between subcommunities on the same platform. In paper 3, I elaborate on content moderation practices and controversies on Reddit during the pandemic. With this paper, I dive into the complex interactions of users, communities, moderators, and platforms, or *platform dialectics* (Squirrell 2019), that shape how conversations around science unfold online.

Across the three papers and these six introductory chapters, I show how STS, IR, and SCR can be combined to investigate the characteristics of informal online science communication. I find that actors and practices in such contexts are far from homogenous even in settings that appear similar. I discuss how attention to localized data practices could help to explain and account for this homogeneity. Further, I examine the informal, collective, and mediated nature of online science communication contexts that blur the lines between public and scientific conversations, private and public discussions, and technical and social influences.

## 1.1 Aim and research question

Over the last decades, sweeping changes in technical, social, and political contexts have influenced patterns of communication and social interactions in general. They also shape developments in science communication more specifically. They have simultaneously led to increased professionalization and increased informality in social conversations around science (Bucchi and Trench 2021). New actants and intermediaries shape science communication activities on social media platforms (Edwards and Ziegler 2022; H. Chen, Hara, and McKay 2021). And new types of actors become involved. This can include patients entering conversations around health-related topics more publicly online (Egher 2019), activists relaying environmental and climate research (Faehnrich, Riedlinger, and Weitkamp 2020) or scientists becoming highly visible public figures in relation to the pandemic (Utz, Gaiser, and Wolfers 2022; Joubert et al. 2023). At the same time, online activities create traces (Bechmann, Sandvik, and Zelano 2019; Geiger and Ribes 2011) that can be used to study even unstructured, informal, and ad-hoc forms of engagement. This opens up new opportunities for studying such influences in science communication.

Public discussions about science and technology, especially in relation to global crises, are increasingly polarized and politicized. Therefore, it is important to understand what shapes and influences these discussions. Professional science communication efforts and the spread of mis- and disinformation receive increasing attention, but research on informal interactions and influences around science online is surprisingly limited. One reason for this could be the difficulty of capturing

their diverse and dynamic nature. In my work, I have narrowed down the broad interest in informal science communication to an investigation of online contexts in relation to climate change and the coronavirus pandemic. I focus on informal actors and mechanisms that contribute to and make use of science communication in these contexts.

In this thesis, I investigate such human and non-human actants. I explore what shapes informal online science communication, how these influences become visible to users of the platform, and how their traces can be used by researchers to examine different online contexts. My empirical investigation focuses on science-oriented contexts in relation to climate change and the coronavirus pandemic. These are examples of highly visible conversations around science tied to questions that affect everyday lives globally. I concentrate on visible traces of what shapes the conversation. I closely follow how the practices of different online contexts present themselves to users, and investigate how researchers could study these practices. In conclusion, I seek to answer the following research question:

**In science-oriented online contexts relating to global crises, what traces are visible of ‘behind-the-scenes actants’ shaping conversations about science?**

With this thesis, I want to contribute to a better understanding of the complex interactions between professional and informal science communication. My work highlights the relations between different actors and actants of various online settings that shape these interactions. I argue that attention to local practices is necessary in online contexts. The notion of data practices serves as one tool to describe and account for such local differences.

## 1.2 Selection of empirical materials

Claims about the important role that science and science communication have in modern societies flourish in the face of complex global challenges. Arguments for the necessity of science (and science funding) often emphasize questions of sustainability and climate change. Following the pandemic, they also highlight the ability to quickly build on existing knowledge to tackle global crises.

Arguments for the necessity of science communication tend to fall along similar lines, claiming a necessity for (voting) publics to understand developments in science and technology and how they impact everyday lives and political decisions.

Much research goes into attempts to trace impacts of science on large scale organizational or economic bases, and into evaluating the effects of more openly accessible scientific communication (for example tracing the spread of research papers in non-scientific online spaces). But surprisingly little attention is given to everyday and informal interactions with scientific content. Therefore, I wanted to explore how conversations around science actually unfold in different public spaces online, when not formally organized. I was particularly interested in *sciencephile* spaces that show support for and deep engagement with science, without being driven by formal or professional norms of engagement (even though these might indirectly come into play).

I originally selected different online spaces loosely related to global challenges, where users engage with scientific information that (at least indirectly) impacts their lives and their decision-making. I was intrigued by the slogans like “listen to the scientists” of climate movements. I chose the websites of two European climate protest groups (Extinction Rebellion and Fridays for Future) and explored their use of science-related hyperlinks in my first paper.

As I moved into work for the further papers, the coronavirus pandemic alongside with what the WHO termed an accompanying *infodemic* (WHO 2020) became an extremely visible topic of public

conversations online. This development has been described as “one of the most acute science communication challenges of a generation” (Wilkinson 2021). During the pandemic, as policymakers and individuals were scrambling to figure out what to do, scientific knowledge was sought, discussed, and criticized among different publics and communities. Individual scientists found themselves suddenly highly visible in the media (Joubert et al. 2023). An initially increasing role and authority of science in the first months of the pandemic was followed by more critical public debate, media highlighting disagreements, and conspiracy theories (Metcalf et al. 2020). In addition to a flurry of science communication about pandemic- and health-related research, scientific expertise was discussed more generally in the context of the pandemic. This sparked renewed debates about relationship between science and non-science, science communication and expertise “at a time when science, science policy and science communication are explicitly matters of life and death, and are being enacted before us all, every day” (Gregory 2020).

The complex and rapidly evolving situation highlighted questions such as which specialists could comment on which topics, or how to combine different fields of expertise. The health crisis has been named as an important reason to reflect on the role of science and science communication, as well as their relation to democracy (Davies 2022a). For example, how should politicians balance virologists’ and epidemiologists’ warnings about the risks related to the virus, psychologists’ warnings about mental-health risks related to social restrictions, and economists’ warnings about financial consequences of different mitigation strategies? Questions of knowledge production as well as science communication and impact received sudden public attention. Topics included explanations on pre-print publications, journal rankings, and the peer-review system. Detailed descriptions about stages of clinical trial needed for an approval by different health authorities were widely shared. And heated discussions on differences and boundaries between different academic disciplines such as virology, epidemiology, or immunology made their way into various online knowing spaces.

These pandemic-related science communication efforts presented me with an unexpected opportunity to explore informal engagement with science by following this topic that suddenly permeated various online spaces. After following developments across several contexts, I landed on using Reddit for my further empirical work. Reddit is a social media platform originally built on link-sharing, which remains one of the main features of the site. All content on the site is organized into “subreddits”. These gather content around particular topics but also develop distinct user communities and create individual rules for what content can be posted in this community. This leads to diversity across the different communities (as well as tensions between them).

The diversity of subreddits is reflected in a diversity of research interests and findings related to Reddit. Amongst others, the platform is described as being toxic, having potential for science communication, linking to misinformation, and hosting support networks for vulnerable groups. With COVID-19, a topic emerged that a lot of existing communities had to relate to in their decision-making around content moderation. Dedicated subreddits on the topic grew quickly, allowing me to follow the development of new subreddits and the negotiation of rules and moderation tools shaping these emerging knowing spaces.

Due to the link-sharing nature of Reddit, it also presents connections between professional science communication (for example newspaper articles or academic texts), and informal science communication (for example comments, lived experiences, or individual efforts such as graphs made from publicly available data). I observed the subreddits on the topic of COVID-19 as they developed distinct profiles. I focused first on the collective data practices (paper 2) and then on moderation tools and conflicts that influence the subreddits (paper 3). Moderation controversies and decisions about how to engage with the flood of coronavirus-related information are easier to trace on Reddit

in comparison to other platforms. The wiki format that many subreddits use to present their rules allows researchers to examine existing rules for each subreddit as well as trace changes over time. Moderators and users frequently discuss moderation rules and users actively demand for or push back against changes. Finally, “meta subreddits” comment upon events across the entire platform, discussing for example moderation controversies in different subreddits.

These characteristics make it easy to follow relationships between local and platform-wide aspects of Reddit. But other platforms have similar interactions between platform-wide and local agreements on how to use a certain online space. This includes for example Facebook groups or pages where administrators hold the power of deciding who can enter the space and shape what can be posted and how. Another example are YouTube channels with distinct identities of subscribers and channel-specific content moderation practices.

### 1.3 A note on Interdisciplinarity

Having received both a Bachelor’s and a Master’s degree from interdisciplinary study programs, and being hired into a PhD position within a project and a department hosting researchers from multiple disciplinary backgrounds, I began my PhD work with no strong disciplinary affiliation. I had a substantial amount of freedom to explore different research approaches regardless of their disciplinary background. This has given me the challenge and opportunity of building my work on a combination of different strands of research from diverse backgrounds.

With internet research, science communication, and science and technology studies, I combine three social science research fields that grew out of interdisciplinary collaborations. They, in turn, draw on a variety of backgrounds and roots. They relate to fields such as anthropology, sociology, education, human-computer interaction, computer science, cultural studies, or media studies.

Interests in the digital as opportunity and challenge for new methods, new field sites, and new research objects also fuel increasing interdisciplinarity. They lead to a “wild interdisciplinarity” (Goulden et al. 2017) or can act as a “gateway” to interdisciplinary research (Cosgrave 2019). At the same time, internet research has moved from a niche to a core interest within communication studies (Puschmann and Pentzold 2020).

Work that crosses boundaries between traditionally separate research traditions is on the rise. Strategies for doing so include disciplinary innovation, niche seeking, creating whole new research fields, or attempting to comply with the opposing forces of calls for interdisciplinarity and academic structures reinforcing traditional disciplines (Woiwode and Froese 2020). Many scholars that I have referred to merge work from different backgrounds and use these strategies. Disciplinary innovation has added digital research to existing disciplines, creating for example digital STS (Vertesi and Ribes 2019), digital sociology (Marres 2017), or digital humanities (Svensson 2010). Similar to my combination of fields, PhD theses position themselves in niches combining for example STS and fan studies (Marsh 2018), STS, science popularization and cultural studies (Gunnarsson 2012), or SCR, STS and citizen science (Yang 2021).

Besides STS as a comparatively new discipline, I also work with SCR, connected to education research amongst others and “maturing as a field of scholarly activity” (Guenther and Joubert 2017). Science communication has been observed to have moved from “a discipline-in-the-making” to “an inherently, even joyously, interdisciplinary field” (Bucchi and Trench 2021, 2). Scholars are seeking niches by combining STS and SCR (e.g. Felt and Davies 2020), STS and the digital (e.g. Vertesi and Ribes 2019; Marres 2017), or SCR and the digital (e.g. Hara, Abbazio, and Perkins 2019). Some even

combine all three (e.g. Squirrell 2020; Marsh 2018; Pearce et al. 2019) in similar ways that I have done in this thesis. I found myself struggling with where to place these authors in my background chapter that I organized by the three fields of STS, IR, and SCR. Perhaps this also illustrates both the common roots and the increasingly shared research interests between them.

This thesis could alternatively be read as located mainly within STS, combining the strands of digital STS (Vertesi and Ribes 2019) and public understanding of science as an interest within STS (Sismondo 2011, chap. 15). However, with my own interdisciplinary background, I prefer to understand my interests in the digital and in science communication as separate (though closely connected) influences in my research. I combine them with STS both as a field and as a method or approach concerned with “knowing spaces” (Law 2016), paying attention to STS sensitivities such as infrastructures, publics, or expertise (Felt and Davies 2020).

In addition to the three fields presented as my main interest here, this thesis originally started out as an investigation of public impact of science, in connection to the Oslo Institute for Research on the Impact of Science (OSIRIS). However, as I started working towards tracing more public-facing and informal types of impact, I found science communication to be a more fitting framing. What remains from my ties to OSIRIS is a focus on users and their practices. While impact studies do not play a big role in this final version of my thesis, I was surprised of the many parallels between impact studies and science communication research. Both are characterized by the rejection of linear models or deficit models that nevertheless are found to remain pervasive among practitioners and policymakers as well as scientists themselves. Both struggle to measure and attribute connections between science and society, amongst others due to long time scales and complex interactions not linked to individual papers, projects, or researchers. And both are shaped by an underlying normative ideal that science and science communication are inherently useful to society and should be encouraged and improved. These parallels point to converging research interests, showing for example in work on digital methods combining STS and altmetrics (Costas, Rijcke, and Marres 2020). However, I leave it to others to explore these common interests in more depth, focusing here on science communication, STS, and internet research.

#### 1.4 Overview of the thesis

This thesis is divided into six chapters accompanying three journal articles. Table 1 gives an overview of the three articles and their main contributions.

<b>Paper 1: Experts, influencers, and amplifiers – Exploring climate movements' hyperlinking practices</b>	Contributes to the discussion of activists as alternative science communicators, adding a focus on online communication and hyperlinks.
<b>Paper 2: A tale of three subreddits – Community data practices shaping engagement with COVID-19 on Reddit</b>	Expands the notion of data practices from describing differences between platforms to community data practices describing differences within one platform.
<b>Paper 3: Moderating an infodemic – Platform dialectics in coronavirus-related knowing spaces on Reddit</b>	Investigates the role of moderators in shaping content in online communities and the relationships between users, moderators, and platform management; proposing a distinction between in-community and cross-community platform dialectics.

*Table 1 Overview of the articles and their main contributions*



Following this introductory chapter, I expand on the background and literature referred to in my work and related theoretical concepts in chapter two. Chapter three introduces concerns of working with digital materials and methods and relates these to my own methodological choices. Chapter four gives a summary of the three articles that make up the main body of my work. Finally, in my discussion (chapter five) and conclusion (chapter six), I present the themes and implications of my work across the three articles taken together. The three articles are appended at the end of the thesis.



## 2 Background and theoretical concepts

There is a general understanding that science and technology play an increasingly important role in peoples' daily lives. Scientific research is considered relevant for debating and solving societal problems and for tackling global challenges such as climate or health crises. This makes it necessary for scientific knowledge to become accessible to wide audiences. At the same time, emerging changes in communication technology and media landscapes add more complexity and diversity to the relationships between science and society as they have previously been described.

This thesis is situated at the intersections of three connected lines of social science research that address these themes: science and technology studies (STS), internet research (IR), and science communication (SC). In this chapter, I present selected literature from each of these three fields to display their connections to each other and to my own work, followed by a more detailed discussion of core concepts that I have used in my work and which I return to in chapter 5.

### 2.1 Studying relationships between science, society, and the digital

Despite growing from different research traditions and fields, the three areas that my thesis builds upon share some of their roots, research interests, and challenges. All three aim to answer questions about interfaces and interactions that emphasize investigations of social practices, and all three are in a process of exploring new opportunities and challenges related to *the digital* as a research object and as a field site.

Inspiration for my work stems from the combination of STS sensitivities and science communication research interests (Felt and Davies 2020), as presented for example in the investigation of actants shaping online science communication (Edwards and Ziegler 2022). Furthermore, I also relate to an interest in how digital research can be fruitfully employed to study these topics (Vertesi and Ribes 2019; Marres 2017).

#### 2.1.1 Science and Technology Studies (STS)

Science and Technology Studies (STS, sometimes spelled out as “Science, Technology, and Society”) investigates academic knowledge production and its relationship to society at large. Several streams of STS have influenced my work in this thesis. They include a focus on practices and knowing spaces (Law 2016) as well as interactions among different actors in such spaces. In my own work, I have investigated both social interactions (as seen in the different user groups on Reddit), and interactions between knowledges and knowledge-building systems (for example when climate activists or Reddit users reassemble and recontextualize links from different sources).

STS has been described as an approach or method in and of itself (Law 2016). Thus, STS research of the digital is closely tied to developments in digital methods. Like many other fields, STS has had to relate to the opportunities and challenges of the digital realm. With new social behaviors and technical affordances, new materials and methods become available for research. The interdisciplinary nature of STS is also reflected in work on and with the digital, including for example influences from sociology (Marres 2017) media studies (Marres and Rogers 2005) or anthropology (Munk 2019). Methodological interests range from the opportunities emerging from newly built tools such as visual network analysis with Gephi (Venturini, Jacomy, and Jensen 2019) or hyperlink analysis with Hyphe (Jacomy et al. 2016) to questions on how to integrate digital formats with more participatory research approaches such as data sprints (Munk, Meunier, and Venturini 2019; Omena et al. 2022) or how to integrate qualitative and quantitative approaches to working with digital

materials and methods (Munk 2019). As social interactions move into digitally mediated contexts, STS researchers, like other social scientists, have to decide what to make of these new contexts (Marres and Moats 2015) and how to do “digital STS” (Vertesi and Ribes 2019). As all empirical work for this thesis has been conducted online, I expand on these questions in my discussion of digital methods in chapter 3.

In the following section, I focus on interactions as studied by STS scholars, and their relationship with research on networks, controversies, and the concept of symmetry. Then, I briefly introduce the STS focus on knowledge building and knowing spaces. Finally, I reflect on the relationship between STS and research on Science Communication or Public Engagement with Science.

### *Interactions*

Meeting points of different social and sociotechnical contexts are important sites for STS research. Among them is a longstanding interest for interactions between social processes on the one hand, and technical or material processes on the other hand.

Several STS scholars comment upon connections between social and technical processes, such as Donna Haraway’s image of a cyborg (Haraway 1985) describing entangled technical and social processes, or Lucy Suchman’s (1987) description of users’ interactions with photocopiers that laid the foundations for the field of human-computer interaction. Further on, STS overlaps with research on computer-supported cooperative work (CSCW), sharing interests in social practice surrounding technical affordances, and the appropriation of technology by different users, combining social science and computer science interests. An example is the exploration of virtual communities and venues shaping online learning (Ruhleder 2002). Challenging the divisions between technical or material influences and social aspects in work contexts, Wanda Orlikowski presents sociomateriality (Orlikowski 2007). She posits “an inherent inseparability between the technical and the social” (Orlikowski and Scott 2008). Work on infrastructures has explored how actors work across “seams” between heterogenous infrastructural contexts (Vertesi 2014). More recently, STS approaches have included the ethnographic study of algorithmic systems, investigating their “blend of “technical” and “cultural” concerns, spread across institutional settings in broader social contexts” (Seaver 2019, 420). My work follows in these footsteps, exploring the entangled social and technical aspects of informal online science communication.

In various studies of interactions between social and technical influences, STS scholars return to other common themes and approaches of STS work. Among them are the notion of symmetry, conceptualizations of networks, and analyses of oppositional relationships.

Converging research interests about digital infrastructures and platforms (Plantin et al. 2018) follow in the lines of earlier work on social construction of technology (SCOT), emphasizing the human-made nature of technological developments (Trevor Pinch and Wiebe Bijker 1984). Amongst others, SCOT focuses on the tenet of *symmetry* (introduced as one component of the “strong programme” by David Bloor in 1976). The symmetric approach calls for treating different influences in knowledge building processes the same, regardless of whether they are successful or where they originate. This principle has been continued in the exploration of sociotechnical issues, concerning for example the question of whether observations of digital phenomena relate to social phenomena or media contexts (Marres and Moats 2015), further discussed in chapter 3.2. It also applies in the symmetric treatment of human and non-human influences in science communication (Edwards and Ziegler 2022). Furthermore, symmetry is useful in the investigating ‘alternative’ knowing spaces, not taking for granted the implied opposition to “non-alternative science communicators” (Gregory 2020).

The “radically relational” (Law 2016, 41) approach of actor-network theory (ANT) (Latour 1987; 2005; 2017) takes the concept of symmetry even further. In this approach, researchers treat all human and non-human actors (or actants) that influence a given situation symmetrically, assigning agency to all of them, and describing how they assemble into a network. While I did not frame my work directly in relation to ANT, the notion of “‘behind-the-scenes’ human and non-human actants” is inspired by ANT (Edwards and Ziegler 2022, 5). Additionally, my work makes use of the seamlessly interconnected micro and macro scales of digital data (Latour et al. 2012).

The STS focus on interactions often highlights oppositional or adversarial dynamics. STS research has for example described program and anti-program becoming embedded in artefacts such as hotel keys (Latour 1990). Other examples include non-use and recontextualization or interplay between designers and users of technical objects (Akrich 1992) or unintended uses of technology as users appropriate technology, for example for personal communication or entertainment (Latzko-Toth et al. 2019). In STS research, crises and controversies serve as a useful way to study knowledge creation processes. They present a meeting point between communities, lay bare otherwise hidden social processes and assumptions, and challenge the idea of expertise as neutral or unpolitical (Martin and Richards 1995; Scott, Richards, and Martin 1990). Controversy studies have been combined with digital methods to study online settings (Marres and Rogers 2005; Marres 2015; Marres and Moats 2015; Munk, Meunier, and Venturini 2019; Venturini and Munk 2021). In these contexts, the abundance of traces of social interactions means that this mapping process in order to identify different actors and topic related to an issue can be fruitful even for topics not generally understood as controversial (Munk 2019).

Political controversy around global crises like climate change and the COVID-19 pandemic were part of my initial curiosity about the empirical contexts I chose to study in this thesis. However, the science-oriented spaces that I studied revealed little controversy on the topics, at least in the way they present themselves to users. Instead, I found that in the Reddit context, controversy focused not on the content as such, but on questions of content moderation more generally, which is why I decided to focus on these conflicts in my paper 3.

### *Knowing spaces*

The focus on interactions in STS includes for example the description of trading zones and interactional expertise (Galison 1997; 2010; Collins, Evans, and Gorman 2007; 2019), allowing social groups with differing concepts and vocabulary to collaborate in knowledge building processes. Similarly, concepts of boundary work (Gieryn 1983) and boundary objects (Star and Griesemer 1989) or boundary infrastructures (Bowker and Star 1999) have been invoked to study demarcation and collaboration processes between social groups, often considering demarcation processes around what is considered scientific or not, or collaborations across differing disciplines.

In addition to describing interactions, these concepts also describe spaces, or demarcations between spaces, simultaneously differentiated and connected by their relation to knowledge building. In addition to describing interactions between social groups, they comment upon interactions between epistemologies. To STS researchers, knowing spaces imply “that knowing and its methods are materially complex and performative webs of practice that imply particular arrays of subjects, objects, expressions or representations, imaginaries, metaphysical assumptions, normativities, and institutions” (Law 2016, 47). The attention to knowing spaces in STS is also related to an understanding of knowledge as situated (Haraway 1988) and an emphasis on location and local practices shaping knowledge building activities.

The attention to knowing spaces and interactions makes STS a good candidate for investigating science communication.

### *STS and science communication*

Science communication can be understood as a research interest within science and technology studies (Sismondo 2011, chap. 15; Stengler 2015), or the two fields can be seen as separate fields of research that can contribute to each other (Felt and Davies 2020; Davies 2022b; Horst and Davies 2021; Horst, Davies, and Irwin 2017). They can also be described as a set of converging interests in publics and practices relating to knowledge production after initial criticism of public understanding of science research by STS scholars (McNeil 2013). In this thesis, I have chosen to present STS, internet research, and science communication research as separate fields with converging interests.

A recent interest in combining STS and science communication as distinct, mutually beneficial fields of research (Horst, Davies, and Irwin 2017; Felt and Davies 2020) is prefaced by a long-standing STS interest in public interactions with scientific knowledge. This includes observations on tensions between expert and lay knowledges (Wynne 1989), and numerous analyses of concerned groups in health-related research. Among them are observations of patient groups advocating for change in epistemic practices in medical research (Epstein 1995) and the notion of concerned groups deliberately working to blur public-private distinctions (Callon and Rabearisoa 2008). Further research along these lines includes participatory knowledge-production in social media (Wyatt et al. 2013) or the development of interactional health expertise as patients publicly engage in online settings (Egher 2019). Citizen scientists seeking to intervene in knowledge production to address pollution (Ottinger 2010) could be understood as another form of concerned groups.

Moving from these types of engagement with science by concerned individuals or groups to science communication understood as culture and in relation to identity work (Davies et al. 2019; Davies and Horst 2016; Marsh 2020), or considering topics of broad public concern (e.g. global climate and health crises), research interests of STS and science communication converge. In an essay on the relationship between science communication and STS, Sarah Davies (2022b) summarizes the core ideas of STS as the social construction of research-based knowledge and study of what the place of such knowledge is in society, aligning well with an interest in studying social conversations around science. Together with Ulrike Felt, she presents several “STS sensitivities” that can be helpful for science communication research, including questions of expertise, evidence, and authority, attention to the intertwined construction of facts and construction of publics, and investigations of spaces, infrastructures, or structures (Felt and Davies 2020).

My own investigation of actants shaping science communication is informed by these sensitivities, recapped by Davies (2022b) as three key approaches of STS: “1. What is happening here?”, “2. Everything is local”, and “3. All research is political”. My exploratory work seeks to understand “what is happening” in science communication, paying attention to the differing “local” contexts of where these activities occur, and relating to the political nature of knowledge production processes.

#### 2.1.2 Internet research (IR)

Turning to online knowing spaces, my research is informed not only by STS, but also by research on online spaces more generally. In this thesis, I use the term ‘internet research’ to describe (social science) research that has internet phenomena as its object of study. I elaborate on considerations of digital fieldwork (collection of materials from digital sources) and computational methods (analyzing materials with the help of computers) in chapter 3. Here, I present background information and

previous research on the objects and sites that I have worked with: online communities, social media platforms, content moderation, and hyperlinks.

### *Social science interest in the Digital*

As social interactions move into online spaces, internet research becomes relevant for social science researchers. Researchers identify social, economic, and political drivers in the changing interactions that characterize a new “information age” and “network society” (Castells 1996).

The way that researchers describe the internet and its infrastructures has evolved alongside a development from niche interest to broad cultural significance. As online spaces move from being considered separate spaces, to digital services permeating everyday lives, research interests develop accordingly: “emphases in digital social research have shifted from interpreting 'life online' to researching a far broader range of 'mediated life'” (Hand 2014).

Rogers (2013) identifies four broad stages of development: In an early purely virtual “hyperspace period”, hyperlinks acted as navigation devices between disconnected sites. With the rising influence of search engines, links gained significance as an indicator of authority and quality. Finally, a web of separated “spheres” (such as blogs or news), gave way to the current “walled gardens” of platforms (closed ecosystems that strictly control what users can do). Methods and concerns of internet researchers evolved alongside these changes through developments such as web archiving, search engine research, platform studies, nationalization, commercialization and big data (Rogers 2013).

### *Hyperlinks and context*

Web infrastructure and particularly hyperlinks shape how the internet presents itself to users, making it a key point of investigation in internet research. Hyperlinks, even though taking on changing roles throughout the development of online contexts, are an important part of web infrastructure to both internet users and researchers. In the development from an early, open web, to more platforms, open web ideals and mechanisms still can stand behind them (Gillespie 2018). Despite losing their significance as navigation devices that they had in the hyperspace period, and lessening importance as (sole) quality indicator for content search that hyperlinks were associated with in the search engine era, hyperlinks remain a crucial aspect of web infrastructure. They are used both visibly in content sharing via links on or between platforms, and more hidden, when platform functionalities such as user profiles, hashtags, or share buttons implement special forms of hyperlinks. Hyperlinks can be a valuable “methodological starting point for multi-platform analysis” (Rogers 2018), since one of the still pervasive uses of hyperlinks is to point to sites outside of closed platforms. They still are found to fulfil commercial and social purposes, as well as act as navigation devices and citation markers in the context of news links (Ryfe, Mensing, and Kelley 2016).

“For social sciences and digital humanities, the hyperlink is alive and well! Despite the growing influence of gated platforms and their strategies of attention economy, the hyperlink is still a cornerstone of the World Wide Web’s openness and accessibility.”  
(Ooghe-Tabanou et al. 2018)

While early studies of the digital have frequently treated it as dematerialized, STS scholars focusing on materiality have found new ways of engaging with digital and digitized materials (Forlano 2019) that also involves the use of hyperlinks to trace associations. An example of the use of hyperlinks in STS research is the identification of issue networks that can be demarcated by following hyperlinks (Marres and Rogers 2005). However, with large datasets and platforms presenting challenges for

automated crawlers, this approach is limited in a platform context. The amount of data produced this way can go beyond what is possible to manually analyze. Furthermore, content of platforms could be too heterogenous to make domain names a useful unit of analysis (links to a news broadcaster or a health authority give a hint as to what they might contain, links to Instagram or YouTube could contain anything from official announcements to informal discussions). And finally, access restrictions such as paywalls or required logins limit what content is visible without further access.

More recent work building on issue network approaches is experimenting with additional computational methods during data analysis in order to retain information on the context of links (Maier et al. 2018) or to separate issue networks from noise and unwanted data when working with big data (Waldherr et al. 2017). Another approach focuses on manual curation in the data collection process (Jacomy et al. 2016), emphasizing more deliberate intervention by researchers. Similarly, understanding hyperlinks as a proxy of social connections, Severo and Venturini (2016) are an example of researchers combining computational representation of hyperlink networks with manual categorization of the organizations behind each website in the network. Using more manual categorizations in my own work, my first and second paper make use of the more explicit, visible form of linking by analyzing what certain online communities link to, whereas both the second and third paper also investigate some of the links embedded in the functionalities of the platform Reddit.

Online spaces are open to a multitude of readers, collapsing contexts such as family members, friends, colleagues, and perfect strangers. This context collapse creates problems for individual users facing the flattened audiences of social media (Marwick and boyd 2011; boyd 2010). It also creates tensions when imagery becomes viral and part of activist engagement, sharing an individual's "media moment" without the person's personal context and history, or attributing new contexts and histories to the image (Merrill 2020). Context collapse can occur in the shape of intentional collusion, or unintentional collision (Davis and Jurgenson 2014). However, at the same time as audiences are collapsing into merged contexts, different online spaces offer new contexts and recontextualizations. Context returns as an important aspect in social media research. Understanding the origin of (automated) content posted to social media (Gerlitz and Rieder 2018), users' expectations of privacy (Nissenbaum 2011), or the influence of commercial contexts online (Özkula 2019) have been highlighted as important aspects of digital research. Context is among the big challenges in working with big data, "taken out of context, data lose meaning and value" (boyd and Crawford 2012).

In the era of walled gardens, or closed platform ecosystems, platforms become an important new way in that context is managed and understood by content producers, audiences, and researchers alike. But on an even more local level, users resist context collapse and create their own practices.

#### *Platforms and content moderation*

With the rise of closed platform ecosystems online, much research focuses on the use of individual platforms, such as Twitter research (Proferes and Zimmer 2014), studies of Reddit (Proferes et al. 2021), research on Wikipedia (Voss 2005; Jullien 2012; Okoli et al. 2014), and others. Both technical difficulties in collecting data across platforms, and methodological difficulties in comparing them – does following someone on Twitter mean the same as befriending them on Facebook or subscribing to their YouTube channel, for example? – lead to not only users but also researchers staying within the ecosystem of individual platforms, affecting both what happens and what is being researched in online contexts.

Platforms take on an important role in shaping what is visible to users. Gillespie (2010) notes that "[platforms'] choices about what can appear, how it is organized, how it is monetized, what can be



removed and why, and what the technical architecture allows and prohibits, are all real and substantive interventions into the contours of public discourse”.

Reddit started out as a collective curation of hyperlinks (social bookmarking) and still plays a large role as such. Although the platform allows contributions that do not contain links since 2012 (Lagorio-Chafkin 2018, 205), link posts remain one of the main aspects of the platform, and many subreddits, including the ones I studied, still restrict users to only post content linked to external sources.

A systematic review of Reddit research (Proferes et al. 2021), found that despite increasing social science interest, studies mostly stem from computer science contexts (for example using Reddit data as test- or training data for machine learning approaches) and frequently rely on computational text analysis, pointing to a need for other research methods and disciplines to investigate the platform.

In 2008, Reddit embraced the idea of dividing content, and related user communities, into topically oriented subcommunities, allowing users to freely create new communities or “subreddits” (Lagorio-Chafkin 2018, 142). Differences between subreddits have been investigated, including for example conversation patterns observable by various metrics (Choi et al. 2015) or the creation of rules specific to each individual subreddit (Fiesler et al. 2018). An analysis of the r/science community on Reddit found that users in this community interact with articles at higher rates than elsewhere on Reddit, due to self-selection of users with high interest in science (Pflugfelder and Mahmou-Werndli 2021, 15). The diversity of subreddits might also contribute to different characterizations of Reddit in the academic literature, as either toxic and carrying a risk of dis- and misinformation (e.g. Massanari 2017; Hagen and Jokubauskaitė 2020; Burton and Koehorst 2020), or as a space with great potential for science communication and outreach activities (e.g. Hara, Abbazio, and Perkins 2019; H. Chen, Hara, and McKay 2021; Jones et al. 2019). Reconciling them, Gilbert (2020) describes how moderators carve out a space for public history amidst the “cesspool” of toxic and violent language on the platform.

Together with work on content moderation (Chandrasekharan et al. 2018), observations on subreddit difference present an interesting entry-point to start and explain the diversity of both content, and research observations on the platform: subreddits develop distinctly different cultures and norms. While Chandrasekharan et al. investigate the ‘behind the scenes’ work of subreddit moderators and their decision-making, in my work I focus on visible traces of tensions around those decisions in paper 3, and distributed moderation work including all participants of a subreddit in paper 2.

Among the distinctions between platforms is their approach to content management. Caplan (2018) distinguishes a small-scale “artisanal” approach emphasizing context for making decisions on permissible content; and the opposing “industrial” approach employed by large platforms such as Facebook or YouTube, enforcing policies in large-scale, automated mechanisms. In between them lies a “community-reliant” approach as seen on Reddit or Wikipedia (Caplan 2018). This approach emphasizes self-regulation of users, relying on volunteer moderators to maintain community standards for content moderation.

Reddit users starting new subreddits automatically become moderators of these subreddits. The array of diverse subcommunities along with the founders’ radical defense of free speech and reluctance to ban extreme subreddits (Lagorio-Chafkin 2018, 207) give significant freedom but also responsibilities to moderators in shaping the context of each individual community, and the platform overall. Online content moderators have been described as “custodians of the internet” in the book of the same title by Tarleton Gillespie (2018), with community managers such as subreddit

moderators being only one layer in an extensive system of platform users, human moderators, and algorithms steering the visible content. However, much of the discussion on content moderation revolves around the removal of unwanted content, the spread of misinformation, and other risks related to social media content. STS scholars have contributed to aspects of content moderation criticizing ‘fact checking efforts’ by pointing to the social construction of facts (Marres 2018). They provide insights that expertise can be understood not as inherent to a person or piece of information, but as attributed by others, exemplified by the upvoting mechanism on Reddit (Squirrel 2020, 219). In this thesis, I focus on the curation and recontextualization of benign content, focusing on how scientific content in particular is shaped by actants such as website admins (paper 1), user collectives (paper 2), or community managers (paper 3).

Among the multitude of social interactions moving online, affected by new contexts and expectations, is science communication. Collapsing contexts of private and public communication can be both risk-filled and beneficial for public engagement with science. Scientific knowledge is one among many types of content recontextualized and shaped by infrastructures, platform management, and content moderation practices.

### 2.1.3 Science Communication Research (SCR)

Science communication presents an important link between scientific knowledge production and societal conversations. Like other forms of communication, it has been reshaped by digital interactions, presenting new opportunities and challenges.

Following a definition by Massimiano Bucchi and Brian Trench (2021) I understand science communication as “the social conversation around science” that encompasses a broad range of activities, actors, and intents. Different groups engage in this conversation through various means and at varying degrees of formality and interactivity. This broad and inclusive definition of science communication is related to an understanding of science *as culture* (Horst and Davies 2021; Davies et al. 2019; Davies and Horst 2016) which also influences my own work.

As science communication research is highly interdisciplinary, observations of online science communication also draw from closely linked fields that investigate interactions between science and society, not least from STS. For example, Edwards and Ziegler (2022) show how an ANT-inspired approach can help to study intermediaries and mediators in science communication online.

#### *Deficit models*

Early research on science communication and public understanding of science has often relied on *deficit models*. These assume that public audiences’ reactions (and especially resistance) to scientific knowledge stem from a lack or deficit of knowledge, to be remedied by expert-to-lay communication. A 2003 definition of science communication (Burns, O’Connor, and Stocklmayer 2003) presents a metaphor of science as a mountainous landscape where science communicators provide figurative ropes and ladders to help audiences get closer to the scientists who reside at the mountain tops. Such imagery of scientific knowledge being out of reach for publics without additional help and scientists placed at the top of knowledge hierarchies has been criticized amongst others by STS scholars (McNeil 2013). The field has over time moved on from considering a “public understanding of science” or “public awareness of science” to a more inclusive investigation of “public engagement with science” (Trench 2006). Nevertheless, deficit models and limited understandings of science-society relationships remain common and commonly discussed.

Callon (1999) distinguishes three idealized models of lay participation in scientific knowledge production and dissemination: public education, public debate, and co-production. The public education model puts scientific and lay knowledge in opposition to each other and presents education as the solution to overcome the opposition. The public debate model allows for differentiated publics with relevant expertise to be included when scientific knowledge is incomplete. And the co-production model makes room for actively involving participants from concerned groups in the production of knowledge that directly affects them. However, all three models seem inadequate to describe the informal engagement with science that I have observed. In the context of global crises like climate change or pandemics, affected groups return to the unhelpful category of an undifferentiated “general public”. In the collapsed contexts of social media environments, education, debate, and knowledge production happen simultaneously. And participation in all three can range from evaluating information at a glance with the click of a button, to explicit and purposeful curation, sharing, or translating of knowledge.

Newer models of relationships between science and society risk still implying linear connections when moving from one-way deficit models to two-way dialogue models, rather than a three-way or multidirectional participatory model (Trench 2006). And even STS research, frequently criticizing prevailing deficit models, might still imply the related diffusion model, assuming non-scientific audiences as recipients of knowledge resulting from an ‘elite’ of scientists (McNeil 2013). Deficit attributions can not only be observed from policymakers or scientists toward lay audiences, but also between other actors where they might function as an attempt to resolve deep disagreements (Fuentes, Goñi, and Miranda 2021). In the context of changing media ecologies, deficit models might not become obsolete with information available online. Instead, they are replaced by experts’ skepticism about stakeholders’ abilities to evaluate the overabundance of information. An example of this development from healthcare presents adversarial dynamics that shape interactions between patients and providers (Ko 2016).

One possible solution to the problem of defining models of science communication, and especially to the “deficit or dialogue” framing, is to consider science and science communication an integral part of (popular) culture (Davies et al. 2019). The “social conversation around science” (Bucchi and Trench 2021) involves a vast range of different actors, intentions, and formats, especially when it moves online.

#### *Digital science communication*

Increasing digitalization and developments of social media have several effects on science communication. Science communication practices are characterized by increasing professionalization, but at the same time increasing informality as researchers, science influencers, and hobbyists make use of social media to take part in conversations around science (Bucchi and Trench 2021). Alongside easier access to information (provided by commercial as well as non-commercial organizations, and also influenced by movement towards open access for scientific publications), social media also blur the lines between scientific and non-scientific, public and non-public conversation.

Conference live-tweeting, online question-and-answer sessions with scientists, academics’ social media profiles, or research project blogs can all pose difficulty when trying to categorize them as strictly dissemination and outreach to broad audiences or as internal to scientific conversations targeting only professional stakeholders. People producing online content about scientific knowledge can range from scientists themselves, to professional science communicators employed by large organizations, to self-employed science influencers on online platforms, to hobbyists. At the same

time, despite best efforts to be more inclusive, formal science communication and the education for such roles can still act as gatekeepers restricting who has access to these roles and activities (Bennett, Dudo, and Besley 2022). All in all, research on digital and online science communication is limited. A review of approximately 3000 journal articles in the field found digitization and rapidly changing media systems among one of the four main clusters of research gaps in science communication (Gerber et al. 2020).

When public interactions with scientific knowledge are investigated in online contexts, the research frequently falls into one of two themes: professional science communication, and content moderation along with risks of mis- and disinformation. SCR focuses on opportunities for outreach and interaction online, moving away from deficit models towards more genuine interactions enabled by online contexts, but focusing on scientists science communication professionals involved in such contexts. Scholars in communication research and media studies on the other hand comment on content moderation mechanisms as well as risks of dis- and misinformation in informal contexts and how to address them. Less formal and non-professional forms of science communication practices have so far received little attention in the scholarly literature. Bridging SCR and internet research, a focus on informal practices could help address such challenges and might reveal mechanisms that influence both science communication and misinformation online.

Returning to the problematic metaphor of science as a mountainous area (Burns, O'Connor, and Stocklmayer 2003) with scientists 'at the top' and publics 'needing help', I nevertheless like the idea of science as a landscape. Metaphors of what 'the internet' or 'the digital' are can be evocative and powerful tools for critical internet research (Wyatt 2021) – as shown for example the discussion of the term 'platform', simultaneously helpful in shaping shared understandings, and carefully managed by corporations (Gillespie 2010). Updating the metaphor of mountains with problematic implications of hierarchies, in a newer understanding of science communication scientific knowledge production could be considered a diverse landscape of "knowing spaces" that different people reside in or visit for a variety of reasons. Whether and what kind of help anyone might want to navigate a given part of this landscape depends not on their placement along a vertical hierarchy, but on their familiarity and their previous access to and experiences of the landscape. Formal science communication efforts by scientists trying to make their work accessible to wider audiences, professional science communicators, and various popular science media formats, can all act as travel guides inspiring, informing, and helping visitors who navigate areas of the landscape they are less familiar with.

One of the reasons I do like this image is because the associated changes in accessing travel information with the rise of the internet and social media translate well to science communication. The plethora of available information, the easier accessibility for different groups of people (both as audiences and as communicators), the risks and opportunities associated with decentralized communication channels, multidirectional communication, challenges tied to monetization and algorithmic curation of information, user communities rating and ranking information, winner-takes-all effects of viral communication patterns, and many more affect all online conversations. Just like anyone can both find and contribute to travel information online, the same is true for various actors serving as 'guides' to the science landscape online. Their guidance can range from incredibly helpful to misleading or outright malicious. Actors can range from local bottom-up initiatives shaping their own neighborhoods to global corporations affecting information flows for commercial purposes. In this thesis, I examine climate activists, data practices of science-oriented online communities, and disputes around coronavirus-related content moderation as examples of such influences that shape public experiences of the conversation around science.

### *Science communication and global challenges*

Global crises such as climate change or pandemics affect the relationship between science and society. They entangle scientific knowledge with political decision-making, as politicians and citizens call for certainty, evidence-based solutions, and reliable and trustworthy knowledge bases for decision-making. As new stakeholders such as activists, community managers, or individuals enter the social conversation around science, they both attempt to influence the conversation, and base everyday decision-making on it.

With science increasingly seen as an important contributor to addressing global challenges, various groups position themselves with explicit reference to both. This includes activist movements such as Extinction Rebellion or Fridays for Future, taking on roles in curating and sharing science communication efforts. These “alternative science communicators” (Faehnrich, Riedlinger, and Weitkamp 2020; Faehnrich 2018) follow in the footsteps of environmental groups engaging with and sharing scientific information since “empirical claims about the state of the natural environment are core to their message” (Yearley 2008, 168–69).

The rapid development and urgency of decision-making during the coronavirus pandemic challenged science communication and public trust in science. The pandemic could serve as a mirror on the relationship between science and society (Metcalf et al. 2020). Studies observed an initial reduction in science-related populism and resentment (Mede and Schäfer 2020) but also increased anti-intellectualism and delegitimization of scientists and scientific knowledge (Y. Chen et al. 2023), alongside highly visible scientists (Joubert et al. 2023). Wikipedia editors engaged in large-scale, high-tempo collaborations to update the online encyclopedia with developing information and scientific knowledge as it became available (Keegan and Tan 2020). Although strategies to combat misinformation were widely deployed, scientific observations of debunking efforts had ambiguous results (Schmid and Betsch 2022). Amidst lockdowns, social media users turned to memes and humor showcasing mundane political commentary (Murru and Vicari 2021).

In the light of digitalization and global crises, a combination of SCR, IR, and STS seems suitable to investigate the complex interactions that shape informal conversations around science in online knowing spaces.

## 2.2 Conceptualizing relationships between science, society, and the digital

Especially in the online context, science communication is not restricted to scientists themselves. Nor is it limited to other professional science communicators such as popular science writers, science journalists, museum curators, science educators, or others who create and disseminate materials around scientific research as part of professional roles. With science and technology permeating everyday lives and increased communication opportunities online, many other actors engage with scientific knowledge in varied ways, creating own content, combining sources, linking content on their websites or social media feeds, voting or commenting on it. This, in turn, shapes how yet other groups of actors encounter it. It is these informal, digitally mediated activities that I am especially interested in. So far, these very loosely structured or unstructured practices have rarely been highlighted in science communication research.

Michelle Edwards and Caden Ziegler (2022) point to the opportunities of STS-inspired research for investigating informal engagement online by treating symmetrically the different actants, human and non-human, that shape the public conversations around science. In this thesis, I explore the role of several such actants: informal and alternative actors who are not formally enrolled as science communicators, yet take on influential roles in shaping online conversations around science;

collective actors and virtual communities that are part of such conversations not as passive audiences but as active publics; and data practices, i.e. the social uses of technical affordances that steer and shape online conversations. In the following sections, I present concepts that I have used for describing aspects of these actants and roles which I return to in my discussion chapter.

### 2.2.1 Informal science communication

Besides faster and easier access to information, communication technology and especially social media platforms have also contributed to less formal interactions, blurring boundaries between public and non-public, or scientific and non-scientific communication. The conversation between two scientists, or the commentary on an ongoing academic conference might become public when held on a social media platform. Scientists and non-scientists might engage in two-way conversations on such platforms (Hara, Abbazio, and Perkins 2019). New media formats such as the platform *The Conversation* might blend scientific communication and science journalism (Guenther and Joubert 2021). However, other influences also intervene in such spaces:

“Our findings demonstrate the importance of rejecting the common assumption that science communication on social media occurs solely and directly between scientists and publics. We strongly encourage other researchers to follow our cue in making visible the “behind-the-scenes” actants which also shape science communication.” (Edwards and Ziegler 2022, 14)

Non-scientists might use platforms to collaboratively engage in knowledge-building activities, using tools and vocabulary similar to established sciences (Squirrell 2020). Patients can turn into expert mediators about health topics (Egher 2019). Even less formally, people engage with science in many ways. For example, they conduct their own experimentation and knowledge building activities (Squirrell 2020), request ad-hoc information from social networks (Daume and Galaz 2016), are highly supportive of and actively seek out scientific knowledge (M. S. Schäfer et al. 2018). Users of social media platforms might relate to scientific content through humor and emotional engagement, building identities (Marsh 2020; 2018) or engage more critically through humor and ambivalence, as seen in the behavior of trolling (Mendel and Riesch 2017; Birkbak 2018).

Furthermore, activist groups can engage as “alternative science communicators” (Faehnrich 2018; Faehnrich, Riedlinger, and Weitkamp 2020; Maesele 2009). Science popularization can also be “captured” by interest groups, for example seen in dietary advice (Gunnarsson and Elam 2012). Nevertheless, the label of “alternative” science communicators also suggests an opposition to “non-alternative” science communicators that should be treated with caution (Gregory 2020). Lay-people communicate about climate science differently than journalists, suggesting different contexts or “arenas” for engagement (Lörcher and Taddicken 2017). Various participants in social conversations around science online might join by different means, be it humor, visual imagery, video and audio content, text discussions, or others; and have different reasons and purposes for engaging. I summarize them here as informal science communication activities.

Education research distinguishes formal learning (linked to schools and training institutions), non-formal learning (structured learning offered by other organizations and institutions, e.g. museums, book clubs, etc.) and informal learning (learning from everyday activities without having a learning goal in mind), often linked to policies connected to lifelong learning (Colardyn and Bjornavold 2004). Transferring this distinction to science communication, much research focuses on formal (originating from scientists) or non-formal (originating from professional science communicators) activities, with limited attention to informal actors who do not necessarily act in the roles of professional scientists or science communicators.

Although research and practice of science communication has vastly expanded, the focus on professional and formal activities risks leaving out important aspects of “the social conversation around science”. Despite efforts to be inclusive, formal science communication and the education of professional science communicators can act as gatekeepers maintaining unequal access to resources for different social groups (Bennett, Dudo, and Besley 2022). At the same time, researchers treating science and science communication as culture observe rich and diverse engagement practices by non-professional actors, both in dedicated popular science spaces and in other knowledge building practices.

With a longstanding interest in interactions between scientific and non-scientific actors, STS-inspired research is well-suited to study such informal actors and interactions around science online. STS observations range from the expert patient or “increasingly informed patient” (Squirrell 2020, 50) to a broad understanding of science communication as culture (Horst and Davies 2021; Davies et al. 2019; Davies and Horst 2016) and as identity building (Marsh 2020; 2018). In health as in other contexts, activists are an important group of informal or “alternative” science communicators (Faehnrich, Riedlinger, and Weitkamp 2020). Especially in relation to global crises like climate change or pandemics, affected groups can become so large they encompass global publics, due to global concerns. They may involve researchers themselves, acting as issue advocates, challenging the idea of scientists as neutral “honest brokers” of information (Pielke 2007).

A different informal engagement practice is that of highly interested groups acting out of personal curiosity or identification with a community, rather than personal information needs or political appeals. Non-professional actors in science communication (Marsh 2018) or ‘citizen science communicators’ (Yang 2021) move beyond the personal reasons that link them to health-related informal science communication. In an analysis of media use in Switzerland, researchers identified four groups of media users with respect to engagement with science: sciencephiles, critically interested, passive supporters, and disengaged:

“the “Sciencephiles,” with strong interest for science, extensive knowledge, and a pronounced belief in its potential, [...]; the “Critically Interested,” also with strong interest and support for science but with less trust in it, who use similar sources but are more cautious toward them; the “Passive Supporters” with moderate levels of interest, trust, and knowledge and tempered perceptions of science, [...]; and the “Disengaged,” who are not interested in science, do not know much about it, harbor critical views toward it, and encounter it—if at all—mostly through television.” (M. S. Schäfer et al. 2018)

The ‘sciencephile’ highly engaged group has also been described as boosters (Perrault 2013). These groups are only loosely organized and may or may not be scientists or science communicators in their professional lives but act in informal engagement out of a role and identity of curiosity. The interests of such groups can range from a very generic interest in ‘Science’ to particular communities such as bird watchers, participants in citizen science projects, and many more. One example is the proud self-identification of a reviewer of the ‘Ologies’ science podcast as part of a “siblinghood of enthusiastic learners” (Ward 2019). Other categorizations have found similar roles. In popular science writing, authors can act as “boosters”, “translators”, or “critics” (Perrault 2013). Members of online communities perform social identities as “science lovers” through the use of comments, memes and humor, without the intervention of professional scientists or science communicators (Marsh 2020, 185).

In my own work, most of the observed communities also fit into the category of sciencephiles. In some cases users build credibility by explaining why they have expertise to comment on an issue, but in most cases it is not visible whether they have an academic background or expertise in the topic

they comment on. But the self-selection of users into communities leads to a high number of users that could be identified as “sciencephile” in most of the contexts I have observed, including the websites of the two climate movements, and two of the three observed communities on Reddit. The third community falls into more of a “criticis” or “critically interested” category, nevertheless engaging with scientific knowledge, but taking on slightly different roles and perspectives.

### 2.2.2 Online publics

The investigation of social structures in digital contexts is closely tied to its technical infrastructures. Internet research has treated online spaces, and in turn, online communities, differently alongside developing internet eras (Rogers 2013). Descriptions range for early work on cyberspace as enclaves disconnected from real-life communities, all the way to ‘onlife’ experiences in social media platforms merging online and real-life experiences (Bechmann, Sandvik, and Zelano 2019). Alongside these developments, different conceptualizations emerged to describe groups of people engaging in common activities online. Relating to the concept of “communities of practice” (Lave and Wenger 1991), some research conceptualized online spaces as “communities of shared interests” (van Schalkwyk, Dudek, and Costas 2020), with more recent work shifting to considering “communities of attention” (Costas, Rijcke, and Marres 2020; Díaz-Faes, Bowman, and Costas 2019). Communities can take on fleeting and ad-hoc characteristics as users call on their personal networks to answer questions (Daume and Galaz 2016).

A similar shift has occurred in science communication research. In line with moving away from deficit models, and alongside the increased opportunities for many-to-many communication, researchers are no longer considering groups of people as passive audiences receiving science communication efforts, but instead as (representatives of) varied publics participating in science communication activities in diverse ways. This lines up with STS interests in publics, especially the work by Noortje Marres and others on (online) issue publics in connection with digital controversy mapping (Marres 2007; 2015; Marres and Rogers 2005; Birkbak 2013).

Networked publics (“publics that are restructured by networked technologies”) are characterized by invisible audiences, collapsed contexts, and a blurring of public and private activities (boyd 2010). Social media have contributed to blurring the lines between public and private, and between publics and audiences. Although in theory, opportunities to produce own content are open to anyone, participation is often found limited to more passive activities such as watching or reading. Fuchs (2017) goes as far as calling it a “myth that social media has radically transformed media use from passive reception to active participation”, with only small numbers of users actually producing content. However, users can intervene in online spaces through smaller actions such as likes or comments, and relate directly to various communities. This combination paradoxically leads to a simultaneous development towards more political and more mundane engagement (Baym and boyd 2012):

“As people communicate publically through social media, they become more aware of themselves relative to visible and imagined audiences and more aware of the larger publics to which they belong and which they seek to create. They negotiate collapsed contexts, continuously shifting power dynamics, and an openended time frame. Through discussing the personal, mundane, and everyday, people negotiate a sense of public place and help new publics—both wanted and unwanted—to coalesce.”

Even though Reddit has been described as “going back to the roots of the internet” with a focus on communities of pseudonymous users gathering around a topic of interest (Squirrell 2018) and my



paper 1 examining organizations' websites, both of these contexts still showcase the mixed informal and political nature of online conversations.

The conflation of informal and political categories online is also reflected in the academic literature. An overview from a political science perspective defines publics as having a common issue and a common position, which they try to make relevant in a political system (Møller Hartley et al. 2021). The authors summarize four approaches to conceptualizing publics in datafied spaces: 1) Publics seen as connection and civic cultures (from audiences studies and political citizenship), 2) Publics as pragmatic issue-solving spaces (seen in the above-mentioned STS work by Noortje Marres), 3) Publics as networked spaces of digital interaction (found for example in the concept of personal publics (Schmidt 2014)), and 4) Publics as calculated and manageable entities (found in critical data studies).

Therefore, it is unsurprising that identity work enabled through communication technologies has been observed in several contexts. It has been researched in the collective identities of social movements (Ilten and McInerney 2019), or the identities of communities migrating between social media platforms if the need arises (Fiesler and Dym 2020). It also is seen in individual identity work similar to fan culture tied to various forms of non-professional discussions around science online where "scientific authority was maintained by communal sanctions rather than accredited expertise" (Marsh 2018). And it occurs in alternative knowing spaces online building collective practices of generating, evaluating and organizing information (Squirrell 2020).

By joining online conversations around science, users help decide what does and does not belong into the conversation. They use the affordances of digital spaces to vote on, like, respond to, discuss, contextualize, or curate the content of visible in knowing spaces, simultaneously acting in political and mundane ways. In this thesis, I have focused my empirical work on science-oriented or sciencephile online publics as knowing spaces reflecting both informal and political dimensions of online science communication.

### 2.2.3 Data practices

At a first glance, one might suspect a clash between STS research emphasizing the social construction of technology (Trevor Pinch and Wiebe Bijker 1984) or describing the interwoven aspects of sociomateriality (Orlikowski 2007) and internet research from technical or media studies backgrounds focusing on technical affordances as separate influences from the social. However, in my own and others' work, a focus on practices and an emphasis on use and users serve to reconcile these approaches. In all three fields, STS, SCR, and IR, researchers pay close attention to combinations of social or cultural effects as well as technical or media effects, together with questions about whether and how these can be untangled from one another. The STS focus on practices is helpful here, both in regards to science communication practices, and digital practices; as is the understanding of knowledge as socially constructed, both referring to the content of conversations around science online, as well as the sociotechnical contexts of the platforms where they take place.

Conceptually, several researchers have brought together social and technical influences. I have been particularly drawn to concepts working with the idea of affordances and their use in practice. Similar to the ANT-inspired investigation of actants in science communication by (Edwards and Ziegler 2022), I study aspects of the complex network of influences that shape online science communication, and assign some level of agency to both human and non-human actants. However, I found a distinction of technical and social aspects helpful as an analytical category when considering the platform from a

user perspective, which is why I have landed on the concept of data practices describing both technical affordances and their use.

On the level of technology, different social media platforms can be described as having different technical “affordances”, defined as “what material artifacts such as media technologies allow people to do” (Bucher and Helmond 2018). While the concept was introduced by James J. Gibson (1977), the work of Donald Norman (1988; 2013) has brought attention to affordances in design work and in the design of digital interfaces in the field of human-computer interaction. Norman focuses on “perceived affordances” that suggest to the user of an item what to do with it, for example with pull bars and push plates that correctly installed ease the use of doors, and incorrectly installed cause confusion. This notion of affordances is still widely used in human-computer interaction. It also remains a common conceptual approach in media studies (Ilten and McInerney 2019). Bucher and Helmond (2018) provide a detailed overview of the history of the concept and its use in relation to social media.

However, the concept of affordances has also been criticized by STS scholars as it “renders users passive” in the analysis of digital artifacts (Vertesi 2019, 371). Furthermore, the attempt to separate technical and social aspects can be somewhat artificial, since they are very much intertwined. Especially STS scholars are frequent to point out that technical affordances are not created in a vacuum but continuously shaped through social processes and interactions (Trevor Pinch and Wiebe Bijker 1984). This can be described as socio-technical systems with “social and technical components independent but intertwined in mutually influencing relationships” (Cozza 2021, 177) or even as sociomateriality (Orlikowski 2007; Orlikowski and Scott 2008), challenging any division between social and material influences.

Nevertheless, the technical possibilities available to users (who can be far removed from the development process of these systems) are interesting to consider when investigating social media contexts. The notion of affordances can be a helpful analytical category “that captures the relationship between the materiality of media and human agency” (Bucher and Helmond 2018). For example, Tim Squirrell (2019) uses the concept of affordances to investigate relationships between moderators and users on Reddit, combining it with the STS notion of boundary work.

Indeed, the notion of affordances seems especially useful when taken together with an STS interest in social practices: Several scholars have offered concepts that expand on the idea of affordances by considering them in connection to social practices. This includes ‘platform vernacular’ illustrating how communication practices emerge within social media platforms (Gibbs et al. 2015), ‘device cultures’ understood as the interaction between users and platform (Weltevrede and Borra 2016), or platform dialectics describing how Reddit users and moderators respond to each others’ efforts to shape the platform (Squirrell 2019).

Since I am interested in applying the concept on a more localized level, considering not just platforms but individual communities on these platforms, I focus on the term ‘data practices’ in my own work. The term is used to describe the interplay of technical affordances and the social practices of their use in different contexts (Weltevrede and Borra 2016). Considering data practices allows a better investigation of user agency compared to affordances alone. This is shown for example in the work by Milan (2017) describing “bottom-up data practices” and showing how social movements produce, make sense of, and exploit social media data for their own purposes. Similarly, in relation to discussions about data literacies, Gray et al. (2018) describe “inventive data practices” and ways that data infrastructures are re-assembled in different ways than original designs intended.

In this thesis, I understand data practices as the social practices tied to the affordances and to the data<sup>1</sup> created through the use of these affordances in online platforms. I argue that data practices and local differences in data practices offer valuable insights to help understand contextual differences between online communities.

For example, both the websites I investigated in paper 1 and the subcommunities on Reddit I examined in papers 2 and 3 make use of hyperlinks, but where the website is unrestricted in how to use them, both technical affordances and social practice limit how they can be used on Reddit.

Another example is the “flair” explored as part of my second and third paper. Allowing Reddit users to add a little colorful tag to their profile or their posts is a design choice in the overall platform ecosystem of Reddit. It has been constructed by users, developers, moderators, technical necessities and commercial interests over more than a decade. While the creation and configuration of this design choice could be an interesting social process and aspect of the platform to investigate, to users and moderators this feature is a given part of the platform infrastructure and can be considered a permanent and stable technical affordance. At the same time, what users do with this feature in practice is far from set in stone, varying both between subreddits and over time, with moderators setting up elaborate flair systems that fit the collective needs of each subreddit. A focus on practices centered around the use of flairs allows me to both assign agency to flairs, consider them as socially constructed systems within subreddits, and consider them as technical affordance of the platform.

As this example shows, social and the technical aspects of what is happening on the platform are closely intertwined. Nevertheless, from a user’s perspective the technical affordances of a platform are set, and users themselves can influence what they do with these affordances and data as data practices. Previous research has called for being attentive to differences between platforms (Bucher and Helmond 2018). An example is the over-utilization of hashtags on Instagram and the under-utilization of hashtags on Facebook in comparison to Twitter, shedding doubt on “the comparability of the ‘same’ objects across platforms (likes, hashtags)” (Rogers 2018). In my work, I expand on this, noting that comparability even within the same platform could be challenged if social processes shape the use for different groups of users. In my paper 2, I have made explicit reference to the concept of data practices, expanding it to differentiate not only between platforms, but also between communities. In paper 3, I chose to work with the concept of platform dialectics to focus on interactions between moderators, users, and platform management, in part centered around platform affordances. Similar underlying ideas about the combined technical and social influences shaping online science communication also present undercurrents in the first paper and the thesis overall. In the discussion chapter, I expand on my use of the concept of data practices to describe the mediated nature of online science communication.

The practices around informal online science communication are illuminated by a range of different research fields, among which STS, internet research, and science communication research are some. Furthermore, many more concepts beyond informal science communication, online publics, and data practices highlight aspects of informal online science communication. The three fields and

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<sup>1</sup> It should be noted that ‘data’ in this context refers to a computer science understanding of the term as a sequence of symbols: the data that are produced, stored, changed, or displayed by and to users of social media platforms such as texts, data stamps, likes, links, images, and many more (differing from an understanding of data in scientific research as collection of values conveying meaning).

conceptual backgrounds presented here serve as a way to structure this thesis, but they are connected among each other and to other topics.

For example, when commenting on aspects of digital science communication, the focus of research frequently lies on practical aspects of professional roles in knowledge dissemination. Hence, it connects to further research interests such as science education (for example internet researcher danah boyd's commentary on media literacy 2018), science journalism (including STS scholar Noortje Marres' critical discussion of the notion of fact-checking 2018), or altmetrics research attempting to trace and measure academics' use of social media (for a review, see Sugimoto et al. 2017).

Such examples show that many links and longstanding interactions exist between the three areas of STS, internet research, and science communication. This thesis builds another such link through the investigation of informal interactions around scientific knowledge production online. Furthermore, I consider informal practices by actors not necessarily enrolled in dedicated science and science communication roles, but nevertheless shaping the social conversation around science in practice.

With my first paper as part of this thesis, I have contributed to an ongoing discussion about activists as science communicators. In the second and third paper, I turned to informal science communication activities on Reddit. With both of these contexts, I focus on "sciencephiles" as informal science communicators. They have an enthusiastic view of science, frequently defend the usefulness of scientific research and closely align themselves with scientific processes of knowledge building. This is evidenced for example by many references to scientific journal articles on the website of Extinction Rebellion (paper 1) or in submissions to the scientifically oriented subreddit r/covid19 (paper 2).

I return to the concepts presented in this chapter in my discussion in chapter 5.

### 3 Working with digital materials and methods

Over the last decades, digitalization has dramatically changed the ways that people interact. But in addition to changing social interactions, digitalization also influences how researchers can study them. In this chapter, I explore how the emergence of digital source materials and computational capabilities have influenced research methods. I present how different researchers answer the question whether traditional social science methods are still applicable to understand online interactions or whether new approaches, theories, methods, or tools are needed.

The interest in online spaces and the realization that new or adapted methods might be needed to study them has emerged simultaneously from several research fields. Overlapping research interests in developing new methods to study social practices related to online contexts can be found for example in media studies, digital humanities, or computational sociology. They are united by the idea of studying digital practices as culture and maintaining qualitative and interpretative research traditions even for a “datafied society” (M. T. Schäfer and Es 2017) a “digital sociology” (Marres 2017) or a new “data theory” (Lindgren 2020).

Aligned with these interests, STS (already drawing from various fields and having a long-standing interest in interactions with technology) is increasingly making use of digital sources and computational methods. This stream of research has been dubbed ‘digital STS’ (Vertesi and Ribes 2019). Influential work in this field includes amongst others Richard Rogers’ work on digital methods (2019; 2013) and Noortje Marres’ work on digital sociology (2017). An early collaboration between these two authors built on hyperlink tracing to identify and map issue publics (Marres and Rogers 2005; Rogers and Marres 2000). The relationship between issues, publics, and online networks is a recurring theme in digital STS. It connects closely to the seamless and blurry relationship between micro and macro contexts online (Latour et al. 2012).

In my own work, I combined several approaches into what can be summarized as ‘digital fieldwork’ (Lindgren 2019; Venturini and Rogers 2019). I used the opportunities of digital materials and methods to explore social practices with attention to both the technical and the social contexts that shape them. This included website and hyperlink analysis (paper 1), a combination of ethnographic lurking and complimentary computational methods (paper 2), and analyzing online controversies (paper 3).

In this chapter, I present reflections about my work with digital materials and methods. First, I explain concerns relating to the use of digital materials and field sites, followed by a discussion of issues relating to the use of digital methods. I conclude the chapter by elaborating on ethical issues surrounding online and social media research.

#### 3.1 Studying digital sites

The new modes of interaction enabled by digitalization produce a range of different materials and data that researchers can use to study social phenomena. They present both opportunities and challenges for social scientists. Two of the main concerns relate to the nature of data that is not produced with scientific inquiry in mind, and to the entanglement of media and societal effects. Furthermore, the transient and dynamic nature of the field sites poses methodological and ethical questions.

##### 3.1.1 Found and made data

Online sources present a wealth of data potentially available for research. However, they also present researchers with questions on the ethics of using these materials (discussed in more detail below) as well as the selection and interpretation of datasets. In the same way that research

methods are political, shaping the research object (Law 2004), data are not neutral or objective. Data, especially from social media contexts, are fraught with assumptions (Luka and Millette 2018).

Jensen (2012) distinguishes between data that is 'made' for research purposes and data that is 'found' and repurposed from other (often commercial) sources such as social media platforms. The wide availability of the latter makes it attractive for researchers in different fields. However, the data from these platforms is usually not created for research purposes. Therefore, it might be formatted differently than if a researcher had planned the data collection. Where scientists 'make' data, for example in surveys or experiments, they plan carefully to avoid or at least measure potential sources of bias or distortion. But 'found data' is at a higher risk of these issues going unnoticed. Especially with the allure of big data, researchers risk an assumption that they have collected data from a whole population. But this population is not necessarily representative of society. There likely are selection biases in which users are present on a given platform at all and how much they chose to contribute actively. Similarly, categorizations of data on platforms are designed for commercial or legal purposes rather than research interests. They might also incentivize users to provide false or incomplete information on categories such as gender, location, or age.

In my own work, I have made use of found data exclusively. One of the reasons I focused on more ethnographic approaches and qualitative understandings of my data through 'digital fieldwork' was to understand influences that shape the found data I have worked with. Since I have collected found data, I can only speculate about potential biases. From other research, I know that Reddit in general is dominated by male, younger, and US-based users (Gilbert 2020). Similarly, I know that highly educated participants tend to be overrepresented in climate activism with the new climate movements able to mobilize young people and especially women and girls (de Moor et al. 2020). I assume that the spaces I have observed skew along these lines, but just like data practices differ subtly between communities, participation might differ, too.

At a first glance, the lack of contextual demographic information in online spaces creates apparent 'global' or 'universal' participation. But at a closer look, participation is skewed, both in who can access the site, who does, and who becomes visible, and who chooses to become an active contributor. In the sense of 'ethnographic lurking' (Squirrell 2019), this is exactly how online spaces such as Reddit or the climate activist websites present themselves to users. By using only public materials from the respective sites, I take on the perspective of their users or audiences, studying not so much what the individual intentions, backgrounds, or contexts of the interactions are, but focusing on how they come across and work to shape the observed spaces overall. Paying close attention to social and technical contextual clues, I was able to recognize subtle differences that I have characterized as distinct localized data practices, even for groups that seemed similar at a first glance. Nevertheless, even this perspective can differ, for example with users in different locations or with different devices getting a different version of the page. I also observed Reddit users criticizing for example too much US-focused media coverage, and requiring that content should be labeled with geographic information. While both climate change and the pandemic are global issues, and online spaces can potentially be accessed by global audiences, it should be noted that the observed spaces mainly cater to and represent discussions of Global North audiences.

### 3.1.2 Media and societal effects

In online spaces, societal and media or technical effects converge. This presents researchers with questions on whether and how to untangle these two aspects and what exactly the collected data may represent.

For social scientists, the ubiquity of internet services means that online interactions increasingly are considered as a mirror (though perhaps with varying degrees of distortion) of societal phenomena. At the same time, there is a challenge in untangling what can be attributed to media effects or societal effects when working with such digital data. Practically, (Marres and Moats 2015) identify three common approaches to this question: A cautionary approach, removing the ‘noise’ of unwanted media effects or technical influences; an affirmative approach, specifically making use of media or technical effects for research purposes; and an empiricist approach, investigating empirically “which effects belong to media technologies, which to the issues, and which to both” (Marres and Moats 2015).

In my work, I am interested in the intertwined effects of data practices on the media side and informal science communication practices on the societal side. I follow the empiricist or symmetric approach suggested by Marres and Moats (2015) to consider both technical and societal factors in my research and how they interrelate. For example, in working with Reddit data, I observed both the technical affordances of the platform, and how they were used differently in the various subreddits. An example of this is the “flair” or tag that can be added to each content submission. While the affordance exists platform-wide and is used across Reddit (media effect), the system of which flairs can be chosen from is set up for each subreddit by the moderators, often in negotiation with users (social effect). My selected conceptual frameworks of data practices and platform dialectics mirror this approach in their attention to both technical affordances and social practices.

### 3.1.3 Transient and dynamic sites

Digital field sites are characterized by their transient and dynamic nature. Content changes over time and can be shown differently from user to user. Any data collection from digital field sites is only a snapshot of the site at that time, not representing how it might have changed over time, or how it continues to change.

For social media data, such as the data I collected from Reddit, the content and the order it is displayed in are continuously updated. Users see similar but different versions of the site depending on the time of their visit, even if it only happens minutes apart. Ranking algorithms and platform ecosystems affect the displayed content. They also change over time themselves, for example with changing options for sorting content on Reddit (solutioneering 2021).

And even the websites of XR and FFF I studied in paper 1 have changed both during and since my analysis, despite my focus on the more static content of both sites. Additionally, the hyperlinks investigated in papers 1 and 2 also connect to changing content. At the time of my analyses, some links had already broken, and more are likely to have broken since. Links to dynamic content, such as dashboards of coronavirus case numbers, look different than in the originally posted context even briefly later. I have made use of the Internet Archive Wayback Machine whenever possible to be attentive to changes over time, and to access websites that have become unavailable. For Reddit, I combined a data collection through the pushshift archive that includes even deleted submissions (Baumgartner et al. 2020) and an “ethnographic lurking” process (Squirrell 2019) of the site over the course of the pandemic. In this way, I have attempted to capture a process of development over time in the three observed coronavirus-related subreddits. I found activity in the subreddits to be unevenly distributed over time, leading me to focus on moments of controversy that receive platform-wide attention in paper 3.

How websites and especially social media platforms present themselves to the user can also be affected by browser settings, geographic location, and platform features to customize displayed

content. For Reddit, users can access the site through the starting page that merges the content of all subreddits, the subreddit page showing subreddit-specific submissions, or external links leading directly to a post with its comment thread. Users that create a profile can also opt to get a customized feed highlighting content from subreddits they ‘subscribed’ to. And users can change the default sorting order, for example to highlight new posts instead of the default order determined by upvotes in the last 24 hours.

Sites might look different to different visitors. The notice on Reddits’ starting page during the pandemic shown to me in Norway linked the website of the World Health Organization. However, archived versions on the Wayback Machine show the notice linking to the US Center for Disease Control and Prevention, indicating that US-based users saw this version. While I could not examine all possible ways of accessing the site, I have explored which affordances are more or less prominent for different users. One outcome from this has been the realization that the “flair” is one of the affordances visible for all ways of accessing a Reddit post. This makes it a signal of community context across the platform at large.

### 3.2 Using digital methods

Increased availability of computational power not only gives researchers access to new types and amounts of data. It also allows them to process empirical materials differently and with new or adapted methodological approaches. Following a realization that big data and social media data should not be left to STEM scientists and commercial data analysts, social scientists engaged critically with existing approaches and notions of big data. Eventually, attempts at codifying social science approaches to big data and social media research emerged. Several authors have given overviews and guidelines for working with computational methods in the social sciences. This includes for example the ‘Leiden Manifesto’ for bibliometrics (Hicks et al. 2015), a ‘reality check(list) for digital methods’ (Venturini et al. 2018), “critical questions for big data” (boyd and Crawford 2012) or a summary of ‘Ten simple rules for responsible big data research’ (Zook et al. 2017). They share emphases on reflexivity and attention to researchers’ and other actors’ involvement in shaping the data.

In the following sections, I give an overview of two issues relating to the use of digital methods for research in the social sciences: discussions on the use of virtual compared to natively digital methods, and questions on the distinctions and relationships between qualitative and quantitative research methods. Both relate to the bigger question of whether studying the digital requires new methods uniquely created for these contexts, or whether traditional methods should merely be adapted to fit new sites and topics of inquiry.

#### 3.2.1 Virtual vs natively digital

In his definition of digital methods, Richard Rogers (2019, 9) distinguishes between digitized data and natively digital data. Digitized data such as digital archives of historical books have previously been available to researchers in analogue formats and can be treated with established or slightly adapted research methods. Natively digital data such as hyperlinks or tweets on the other hand might enable or require different methodological innovations.

Additionally, Rogers differentiates natively digital methods (only made possible through the use of the digital) from digitized or virtual methods that adapt traditional research methods for use with digital data sources. The latter might for example include altmetrics (using natively digital data such



as tweets or hyperlinks but relying on established methods in bibliometrics), or adaptations of ethnographic approaches, such as trace ethnography (Geiger and Ribes 2011). Natively digital methods, on the other hand, involve “following the medium” (Rogers 2013) and using media affordances to create novel methodologies. In this approach, methods often develop together with digital tools. Examples include “seealsology” (“Seealsology” n.d.), visual network analysis with Gephi (Venturini, Jacomy, and Jensen 2019; Bastian, Heymann, and Jacomy 2009), and analysis of hyperlink networks with “Hyphe” (Jacomy et al. 2016) or the “issue crawler” (Marres and Rogers 2005). To Rogers (2019, 9), ‘digital methods’ include only natively digital methods used on natively digital materials while I use the term more broadly in this dissertation.

Despite experimenting with various natively digital methods, I found myself drawn back to elements of more virtual or digitized methods. My work is inspired by ethnographic lurking (Squirrell 2019), trace ethnography (Geiger and Ribes 2011) and digital controversy analysis (Marres 2007; 2015). At the same time, my approach did include elements of “following the medium” (Rogers 2013). An example of this was investigating what parts of the live site the data structure of Reddit maps onto and how it might be used to explore localized data practices. I summarize this mixed approach as ‘digital fieldwork’ (Lindgren 2019; Venturini and Rogers 2019). More detailed explanations of my methods for each empirical site can be found in each of the three papers.

### 3.2.2 Computational vs interpretative

Digital methods provoke questions about the distinction between qualitative and quantitative research approaches. At a first glance, computational methods seem to align with more quantitative research approaches, challenging qualitative research traditions in the social sciences and humanities. However, in attempting to balance these tensions, some researchers find that qualitative approaches might be particularly useful for large, complex, messy, or incomplete digital datasets. Traditions such as ethnographic observation or historical document analysis that have long dealt with real-world empirical data and its complexities can be fitting for digital contexts.

Some authors argue for abolishing the distinction between qualitative and quantitative methods altogether: With a background in sociology, Simon Lindgren argues for ‘hacking’ social science (2019), arguing that ‘digital fieldwork’ is more aligned with the immersive ethnographic approaches of anthropologists than with quantitative studies. He puts forth the idea of a reflexive “data/theory” that is simultaneously grounded in (sociological) theoretical frameworks and that considers exploratory and experimental approaches to data (Lindgren 2020). Lindgren laments that certain data science methods resemble a “data piñata” approach (“whacking data with a stick and hopefully some insights will come out”). At the same time, Lindgren acknowledges that the dynamic, messy, and complex nature of digital data lends itself to tinkering and exploratory or iterative approaches. He concludes that “a viable method for social analysis in the age of datafication must have the best of both worlds: the gung-ho debauchery of the data piñata approach, and the critically reflexive ethos and theoretical sensitivity of sociology” (Lindgren 2020, 175). In line with Lindgren, I think that using both exploratory and reflexive moments, and a combination of computational and interpretative moments in the analysis can provide new insights that neither approach can produce by itself. In choosing my empirical material and analyzing my data, I have worked in exploratory and iterative ways, experimenting with a variety of approaches before landing on the ones presented in this dissertation.

An alternative to rejecting the distinction of qualitative and quantitative methods is combining both worlds. Anders Munk (2019) offers a descriptions of four styles of combined “quali-quantitative analysis”. The complementary style uses both side by side to examine the same object of interest.

Single-level analysis makes use of the seamless movement between micro and macro scales that digital data can offer. The curative style uses quantitative methods to select data for qualitative analysis. And finally, algorithmic sensemaking uses computational algorithms to find patterns in data that researchers can then study in more detail. I have experimented with methods of algorithmic sensemaking during my research; however, the final results presented in the papers are closer aligned with a complementary approach and a curative approach.

### 3.2.3 Digital fieldwork

As websites and platforms change, the tools to capture and work with their data need to be maintained and updated to reflect the changes as well. With tools created by researchers or developers as side projects, rather than for commercial interest, it is more a rule than an exception that tools quickly become obsolete or unavailable.

One reason for researchers to rely on tinkering and building their own tools is the risk of not knowing or understanding how ready-built solutions process data and shape outcomes without the researchers' knowledge. Tools for digital social science research contain an inherent "black-box-tradeoff" (Jacomy and Munk 2022) in that tool design can either prompt reflection and critical thinking (resulting in complex tools) or emphasize ease of use (but risk black-boxing decision-making processes). In my work, I opted for more manual approaches such as keyword searches or simple filtering criteria, alongside ethnographic observations, over more blackboxed tools for representing or analyzing my collected data.

All methods of data collection have different drawbacks for preserving context of online sites. Besides ethnographic observations and manual notetaking, three common approaches include screenshotting, web scraping, and API access. All of them only capture static snapshots of sites at a certain time, posing a challenge for observing fast-changing online contexts.

Web scraping uses software to extract human-readable data from a website. It often focuses on text content and makes it difficult to preserve the original layout of a site. But since it focuses on human-readable data, web scraping can be valuable to collect the content that a user would encounter on the site, while still allowing some degree of computational processing of the data later on. My extraction of hyperlinks for the climate activist websites falls in this category. Since I was only interested in the use of hyperlinks, this approach was suitable here; it was supplemented with observations of the site and comparisons of versions in the Internet Archive Wayback Machine, also based on scraping by automated crawlers.

APIs (application programming interfaces) allow communication between software, for example to access data from platforms systematically using own or third-party software applications. The structured data resulting from API access is well-suited for further computational processing. It allows for simple filtering, for example to systematically find all posts mentioning a certain keyword. For paper 2, I collected data via API access. This also allowed me to go back in time, collecting posts from the coronavirus subreddits in the first few months of 2020, before I started my ethnographic observation. However, the structured data extracted through the API does not have the visual format that users encounter on the site. Where users would encounter only a few posts at a time, within the website framing, and accompanied by visuals, the API access presented me with a well-structured database of posts limited to text content only.

Screenshotting has the advantage of preserving original visual context from the perspective of one user at a certain time. It creates a static image that is not machine-readable, making it difficult to for example search for keywords, follow hyperlinks, or access meta-data. In paper 3, I used images of the

banner shown on Reddit during the pandemic and of a moderator post on flairs to show the original visual representation as it would have been visible to users.

Frequent changes and breakdowns of tools and strategies for accessing or analyzing data mean that even recent scientific publications, having gone through a slow academic publication process, may contain outdated approaches by the time they reach readers. This will be true for my own publications, with data collection from Reddit not possible with the same tools anymore.

The Python Pushshift.io API Wrapper (PSAW) that I used as part of the code provided in the “Introduction to Cultural Analytics & Python” textbook (Walsh 2021) is no longer maintained, with the developer suggesting the alternative Pushshift Multithread API Wrapper (PMAW) on the projects’ GitHub repository instead. The pushshift dataset itself (Baumgartner et al. 2020), that I used to collect data in late 2021, became partially unavailable in 2022, and was eventually disrupted due to changes in the Reddit API in 2023.

This limitation on API access is paralleled by limitations on other platforms. Many researchers were affected by Facebook’s tighter access control over Facebook data in the wake of the Cambridge Analytica scandal (Venturini and Rogers 2019). Twitter data, previously overrepresented in social media research due to easy accessibility, became restricted to paying users in 2023 (Calma 2023). And larger technical developments affect tools as well. The “issue crawler” (Marres and Rogers 2005) struggles to work with modern website layouts. “Hyphe” (Jacomy et al. 2016) offers an updated approach for a crawler. However, all crawler-based methods encounter problems when following links to sites that require logins or payments.

Summarizing several researchers’ experiences with API breakdowns, Perriam et al. (2019) give three possible ways out of dependency on platform access in “post API research”. These include “interface methods” (Marres and Gerlitz 2016), a return to webscraping (Freelon 2018), and a call for officially established public research APIs (Bruns 2018).

If I wanted to repeat my research project, I would have to chose different approaches to data collection, due to the lack of Reddit API access as of 2023. Although content can still be found in other archiving efforts, such as the Wayback Machine, the systematic search and data collection that pushshift allowed is no longer feasible. Developments like these have been argued to make a case for more qualitative “digital fieldwork” instead of relying on fragile API access (Venturini and Rogers 2019). They also highlight the digital as a messy and changing field site, rather than an organized, let alone complete or reliable archive of social interactions.

### 3.3 Internet research ethics

Working with digital data, especially social media data, presents ethical challenges. Researchers find themselves facing “a contradiction between big data positivism and research ethics fundamentalism” (Fuchs 2017). In digital research, an initial enthusiasm for new opportunities was followed by the realization that publicly available data could be more easily de-anonymized. Alongside developing digital research practices, discussions about the ethics of using digital data and methods are evolving, too. At the same time, large platforms increasingly restricted access to their data as they realized both the financial value and potential harms of amassed datasets.

Following first studies on social media platforms, researchers recognized that public availability alone was not a good enough argument to use for example Facebook data (Zimmer 2010). Researchers were not alone in this realization. Countless organizations discovered that presumably innocuous or anonymized data could be linked back to individuals, especially in combination with other datasets.

When Netflix published viewer preferences for a competition to develop recommendation algorithms, individual users could be identified by cross-comparison with data from the Internet Movie Database (Narayanan and Shmatikov 2006). AOL search queries gave detailed insights into users' lives, as shown in a mini documentary on "the heartbreaking search history of user #711391" (Engelberts and Plug 2009). More recently, a heatmap of data from the fitness tracker Strava was found to reveal the location of US army bases (Metzger et al. 2021). With the increasing availability of both datasets and computational power, identification of particular user groups as well as de-anonymization of individuals is only becoming easier. This makes it crucial to consider implications of collecting, combining, and publishing social media data.

At the same time, there is criticism that companies like Facebook are engaging in large-scale data analysis and user manipulation for commercial purposes, while researchers are excluded from working with such data for scientific purposes (Hård af Segerstad et al. 2017). The participants of the Facebook study criticized by Zimmer (2010) do not seem to have been individually "identified and in some way harmed through outing" (Rogers 2018). At the same time, Rogers points out that consent might not have been enough to protect them from harm, since participants might be unable to predict potential risks. Therefore, it is important to understand the expectations users had when sharing content (NESH 2019). Several dimensions of context can come into play in where and how social media data was shared to determine how it can be used in research (Özkula 2019).

The Association of Internet Researchers (AoIR) has developed guidelines for internet research first published in 2002 (Charles Ess and the AoIR ethics working committee 2002), updated in 2012 (Markham and Buchanan 2012) and again in 2020 (franzke et al. 2020). These try to take the different concerns related to social media research into account. Nevertheless, much research on social media still is conducted without accounting for ethical considerations. Only 16 of 382 examined studies using Twitter data mentioned ethical concerns, five of those merely indicating that ethical review was not needed due to the public nature of Tweets (Proferes and Zimmer 2014). Similarly, 101 of 727 examined studies on Reddit mentioned ethics, in most cases noting an exemption from ethics review for the use of Reddit data, while only interviews or surveys with users of the platform fell under the more traditional ethical review processes (Proferes et al. 2021).

In Norway, my research falls under the review of, and has received permission from, the Norwegian Centre for Research Data (NSD) concerning the collection, treatment, and storage of data for my research. Furthermore, I have taken the AoIR recommendations into account in addition to Norwegian recommendations for internet research ethics (NESH 2019), making sure to consider ethical implications for my work overall and especially for the two papers that work with Reddit data. For Reddit, expectations of privacy, along with subreddit rules for what can be shared in the first place, might differ between subreddits (Proferes et al. 2021; Fiesler et al. 2018). In the following sections, I elaborate on ethical issues I have encountered as part of my work.

### 3.3.1 Public, personal, and sensitive data

A summary of rules for responsible big data research reminds scholars that "data are people" (Zook et al. 2017). The connection between data collected online and the individuals producing them is not always clearly visible but should be accounted for. The European General Data Protection Regulation (GDPR 2016) distinguishes between personal data (data that can be tied to an individual person) and sensitive data or "special categories of personal data" (such as political opinions, health data, or religious beliefs). These can be helpful categories to think about risk from collection, analysis and publication of social media data.

I have not considered the data collected from climate activists' websites in paper 1 as personal data. Although the Extinction Rebellion page on scientific information mentions an author responsible for the content, and the Fridays for Future website might have one or several individuals filling the site with content, the pages publicly speak for the organizations in their entirety. I have treated them as public information, like for example press briefings might be. The same applies for the rules of subreddits and moderator or staff statements collected for paper 3: even if posted from individual accounts, they reflect the overall intentions and agreements of the community, rather than an individual's views. These also can be argued to fall under a "reasonable expectation of publicity" (NESH 2019) due to the public-facing roles of these particular user accounts.

However, much of the data collected from Reddit for papers 2 and 3, such as usernames tied to posts must be considered 'personal data' since it can be linked back to individuals. At the very least, the username is connected to a pseudonymous Reddit user account. Depending on the username, the content of the post, and the user's activities on the platform overall, it may be more or less difficult to identify an individual person behind the account. There is also a potential risk that Reddit users could reveal sensitive personal information, such as religion, ethnicity, political affiliation, or health information. There could be photographs of users posted to the platform; or users might lie about their age to get access to the platform and hence the dataset may contain information by or about minors. During the pandemic, the risk of encountering sensitive data might even have increased, as social media users were observed to change their self-disclosure behavior, for example with regards to health information (Nabity-Grover, Cheung, and Thatcher 2020; 2022).

To mitigate the above-mentioned risks in my work with Reddit data, I have only collected submissions (not comments under each submission). Furthermore, the subreddits I selected for data collection only allow media links to secondary sources, not "original content" produced by individual users, thus further limiting the risk of collecting sensitive information. I have therefore treated the collected Reddit submissions in accordance with NSD and University of Oslo guidelines for storing and processing personal (but not sensitive) data. Although I have encountered sensitive information as part of the ethnographic lurking process, I have neither recorded, nor used such data in further analysis.

### 3.3.2 User privacy

Anonymization of data and obtaining consent from the people involved in the research are among the standard procedures to ensure ethical research processes. However, with publicly available digital data, both are difficult, if not entirely unfeasible. Quoting from publicly available digital materials means that anyone can re-identify user accounts linked to this quote with the help of a search engine. And collecting data from social media involves large numbers of users. Many of them might only contribute a few data points each to the datasets and move between different platforms or communities. This makes it unrealistic to obtain consent before data collection, or even to reliably notify users of the data collection after the fact. With my use of the pushshift data (Baumgartner et al. 2020), I additionally accessed data that might already have been deleted from the platform. Although users can ask for deletion from pushshift, they have to be aware that the data is even stored there (Proferes et al. 2021).

Even though I see no possible harm in the data that I have collected, and much of it is still accessible on Reddit, I have opted to be cautious in the publication of my results. Since users had no way of knowing they were included in my data collection, and no way of withdrawing from the research, I refrain from using identifiable quotes. In paper 2, I only have quoted the headlines of posts (which are all headlines from secondary sources and therefore not linked to any individuals). For both Reddit

papers, I did not analyze or point out any individuals' posting behavior, nor attribute actions to individual accounts (with the exception of moderators and Reddit staff). In my data collection, I originally included a fourth, smaller subreddit. However, analysis of the submissions revealed that most of the content in the subreddit was contributed by its founder and moderator only. Despite being a public-facing subreddit, it was excluded from publications to avoid pointing out behavior of one individual moderator. In paper 3, I have quoted verbatim from posts by moderators of large subreddits (who act as a team of moderators, and speak as such, or even act as representatives of the entire community) and by Reddit staff who act as public figures. The same applies to the content on the XR and FFF websites examined in paper 1. Since the moderators or website admins are a small group, a risk remains that quotes could be linked back to accounts. I assume a "reasonable expectations of publicity" (NESH 2019) in this case. For the posts of other users in paper 3, I followed the same strategy as Marsh (2018) and used paraphrased or aggregated quotes marked in 'single quotes' for users not having a moderator or staff role.

### 3.3.3 Sharing back results

As Proferes et al. (2021) point out, another aspect of social media research ethics is the sharing back of results. For Reddit in particular, they observed that research using Reddit data tends to make its way onto the platform, even if it is not posted there by researchers themselves. This indicates an interest of the platform users to learn about such research. An analysis of interactions in the *r/science* subreddit suggests that open access articles are helpful for public engagement on Reddit. Researchers observed that "when original research articles were accessible without fee, comments were more engaged and subject-matter-relevant" (Pflugfelder and Mahmou-Werndli 2021).

Following Norwegian regulations, all my publications will be made available for open access, removing at least one barrier for the research to be accessible to the communities I studied. I plan to share back results after the Reddit articles have undergone blind peer review and been published.

## 4 Summary of the articles

This dissertation answers to calls for “making visible the ‘behind-the-scenes’ actants” in science communication (Edwards and Ziegler 2022) and for research on “alternative science communicators” (Faehnrich, Riedlinger, and Weitkamp 2020). It consists of three single-authored articles illuminating several aspects of informal science communication in online contexts. All three articles build on a combination of Science and Technology Studies (STS), Internet Research (IR), and Science Communication Research (SCR). Table 2 gives an overview of the three articles and their findings and contributions.

<b>Paper</b>	<b>1: Experts, influencers, and amplifiers – Exploring climate movements’ hyperlinking practices</b>	<b>2: A tale of three subreddits – Community data practices shaping engagement with COVID-19 on Reddit</b>	<b>3: Moderating an infodemic – Platform dialectics in coronavirus-related knowing spaces on Reddit</b>
<b>Topic</b>	Climate activists acting as (alternative) science communicators online	Online communities’ localized social practices tied to technical affordances	Content moderators shaping coronavirus-related online communities
<b>Empirical context (and what it is an example of)</b>	Websites of Fridays for Future (FFF) and Extinction rebellion (XR) (new European climate activist movements engaging online)	Three information subreddits on COVID-19 (closely related but different online communities, distributed moderation)	Moderation practices and controversies related to COVID-19 on Reddit (relationships between platform, moderators, and users)
<b>Methods and materials</b>	Website and hyperlink analysis	Ethnographic lurking, analysis of reddit submissions and their metrics	Ethnographic lurking, controversy analysis, analysis of reddit submissions and subreddit rules
<b>Findings</b>	FFF and XR use their websites in slightly different ways: FFF refer to ‘influencers’ and popular science formats, while XR is academically oriented. But both emphasize their ties to science and especially climate science.	Similar subreddits have distinct data practices that contribute to different contextualization of online content. Collective use of platform affordances shapes and maintains these differences and can also make them visible to researchers.	Moderators are important gatekeepers shaping online science communication. At the same time, they must relate to both user demands and platform restrictions. These platform dialectics usually occur within subreddits, but can spill over across the platform.
<b>Contributions</b>	SCR: different styles of activists as alternative science communicators	IR: community data practices relating to (sub)communities’ micro norms SCR and STS: data practices as actants in online SCR	STS and SCR: moderation controversies and two forms of platform dialectics IR: content moderation during the pandemic

Table 2 Overview of the three papers

For all three papers, I have investigated “knowing spaces” (Law 2016) related to conversations about global crises. In my selection of spaces, I focused on informal engagement with science in science-

oriented or “sciencephile” (M. S. Schäfer et al. 2018) sites and communities. My work builds on existing connections between STS, IR, and SCR, such as the understanding of science communication *as culture* (Horst and Davies 2021), and attention to *data practices* (Weltevrede and Borra 2016), i.e., the social practices surrounding the use of technical affordances.

Paper 1 explores how climate activists can be considered science communicators in their practice of providing hyperlinks on their websites. This article contributes to an ongoing SCR discussion about environmental NGOs and activists acting as science communicators (Yearley 2008; Maesele 2009; Faehnrich 2018; Faehnrich, Riedlinger, and Weitkamp 2020; Gregory 2020; Windfeldt 2020; Soßdorf and Burgi 2022). The paper expands the existing literature by examining online contexts and describing how activists recontextualize professional science communication. Although I did not explicitly use the concept of *data practices* here, the observed sites could be considered under this conceptual lens: While both groups make use of the affordance of hyperlinking, their individual practices enact slightly different norms or ideals for using this affordance. Despite the complete openness of a website in what hyperlinks can be used for, the two groups show two main practices of hyperlinking. Fridays for Future mainly uses hyperlinks to provide further resources for information in the form of a link list. And Extinction Rebellion emulates an academic article format using hyperlinks as references to sources of information. Connected to these practices, Fridays for Future links to more popular science and traditional news formats, whereas Extinction Rebellion refers to academic publications.

In papers 2 and 3 I focused on the platform Reddit and the coronavirus pandemic. The platform can be understood as “an assemblage of over one million online communities” (Chandrasekharan et al. 2018). These communities or “subreddits” develop distinct norms and rules for what can or cannot be submitted in each space (Fiesler et al. 2018). Unlike the sweeping “industrial” approach to content moderation seen on other large platforms such as YouTube or Facebook, rules on Reddit are created and enforced by volunteer moderators for each individual subreddit (Caplan 2018). Since THE negotiation of moderation practices happens in each subreddit, the practices and conflicts related to content moderation can become transparent to users of the platform, and leave traces that can be used for research.

During the pandemic, I observed how three subreddits emerged at the same time, sharing the ambition of providing reliable information about the virus. The subreddits developed into three distinct communities, with the “r/coronavirus” subreddit focusing on traditional news sources, “r/covid19” emphasizing scientific information, and “r/china\_flu” providing a space for critical and skeptical engagement. In paper 2 I studied the contribution of collective data practices to shaping these distinct spaces, and in paper 3 I focused on interactions around the subreddit moderators.

Paper 2 examines the data practices, or the collective use of affordances, in each subreddit. With its attention to mechanisms in online communities, this paper emphasizes ties to internet- and social media research. In this article, I studied submissions to the three different subreddits. I combined the concept of platform-specific data practices (Weltevrede and Borra 2016) with the observations of community-specific norms and rules (Chandrasekharan et al. 2018). I focused on five practices related to platform affordances that stood out as main drivers of subreddit differences: Submissions of new content, crossposting of content between different subreddits, commenting on submissions, voting to influence the order that content appears on the page, and the use of “flairs” (tags showing categorization or evaluation in subreddit-specific context). This paper shows that the concept of data practices can be useful to examine not only differences between platforms, but also differences between communities on the same platform, allowing researchers to tease out contextual



differences of online knowing spaces. I suggest the notion of “community data practices” to describe differences in use of technical affordances within the same platform.

Paper 3 investigates moderators and moderation practices as important gatekeepers of online science communication. Taking moderation tensions and controversies as starting points, this paper is the most STS-oriented of the three articles. Following interactions in the three coronavirus-related subreddits, I noticed that highly visible conflicts in the communities were not so much centered around scientific information about the virus, but rather around content moderation of the topic. Within subreddits, moderators acting as community managers (Gillespie 2018) have considerable power to shape the community. At the same time, users comment upon moderator decisions, voicing criticism, approval, and suggestions for changes. Building on the concept of platform dialectics (Squirrell 2019), I examined moderation tools and strategies such as rules or frequently asked questions used within subreddits, as well as three moderation conflicts that spilled over into other subreddits.

First, I followed the development of distinct subreddits in the first three months of 2020, leading to competing subreddits and users commenting on what types of content belong where, as well as disputes about appropriate levels of content moderation. Second, I observed a brief episode in March 2021, where a disagreement between moderators of r/coronavirus briefly threatens to rearrange the established practices of which content belongs in which subreddit. And finally, I investigated an organized protest against coronavirus-related misinformation that reached across the platform in August 2021, prompting interventions by platform management. In these three examples, moderators first work with selected community members and against others to establish subreddit rules, then take communities hostage in an internal dispute, and finally act as spokespersons of said communities, showing the power but also difficult interactions they have in relation to users, other moderators, and Reddit management. I argue that the dialectics both within communities as well as across communities on the platform are important contributors in shaping the knowing spaces of informal conversations around science.

While papers 1 and 2 share an investigation of hyperlinking practices and use of sources, papers 2 and 3 share Reddit and the pandemic as field site and context. To investigate the actants in these online informal science communication contexts, I have opted to study the digital traces that are visible to users of these sites and that users relate to and interact with.

In all observed contexts, hyperlinks connect to scientific information in different formats. But what is shared and how it is recontextualized is shaped by the features of the platform and collective interactions as well as volunteer moderators acting as community managers (on Reddit) or by administrators choosing how to use links (on the websites). Focusing on these data practices reveals differences that allow to take context into account for research in each of these knowing spaces. For example, while most of the investigated spaces can be called “sciencephile” and share almost idealized imagery of how science works, the users and moderators of r/china\_flu create encourage more critical and skeptical engagement – even though they refer to similar sources and employ the same platform mechanisms to do so.

With my papers, I want to highlight informal online engagement with science and how it is mediated by social influences. While some of the involved users and moderators might have scientific backgrounds, and some rules or data practices pay homage to scientific research (for example highlighting academic reports as reliable sources), these spaces are not built as formal science communication efforts. Rather, they build on users’ self-selection and identification with each space (Marsh 2020). This create distinct communities or knowing spaces with distinct norms and practices.

Both practitioners and researchers in science communication can benefit from attention to these local contexts, which can be identified and characterized using approaches from STS and IR.



## 5 Discussion

This thesis is a contribution in both showing the importance of considering local contexts for science communication research (SCR), and in showing how concepts building on Science and Technology Studies (STS) and internet research (IR) can be used to characterize such contexts. In online science communication, attention to actants that mediate conversations around science highlights the relevance of informal science communication efforts, their ties to formal science communication, and their diversity across different online communities and contexts.

I understand science communication broadly as “conversations around science” (Bucchi and Trench 2021). This creates fuzzy boundaries of what can be considered science communication. Although methodologically challenging, this understanding is fitting for rapidly changing online landscapes and an understanding of science communication as culture (Horst and Davies 2021; Davies et al. 2019; Davies and Horst 2016). In online conversations around science, boundaries between public and non-public, scientific and non-scientific, technical and social influences become increasingly blurred.

Building on scholarship from STS, internet research, and science communication, I asked: In science-oriented online contexts relating to global crises, what traces are visible of ‘behind-the-scenes actants’ shaping conversations about science? Investigating “knowing spaces” (Law 2016) related to climate change and COVID-19, I have found conversations around science mediated by informal actors, by collective activities and community dialectics, and by data practices that can characterize variations between communities.

My work responds to calls for research on intermediaries shaping science communication (Edwards & Ziegler, 2022) and alternative actors in science communication (Faehnrich et al., 2020). It highlights that people in online contexts are not passively exposed to algorithms, nor to professional science communication, but instead engage and interact as communities. They individually and collectively shape what becomes highly visible, negotiate what is allowed in a particular space, and relate to a complex network of technological and social influences. I have found actors moving through different forms and formats of informal engagement, localized data practices shaping context on a community basis, and socio-technical dynamics on platforms highlighting both the roles of individuals as well as the collectives and the technical features they interact with.

### 5.1 Informal knowing spaces

Science communication is simultaneously influenced by increased professionalization and by increased informality (Bucchi & Trench, 2021). In this thesis, I have focused on the latter, investigating contexts where scientists and professional science communicators only play secondary or indirect roles. As scientists and non-scientists act in diverse online contexts, the categories become blurry between scientific communication among scholars, and public science communication or popularization involving wider audiences. This is especially relevant in informal contexts where contributions of professional science communicators or scientists stand side-by-side with those of others, and where various actors can take on roles of science communicators.

With research focused on either professional science communication, or content moderation and misinformation, informal and alternative actors shaping the conversation around science risk being overlooked. I argue that science communication research and practice can benefit from attention to informal activities.

Several types of “knowing spaces” with distinct “webs of practice” (Law 2016) exist that relate closely to academic practices, but nevertheless follow own ideals and practices. I recognized elements of the

interactions surrounding climate activism and discussions of COVID-19 on Reddit in several scholarly debates. Taken together, they can build a basis for discussing informal conversations around science.

The categorization of media users identifying “sciencephile” engagement (M. S. Schäfer et al. 2018) and a description of “ad-hoc” information seekers (Daume and Galaz 2016) informed my initial understanding of informal engagement with science. However, after encountering the discussion on activists as alternative science communicators (Faehnrich, Riedlinger, and Weitkamp 2020), my first paper developed in that direction. Later, I noticed that this engagement with science stands in interesting contrast to STS work on concerned groups (Callon and Rabeharisoa 2008). While concerned groups are portrayed as antagonistic to academic science, the climate activists I followed in my research showed close alignment with and idealized discussions of science. Working with Reddit data in paper 2, I returned to the contrasting categorization of “critically interested” and “sciencephile” engagement that I observed on the platform.

Combining and building on these existing descriptions, I arrive at five influential roles in informal science communication. Table 3 shows an overview of the five roles and how they map onto both my own and other researchers’ work. The nature of online communication means that users can switch between these roles or even take them on simultaneously, so the categories should not be taken as mutually exclusive or strictly delineated. Nevertheless, I have found them helpful to examine the different contexts that informal science communication can be part of and to synthesize my work across the three papers. Moving from most to least engaged in scientific knowledge production, and from more involved to more casual engagement with scientific content, I present the characteristics of these roles in detail below.

<b>Group</b>	<b>Description</b>	<b>Examples</b>	<b>Own Examples</b>
<b>Concerned groups</b>	Intervention in knowledge building and dissemination mainly out of personal necessity	Patient associations (Callon & Rabeharisoa, 2008) Individual patients as expert mediators (Egher, 2019)	Subreddit moderators organizing against misinformation (paper 3)
<b>Activists</b>	Intervention in knowledge dissemination or use mainly for political purposes	Environmental groups (Yearley, 2008) Climate activists (Faehnrich et al., 2020)	XR & FFF websites (paper 1)
<b>Sciencephiles</b>	Interest in science as part of individual and community identity	“science lovers” (Marsh, 2020) “citizen science communicators” (Yang 2021)	r/coronavirus and r/covid19 subreddits (papers 2, 3)
<b>Skeptics</b>	Emphasis on critical thinking and own experience	Dietary advice (Gunnarsson & Elam, 2012) Self-improvement communities (Squirrell, 2020)	r/china_flu subreddit (papers 2, 3)
<b>Casual information seekers</b>	Ad-hoc engagement with science out of personal curiosity or for entertainment	Species identification on Twitter (Daume and Galaz 2016)	Spillovers of the coronavirus topic into other subreddits (paper 3)

Table 3 Overview of roles in informal science communication

**Concerned groups** turn to online contexts to seek resources and voice their experiences about an issue they are personally afflicted by. I base this category on Callon's observations on co-construction of knowledge (Callon, 1999) and concerned groups (Callon and Rabearisoa 2008). These groups consist mainly of individuals personally affected by an issue and are often described in the context of medical treatments.

When patients and their relatives turn to online resources and support networks, they engage with scientific information about the issue that afflicts them out of a practical and personal need. Patients can develop significant interactional expertise when talking about their disease online (Egher, 2019). The relationship with science can be antagonistic in this case, with suggestions that an adversarial dynamic might even be fruitful for improved treatment (Ko, 2016).

Collectively organized concerned groups (such as patient networks) may shift from fulfilling direct personal needs for information or support to taking more proactive stances, moving towards activism. Encountering incomplete or unsatisfying answers to their personal questions, they may start to intervene in knowledge building about the issue with the expertise they gain from their own experiences. Concerned groups might demand funding or political action to close knowledge gaps, urge decision-makers to help afflicted groups, or call for changes in research or treatment regimes. Many of the health activist groups described in the literature (e.g. Epstein 1995) seem to operate out of an opposition to or dissatisfaction with academic science (even if they gain influence and intervene in scientific knowledge production). Similarly, local communities can act as concerned groups in the context of pollution, questioning scientific evaluation of radiation not matching local experiences (Wynne 1989), or establishing own measurements of pollutants in citizen science efforts (Ottinger 2010).

Concerned groups have not been the focus of my own work. But the organized protest against misinformation staged by subreddit moderators (speaking for Reddit users more generally) could be understood in this framing. Although not intervening in scientific knowledge building, the protest presents an intervention in knowledge building and dissemination activities on Reddit. Community managers who experience the problem of misinformation personally in their role as content moderators are speaking from their role and experience, representing the communities but also seeing the problem in their own work.

However, in my observations of climate activists, despite the political ambitions, I observed a strong contrast in the engagement with science and knowledge building. The activist embrace of scientific knowledge I have seen in the XR and FFF websites is noticeably different from the personal and often adversarial stance towards science found in the literature around concerned groups. Moreover, the notion of "concerned" or "affected" groups with differentiated, relevant expertise, becoming co-producers of scientific knowledge, is challenging in the context of global crises such as climate change or pandemics. Although it might work in specific local contexts of climate change mitigation efforts, the framing of climate activism as concerned groups risks a return to the unhelpful undifferentiated "publics" of earlier deficit models of science communication, and an implication of adversarial dynamics associated with earlier work on concerned groups.

**Activists**, even more than concerned groups acting on personal necessity, engage with science for political purposes. The climate activists observed in my paper 1 do not act out of a direct personal or local concern but refer to global threats. Furthermore, rather than trying to change knowledge production intervene in local knowledge building processes, these groups are focusing on getting decisionmakers to act on existing knowledge to address global issues. Most of the concerned groups described in the literature act in opposition to academic science, or with ambitions to change or improve knowledge building processes. However, the climate movements align closely with

academic science (and scientists align with the movement, for example in the scientists for future movement). Rather than intervening in the process of knowledge building, activists engage with science to promote established scientific knowledge and demand that policymakers act in accordance with it.

Activists learn about and share their understandings of scientific knowledge in order to support their cause. With my first paper on the practices of Extinction Rebellion and Fridays for Future, I was able to contribute to the work considering activists as ‘alternative science communicators’ (Faehnrich et al., 2020). Previous examples include observations of environmental groups engaging with science (Yearley 2008). Further research has also picked up on the “strategic use” of scientific knowledge by FFF to mobilize activists (Soßdorf and Burgi 2022).

At the same time as activists promote scientific research, researchers can also align with activism. Researchers themselves might choose to take a more activist stance, especially if their research ties into global and societal issues. Considering researchers as unaffected neutral observers is questionable to begin with, but particularly challenging when dealing with questions such as climate change, women’s rights, pandemic restrictions, or democratic decision-making processes that necessarily affect researchers themselves. Similarly, organizations can be both part of the scientific field as well as science communicators, not necessarily opposing either political decisions, nor scientific knowledge building, but choosing different sides in different contexts (Windfeldt 2020).

While overlapping with the idea of concerned groups, activists in groups such as XR or FFF may organize not out of a pragmatic personal need but on more normative grounds, demanding local action to address global issues. The two groups I have observed as part of my work here also share sciencephile characteristics (see below) in their at times idealized notion of “the science” being a core point of identification and claimed starting point for political action. They also share the sciencephile characteristic of intervening in knowledge use or dissemination, rather than knowledge production.

**Sciencephiles** are highly interested in scientific content, acting out of personal curiosity, rather than personal information needs or political intentions. The term “sciencephile” stems from an analysis of media use in Switzerland (M. S. Schäfer et al. 2018). Under other terms, similar groups have been identified elsewhere. In a Chinese context, “citizen science communicators” were found to take on science communication roles without formal science backgrounds (Yang 2021). Self-proclaimed “science lovers” on Facebook were observed to take on interest in science as social identity (Marsh 2020) in similar ways as users in “online non-professional discussions around science” on other forums (Marsh 2018).

These groups are only loosely organized and may or may not be scientists or science communicators in their professional lives. Their informal engagement with science is linked to personal curiosity and identity. Most of them have a generic interest in ‘Science’ unlike more differentiated communities such as bird watchers or participants in citizen science projects. Identity work (Davies et al., 2019; Davies & Horst, 2016; Marsh, 2020) drives the engagement with science in this context in particular.

For example, in the material I have collected from Reddit, it is not usually visible whether a user has an academic background or any other expertise relating to the issue they are commenting on. In some cases, users explain their claims to expertise, but in most cases there is no direct contextual information about users submitting content to the coronavirus subreddits. Both the r/coronavirus and especially the r/covid19 subreddit can be characterized as sciencephile in their strong links to and high trust in academic science. Furthermore, the climate activists’ websites also indicate

sciencephile characteristics in that they idealize scientific knowledge production and retain strong ties to academia.

**Skeptics** engage with science more critically. Marsh (2018) adds a “Skeptics” online forum to his examination of non-professional online discussions around science, noting the users’ critical but nevertheless close connections with scientific knowledge production. A similar group of “critically interested users” also occurs alongside sciencephiles in Swiss media use (M. S. Schäfer et al. 2018). Besides an emphasis on critical thinking, skeptical groups can also emphasize own experience, for example in non-scientific knowledge building communities focusing on self-improvement (Squirrell 2020). Such engagement can even capture larger public debates, as for example in the context of dietary advice in Sweden (Gunnarsson and Elam 2012). Deviating from established academic science, the line distinguishing skeptic content from pseudoscience and mis- or disinformation is blurry.

In my own observations, the r/china\_flu subreddit can be considered an example of skeptical engagement. Using similar sources as the more sciencephile r/coronavirus, the engagement in the more critical subreddit nevertheless focused on skeptical interpretations and criticisms of the content. Although questionable content is present in these communities (sometimes marked as such), they have similar ambitions as the more sciencephile communities in providing reliable information as well as room for discussion, and differ from later banned subreddits rejecting scientific content entirely.

**Casual information seekers** also play an important role in informal engagement. Becoming even less formal than what I have explored as the main part of this thesis, instead of turning to dedicated communities, users of social media platforms can also turn to their personal networks on these sites, asking for help or information. This has been described as ad-hoc or embryonic citizen science communities in the context of species identification on Twitter (Daume & Galaz, 2016).

In the context of Reddit, communities define themselves much more explicitly than on Twitter. Hence, reliance on personal or ad-hoc networks is less observable here than other social media platforms. Nevertheless, in global crises, topics are difficult to contain in dedicated communities. Establishing r/coronavirus as an official subreddit to discuss the pandemic might have limited ad-hoc discussions in other subreddits, but existing communities on Reddit, for example language- or region-based subreddits, still had to address questions of coronavirus (mis)information (Rohden, 2022). New subreddits on the topic proliferated to build communities around particular information needs. And users flocking to the coronavirus subreddits that I have observed also commented upon other subreddits’ handling of the topic (as discussed in paper 3).

Further media uses in relation to science identified by Schäfer et al. (2018) include those of passive supporters or disinterested. While these could complete the categories of informal engagement presented here, they have not been part of my observations, and are therefore not addressed at this point.

These five types of communities or knowing spaces presented here imply different knowledge building practices, hierarchies, legitimacies, and data practices. They are also collectively enacted. Finally, despite different motivations, and interventions in different aspects of knowledge building and dissemination processes, all of the above mentioned groups act as mediators of science communication. Most of them engage with scientific content at a significant level (whether to criticize or to amplify) despite not necessarily having formal backgrounds in science or science communication. While rarely producing entirely new content, they play a role in translating, curating, and especially in sharing and spreading existing science communication efforts. Both practitioners



and researchers in science communication would do well to pay attention to the collective mediation of scientific knowledge through various informal communities online.

In the context of global challenges and expectations of science to deliver answers and solutions, informal engagement with science is likely to increase as scientific knowledge permeates day-to-day decision-making. At the same time, politicization increases, for example in appeals to personal responsibility for climate mitigation efforts or carbon footprints, or guidelines for behavior to help “flatten the curve” in a pandemic.

The increased professionalization as well as informality in science communication observed by Bucchi & Trench (2021) occurs alongside entangled mundane and political activities online (Baym and boyd 2012). These developments leave their impact on discussions of science online. Like so many other online phenomena, the five types of communities engaging with science informally described here are not exhaustive, nor entirely distinct from each other. I am left wondering whether the activist intervention in knowledge dissemination and use while emphasizing and almost idealizing trust in science presents a new form of engagement with science, or the beginning of a type of engagement that many STS scholars have highlighted before. The pandemic has both revealed the power of science in finding answers and developing solutions to problems, and highlighted the uncertainty involved in knowledge building processes and the inability of science to give satisfying answers to pressing political questions. There is a chance that the activist engagement I have observed is only an early stage of what could become global concerned groups, intervening not only in dissemination but also in co-production of knowledge. Further research in online science communication would do well to take with them these descriptions of online communities and investigate their developing activities an engagement with science.

## 5.2 Community data practices

One of the ways I have investigated informal knowing spaces, and especially local differences between them, is the idea of data practices (Weltevrede and Borra 2016). This concept combines the examination of technical affordances with attention to their social use. It allowed me to follow the entangled sociotechnical practices on Reddit. In paper 2 I show how this concept (combining approaches from STS and IR) is useful both to examine and to describe differences of online communities. While the concept has previously been used to describe characteristics of large platforms, such as Wikipedia, I argue that it is helpful to describe local (sub)communities as well.

My research calls for attention to community data practices and their implications for research on digital data and for science communication. While research does pay attention to the way that affordances such as hashtags or hyperlinks are used differently on different platforms, I have shown in papers 1 and 2 that even very similar communities with similar ambitions and seemingly similar online environments can develop distinct profiles and data practices. In paper 1, I have shown the different uses of hyperlinks by two climate activist groups. Although not explicitly labeled as such, the two organizations’ different use of hyperlinks could be understood as different data practices. In paper 2, I have shown the differences between communities on the platform Reddit, all discussing information about the coronavirus pandemic. In this paper, I elaborate on the methodological challenges of identifying data practices in relation to different affordances of the platform and propose the concept of community data practices. Finally, in paper 3 I explore the use of moderation tools used to develop and uphold the micro norms and data practices of each subreddit, as well as controversies revealing the negotiation of these practices.

I argue that social media research should pay more attention to localized practices on and across platforms. Amongst others, data practices can highlight whether hyperlinks are used to give further information, or to provide sources to prove the reliability of statements; whether there are expectations for content that is or is not permissible in a certain space; whether there is agreement or disagreement about the purpose and rules of a given online community; and how various actants, including technical affordances and moderation practices, shape the practices of each space.

The importance of understanding the context of data produced in diverse communities is highlighted both in an overview of Reddit research (Proferes et al. 2021) and in discussions about the ethics of using such data (Nissenbaum 2011; Özkula 2019). In both SCR and IR, data practices could offer a way to examine the context of datasets with both attention to community details and the possibility of using data surrounding platform features for larger scale investigations, integrating interpretative and computational approaches. While social contexts collapse in personal social media feeds (Marwick and boyd 2011), communities can collectively recontextualize information in online knowing spaces. For scientists and professional science communicators looking to engage with online publics, awareness of local data practices could also help to find relevant knowing spaces to engage with, and fitting formats and forms of communication to do so.

The use of hyperlinks is a data practice that unites the empirical contexts in my dissertation. All of them have a sciencephile tendencies to lend much authority to academic reports. But they also differ in their use of hyperlinks as academic references, as pathways to further information, as educational, as entertaining, or as the start of discussions. Considering the data practices surrounding hyperlinking has helped me to describe and understand differences between the knowing spaces that I have observed and how they provide different contexts to engage with scientific information. Knowing that submissions in the three coronavirus subreddits were required to be hyperlinks and not “original content” created by Reddit users themselves has also informed my reflections about ethical implications of using such data.

Attention to data practices could help investigate contextual differences in various online knowing spaces. Individual websites and communities on Reddit lend themselves to an interpretation as individual and distinct communities or knowing spaces. Future research could test the concept on other knowing spaces with shared understandings of membership or participation such as YouTube channels or Facebook groups. Taken further, similar dynamics might even describe more loosely delineated knowing spaces such as hashtags used to signal communities in platforms that do not explicitly group content or users into distinct subcategories.

### 5.3 Publics and platform dialectics

In online contexts, people who engage with science communication can move between being passive audiences and active publics, at the same time as public and private, personal and political, individual and collective interactions become increasingly hard to distinguish. People might move seamlessly between roles and knowing spaces such as those presented above. Online, informal, personal and mundane activities are tightly linked to the political, through an increased awareness of belonging with varied publics (Baym & boyd, 2012). Likewise, distinctions of online and offline activities increasingly blur into “onlife” interactions (Bechmann et al., 2019). In the context of concerned groups, public-private distinctions become meaningless to analyze as actors are actively blurring them, changing the relationships between science, politics, and economic markets (Callon & Rabeharisoa, 2008). However, concerned publics do not only assemble around political or pragmatic issues, as in the case of concerned groups or activists. They can also share more mundane, curiosity-

driven, or ad-hoc interests tied to identity work (Davies et al., 2019; Davies & Horst, 2016; Marsh, 2020).

Researchers and professional science communicators can act as moderators themselves, carving out space for public history on Reddit (Chandrasekharan et al. 2018) or hosting shorter formats of engagement (Hara, Abbazio, and Perkins 2019). Nevertheless, they also have to relate to the community expectations and the platform dialectics at large.

The structure of Reddit invites itself for bringing back a consideration of online communities as distinct contexts as seen in early 'cyberspace' studies. Research points to significant differences in subreddits' use of content moderation practices (Chandrasekharan et al. 2018) or their creation of subreddit-specific community rules (Fiesler et al. 2018). Considering these small (sub)communities allowed me to explore their data practices separately, studying the evolving rules about what content is acceptable, but also practices such as flairing that serve to categorize and organize content. At the same time, the ties to the large platform drive continuous engagement in these small communities in ways that separate forums would be unable to sustain (Lagorio-Chafkin 2018, 151). The fast growth of coronavirus-related subreddits to six- and seven-digit numbers of subscribers within few months in early 2020 would have been impossible for an independent platform.

Reddit moderators (or community managers in the categorization of Gillespie, 2018) play an important role in shaping the distinct communities of subreddits, and relating to the platform at large. At the same time, collective interactions within and between communities also play a role. The same incentives that push communities to migrate between platforms (Fiesler and Dym 2020) can also create a movement of communities to different spaces within a platform. Communities depend on platforms to reach large audiences, but that makes it more difficult to impose and maintain local norms. At the same time, local norms are needed to maintain a distinct profile, attracting and maintaining a community of users that enact shared data practices.

Squirrell (2019) has described the interactions between users, moderators, and platform management as platform dialectics. I build on this work, proposing a distinction between two connected dialectics that shape modern online communities. In-community dialectics revolve around content moderation and boundary work of what is permitted in each space. Cross-community dialectics steer users to alternative knowing spaces and shape discussions of wanted and unwanted content at the platform level.

Although the exact setup of Reddit is unique, such collaborative understandings of platform affordances might exist elsewhere. This could be for example Facebook pages or groups, or YouTube channels, with some youtubers explicitly reminding viewers to not engage in negative comments to avoid the algorithm picking up on them or competing Facebook groups being set up with different rules similar to the divergence of users in response to coronavirus-related moderation practices. Moderators especially, but also community members themselves, engage in boundary work of what does and does not belong in this particular context.

This can be considered as publics in the political sense, or issue publics in the STS sense, especially when considering the climate activist websites of paper 1. However, with informal science communication, engagement need not be explicitly political, nor does it have to be limited to one issue. In the example of the overlapping issues of coronavirus (mis)information and reddit moderation practices explored in paper 3, controversies related to COVID-19 where more about how to moderate information than about the information itself and where a personal dispute between moderators briefly threatened to shift the landscape of coronavirus-subreddits on the platform.

The loosely connected online communities on Reddit (papers 2 and 3), especially when including lurkers or reading users, might be more passively constructed as audiences. However, even there, people can make minor adjustments to their use of the platform through which subreddits they subscribe to, whether they change the default sorting order, or even which content they stop to read or click to read comments. They can be simultaneously members of niche communities (German language memes about COVID-19) and of a large Reddit user community, if not a global online public. At the same time, interactions in these spaces can be personal and mundane, and are shaped by a complex assemblage of technological and social influences. One way of examining these in this thesis has been the notion of data practices.

Understanding online publics as communities also helps to understand the platform dialectics I have explored in paper 3. Building on Squirrell's (2019) work, I have distinguished two types of interactions on Reddit: Those happening within one community or subreddit, and those moving across the platform. In both cases, moderators take on roles as representatives of the subreddit and as community managers, but they have to interact with both users and platform management to maintain that role.

Community managers (Gillespie 2018) play large roles in shaping online contexts of discussions around science. However, despite having considerable influence, they also encounter platform dialectics (Squirrell 2019), having to relate to both users and platform management. My paper 3 investigates the platform dialectics relating to coronavirus discussions on Reddit. With additional attention to controversies (or, as Reddit puts it, "drama"), I argue for distinguishing the interactions within and across subcommunities on the platform. Further research could even follow communities across platforms, for example considering connected communities on discord, Reddit, YouTube, and Patreon tied to content creators.

Both science communicators and decisionmakers on questions of content moderation (be they platform-internal or governance oriented) can benefit from renewed attention to community managers. In the face of overwhelming amounts of content uploaded to platforms everyday, 'artisanal' or even 'community-reliant' content moderation, compared to 'industrial' approaches (Caplan 2018) seem to decrease in significance. However community managers fulfil an important function in Reddit communities. They set the tone for the community, collaborate with users to do so, and relate to platform management (at times representing the platform, at times representing the users). Thus, they shape what, where, and how content is discussed on the platform, including discussions around science. For science communication research, the moderators as well as platform dialectics are important mediators that intervene in conversations around science. For practitioners and scientists looking to engage, awareness of platform dialectics could help to identify which publics and how to engage with.

Taken together, the three articles presented in this thesis explore actants in informal online science communication. An STS-inspired focus on interactions and knowing spaces can highlight the involved actants and practices that create differing contexts even in seemingly similar spaces. They overlap with IR discussions of platforms, communities, and content management. Together, they can help to contribute observations of informal engagement with science to SCR.

Formal science communication activities are connected to the spaces that I have observed through hyperlinks. They play a big role, and many of the involved actors emphasize and value academic science. But there also are local differences in how communities relate to science and professional science communication. Attention to these differences, for example using the concept of data

practices, could help to add much needed context to large-scale investigations of digital spaces. They can also help practitioners in science communication to identify relevant communities to engage with and their norms and expectations for engagement.

Global crises, impacting political discussions everywhere, challenge ideas of involving ‘concerned groups’ in knowledge building. But a return to a vague ‘public’ seems unhelpful. Understanding science communication ‘as culture’ is one way of approaching different contexts of the social conversation around science. This ties in with the close connections between mundane and political engagement of online publics. It remains to be determined how far more casual and mundane informal engagement in “sciencephile” spaces stay separate from more skeptical engagement or movements towards co-production of knowledge in concerned groups.

## 6 Conclusion

In this dissertation, I investigated how science communication online is mediated by informal knowing spaces, shaped by collective data practices, and influenced by dialectical interactions within and between communities. My thesis contributes to a better understanding of what shapes the social conversation around science online. I have contributed to investigations of “‘behind-the-scenes’ human and non-human actants” shaping science communication (Edwards & Ziegler, 2022) and to conversations about “alternative” actors in science communication (Maesele 2009; Faehrich, Riedlinger, and Weitkamp 2020; Gregory 2020).

My work is positioned in the intersecting fields of Science Communication Research, Science and Technology Studies, and Internet Research. From the connection of STS and SCR, I take with me the interpretation of science communication as culture (Davies et al., 2019; Davies & Horst, 2016; Horst & Davies, 2021). It offers an alternative to the prevalent framings of science communication online as either misinformation or professional efforts. It might also offer an alternative to the deficit framing still underlying common ideas about science and science communication, or the linear thinking criticized in studies on the impact of science. The combination of an STS focus on social practice with IR attention to technical affordances has produced concepts such as “data practices” (Weltevrede & Borra, 2016) or “platform dialectics” (Squirrell, 2019). I have built on and expanded these concepts in my thesis, showing that they are well-suited to investigate online knowing spaces.

My work in this thesis was sparked by a personal realization that I did not see my own social media and internet use reflected in both scientific and societal discussions on the influence of social media. I do not take my own media consumption as widely representative (indeed, I might be part of some particularly small niches of internet users). But as I investigated science-oriented spaces, I realized that exploring what is happening in various niches is tied to understanding the much broader ‘social conversation around science’ online and has even wider implications than I originally expected. I am continuously fascinated by the diversity of activities that even one single platform such as Reddit, let alone a broader area of diverse online contexts can encompass, and how differently scholars register and interpret these activities. Framing online activities related to science and knowledge building as either professional communication or as misinformation by non-scientists risks overlooking a broad range of spaces, actors, and practices that shape online conversations around science informally. These frames also risk overstating the amount of control that science communication professionals or large-scale content moderation policies have over informal knowing spaces. At the same time, they might underestimate how closely linked these informal and alternative activities are to scientific ideals and practices.

The coronavirus pandemic has pivoted my work in unexpected ways, catapulting conversations around science to the forefront across online spaces in 2020. A flurry of new actors became involved in science communication, sometimes deliberately, sometimes unintentionally. As libraries, universities, swimming pools, and other venues closed to the public, many linked to health information on their websites, highlighting what they deemed trustworthy sources of information. Experts in health research and health authorities became public figures almost overnight, moving from scientific to public contexts. They found themselves explaining not only the virus and the pandemic but also the systems behind the scientific research about them. Professional science communication efforts such as the widely shared infographic of “flattening the curve” (Wiles & Morris, 2020) became viral social media content, shared among memes about toilet paper, speculation about virus origins, nurses’ recommendations on hygiene, and offers to go grocery shopping for vulnerable groups. The pandemic acted as a magnifying lens for societal issues, from (lack of) digitalization in schools to strained healthcare systems, highlighting systemic inequalities

and different outcomes in different populations. It also has magnified and amplified some of the effects in science communication. The ones I have investigated here have certainly become visible during the pandemic. However, they are not unique to the pandemic, but can be found in other contexts as well, not least in conversations about climate change and other global challenges.

Despite the rejection of deficit models, ideas of “fact checking” and a necessity for people to understand “the truth” persist. Especially in the context of urgent issues and explicit denial of scientific knowledge, it is tempting to think that if only we could find the right ways of explaining things, and the right algorithm to spread it, people would agree with a monolithic “science”. While I share climate activists’ frustration with political inaction in the face of overwhelming evidence pointing to an urgent need for action, I acknowledge that an idealized and uncritical “sciencephile” relationship with science could also be harmful. Paying attention to informal and alternative actors in online science communication is important, not least to observe whether there is a risk of returning deficit models. This is of course not to say that misinformation is not a problem. The intervention of moderators organizing collectively to contest Reddit’s handling of misinformation that I have observed in paper 3 was a much needed one. But it also revealed that evidence-based information had a weak influence compared to the data practices shaped by moderators, technologies, and collective publics at work in various subreddits. Users shaped these knowing spaces, whether they were professional scientists, idealist sciencephiles, moderators valuing free speech, conspiracy theorists outright rejecting centuries of established science, or anything in between.

Users in informal knowing spaces are not passively exposed to algorithmic or moderator decision-making and ordering of information but can also become agents shaping the context by use of technical affordances, from simple “voting” to complex suggestions for content moderation. And while moderators or community managers play a big role in shaping the context for online conversations, they also have to relate to complicated relationships within and among communities and platform management.

Following my own investigation of several online science communication contexts, I can only underline Tim Squirrel’s (2019) conclusion that “the relationships between technologies and multiple layers of users are not linear and nor are the interactions they produce straightforward. They are dialectical, messy and complex”. As such, science communication occurring in various online spaces is much more complex and diverse than any individual research project can cover. Exploring other actants and venues than the ones I selected, or other methods to approach them, might well have led me on a different path.

Social media platforms create complicated research objects that are not the same over time or to different users. Treating them as a site to be encountered in ethnographic observation in combination with data collection through API access was my attempt to grapple with this complexity. However, as API access becomes increasingly restricted, researchers need to find other entry points to studying online interactions.

The sites I have examined in this thesis present only one form of informal science communication online. I have alluded to others in chapter 5.1 but many more remain to be explored. The communities I have observed, though informal, are close to academic knowledge production and professional science communication efforts both in the resources they link to and how they discuss them. The ‘knowing spaces’ observed here are not ‘alternative’ to scientific knowing spaces, but have significant overlaps with academic practice. The traditional expertise of academic scientists, or professional translation of scientific content by formal science communication roles is not a prerequisite to join the discussion. Nevertheless, these formal science communication efforts do enter the discussion and still carry weight in the spaces that I have observed. Other informal knowing

spaces could be much further removed from ideals of academic knowledge production. While my work with Reddit data and especially the r/china\_flu subreddit and the controversy around moderation of misinformation briefly touch on it, “skeptical” engagement with science could be an entire thesis on its own. I have chosen to emphasize “sciencephile” spaces here, but the STS principle of symmetry suggests that similar factors might be at play in skeptical or anti-science contexts as in those idealizing scientific knowledge production.

Similarly, I have also largely excluded discussions on misinformation. With advances in generative artificial intelligence, platforms will likely face large volumes of online content in need of drastic moderator intervention far beyond what volunteer community managers can do. Content moderation will necessarily include algorithmic intervention to deal with the volume of information on any given platform. Nevertheless, platforms and policymakers alike would do well to pay attention to community management, too. The risk of black-boxed moderation decisions makes it all the more important to shine a light on various actants in online spaces. For democratic conversations around science, we need to negotiate what is or should be socially or technically mediated, come to shared agreements about community standards, and allow users to collectively voice their unhappiness with decisions, lest they move on to other knowing spaces.

My experience in this project suggests that attention to data practices and platform dialectics might be a good way forward to recognize the sociotechnical influences and local differences of various online communities that engage in the social conversation around science online. As people travel through the landscapes of scientific knowledge production, they enter different spaces that are organized and maintained in different ways. Some of the moderated online spaces are not only shaped and maintained by ‘custodians’ (Gillespie, 2018). To keep with that metaphor, the landscapes of scientific knowledge production also have collective rules and communal agreements on what counts as littering, and how often to mow the lawn; they have kind souls watering the flowers, and angry post-it notes with noise complaints or reminders to stop feeding the seagulls. Most importantly, they are experienced differently by everyone. Navigating these landscapes and their dynamic developments is a complex undertaking – it might help to have professional science communicators at your side, and there certainly is a risk of encountering misinformation, but that is far from the only thing happening. Attention to informal and local activities reveals actors and practices that intervene in our experiences in mundane but significant ways.







## References

- Akrich, Madeleine. 1992. "The De-Description of Technical Objects." In *Shaping Technology/Building Society: Studies in Sociotechnical Change*, edited by Wiebe E.; Law Bijker John, 205–24. Cambridge, Mass.: MIT Press.
- Bastian, Mathieu, Sebastien Heymann, and Mathieu Jacomy. 2009. "Gephi: An Open Source Software for Exploring and Manipulating Networks." In *Proceedings of the Third International ICWSM Conference*.
- Baumgartner, Jason, Savvas Zannettou, Brian Keegan, Megan Squire, and Jeremy Blackburn. 2020. "The Pushshift Reddit Dataset." *Proceedings of the International AAAI Conference on Web and Social Media* 14 (May): 830–39.
- Baym, Nancy K., and danah boyd. 2012. "Socially Mediated Publicness: An Introduction." *Journal of Broadcasting & Electronic Media* 56 (3): 320–29. <https://doi.org/10.1080/08838151.2012.705200>.
- Bechmann, Anja, Kjetil Sandvik, and Karin Zelano. 2019. "Making Sense of Small and Big Data as Onlife Traces." *Nordicom Review* 40 (s1): 3–9. <https://doi.org/10.2478/nor-2019-0010>.
- Bennett, Nichole, Anthony Dudo, and John C. Besley. 2022. "Science Communication Fellowship Programs as Gatekeepers." *Public Understanding of Science*, August, 09636625221115958. <https://doi.org/10.1177/09636625221115958>.
- Birkbak, Andreas. 2013. "From Networked Publics to Issue Publics: Reconsidering the Public/Private Distinction in Web Science." In *Proceedings of the 5th Annual ACM Web Science Conference*. ———. 2018. "Into the Wild Online: Learning from Internet Trolls." *First Monday*, April. <https://doi.org/10.5210/fm.v22i5.8297>.
- Bloor, David. 1976. *Knowledge and Social Imagery*. London: Routledge & Kegan Paul.
- Bowker, Geoffrey C., and Susan Leigh Star. 1999. *Sorting Things Out: Classification and Its Consequences*. MIT Press.
- boyd, danah. 2010. "Social Network Sites as Networked Publics: Affordances, Dynamics, and Implications." In *A Networked Self*, edited by Zizi Papacharissi, 0 ed., 47–66. Routledge. <https://doi.org/10.4324/9780203876527-8>.
- . 2018. "Did Media Literacy Backfire?" Medium. March 16, 2018. <https://points.datasociety.net/did-media-literacy-backfire-7418c084d88d>.
- boyd, danah, and Kate Crawford. 2012. "Critical Questions for Big Data." *Information, Communication & Society* 15 (5): 662–79. <https://doi.org/10.1080/1369118X.2012.678878>.
- Bruns, Axel. 2018. "Facebook Shuts the Gate after the Horse Has Bolted, and Hurts Real Research in the Process." *Medium* (blog). May 13, 2018. <https://medium.com/@Snurb/facebook-research-data-18662cf2cacb>.
- Bucchi, Massimiano, and Brian Trench. 2021. "Rethinking Science Communication as the Social Conversation around Science." *Journal of Science Communication* 20 (3): Y01. <https://doi.org/10.22323/2.20030401>.
- Bucher, Taina, and Anne Helmond. 2018. "The Affordances of Social Media Platforms." In *The SAGE Handbook of Social Media*, by Jean Burgess, Alice Marwick, and Thomas Poell, 233–53. 1 Oliver's Yard, 55 City Road London EC1Y 1SP: SAGE Publications Ltd. <https://doi.org/10.4135/9781473984066.n14>.
- Burns, T. W., D. J. O'Connor, and S. M. Stocklmayer. 2003. "Science Communication: A Contemporary Definition." *Public Understanding of Science* 12 (2): 183–202. <https://doi.org/10.1177/09636625030122004>.
- Burton, Anthony G., and Dimitri Koehorst. 2020. "Research Note: The Spread of Political Misinformation on Online Subcultural Platforms." *Harvard Kennedy School Misinformation Review*, September. <https://doi.org/10.37016/mr-2020-40>.

- Callon, Michel. 1999. "The Role of Lay People in the Production and Dissemination of Scientific Knowledge." *Science, Technology and Society* 4 (1): 81–94. <https://doi.org/10.1177/097172189900400106>.
- Callon, Michel, and Vololona Rabeharisoa. 2008. "The Growing Engagement of Emergent Concerned Groups in Political and Economic Life: Lessons from the French Association of Neuromuscular Disease Patients." *Science, Technology, & Human Values* 33 (2): 230–61. <https://doi.org/10.1177/0162243907311264>.
- Calma, Justine. 2023. "Scientists Say They Can't Rely on Twitter Anymore." *The Verge*, May 31, 2023. <https://www.theverge.com/2023/5/31/23739084/twitter-elon-musk-api-policy-chilling-academic-research>.
- Caplan, Robyn. 2018. "Content or Context Moderation? Artisanal, Community-Reliant and Industrial Approaches." Data & Society. [https://datasociety.net/wp-content/uploads/2018/11/DS\\_Content\\_or\\_Context\\_Moderation.pdf](https://datasociety.net/wp-content/uploads/2018/11/DS_Content_or_Context_Moderation.pdf).
- Castells, Manuel. 1996. *The Rise of the Network Society*. Malden, Mass: Blackwell Publishers.
- Chandrasekharan, Eshwar, Mattia Samory, Shagun Jhaver, Hunter Charvat, Amy Bruckman, Cliff Lampe, Jacob Eisenstein, and Eric Gilbert. 2018. "The Internet's Hidden Rules: An Empirical Study of Reddit Norm Violations at Micro, Meso, and Macro Scales." *Proceedings of the ACM on Human-Computer Interaction* 2 (CSCW): 1–25. <https://doi.org/10.1145/3274301>.
- Charles Ess and the AoIR ethics working committee. 2002. "Ethical Decision-Making and Internet Research: Recommendations from the AoIR Ethics Working Committee." Approved by AoIR, November 27, 2002. <https://www.aoir.org/reports/ethics.pdf>.
- Chen, Hui, Noriko Hara, and Clinton McKay. 2021. "Investigating Mediated Public Engagement with Science on the 'Science' Subreddit: From the Participants' Perspective." *PLOS ONE* 16 (4): e0249181. <https://doi.org/10.1371/journal.pone.0249181>.
- Chen, Yingying, Jacob Long, Jungmi Jun, Sei-Hill Kim, Ali Zain, and Colin Piacentine. 2023. "Anti-Intellectualism amid the COVID-19 Pandemic: The Discursive Elements and Sources of Anti-Fauci Tweets." *Public Understanding of Science*, January, 09636625221146269. <https://doi.org/10.1177/09636625221146269>.
- Choi, Daejin, Jinyoung Han, Taejoong Chung, Yong-Yeol Ahn, Byung-Gon Chun, and Ted Taekyoung Kwon. 2015. "Characterizing Conversation Patterns in Reddit: From the Perspectives of Content Properties and User Participation Behaviors." In *Proceedings of the 2015 ACM on Conference on Online Social Networks*, 233–43. COSN '15. New York, NY, USA: Association for Computing Machinery. <https://doi.org/10.1145/2817946.2817959>.
- Colardyn, Danielle, and Jens Bjornavold. 2004. "Validation of Formal, Non-Formal and Informal Learning: Policy and Practices in EU Member States." *European Journal of Education* 39 (1): 69–89. <https://doi.org/10.1111/j.0141-8211.2004.00167.x>.
- Collins, Harry, Robert Evans, and Michael E. Gorman. 2019. "Trading Zones Revisited." In *The Third Wave in Science and Technology Studies : Future Research Directions on Expertise and Experience*, edited by David S. Caudill, Shannon N. Conley, Michael E. Gorman, and Martin Weinel, 275–81. Cham: Springer International Publishing. [https://doi.org/10.1007/978-3-030-14335-0\\_15](https://doi.org/10.1007/978-3-030-14335-0_15).
- Collins, Harry, Robert Evans, and Mike Gorman. 2007. "Trading Zones and Interactional Expertise." *Studies in History and Philosophy of Science Part A, Case studies of expertise and experience*, 38 (4): 657–66. <https://doi.org/10.1016/j.shpsa.2007.09.003>.
- Cosgrave, Mike. 2019. "Digital Humanities Methods as a Gateway to Inter and Transdisciplinarity." *Global Intellectual History* 0 (0): 1–10. <https://doi.org/10.1080/23801883.2019.1657639>.
- Costas, Rodrigo, Sarah de Rijcke, and Noortje Marres. 2020. "'Heterogeneous Couplings': Operationalizing Network Perspectives to Study Science-Society Interactions through Social Media Metrics." *Journal of the Association for Information Science and Technology* n/a (n/a). <https://doi.org/10.1002/asi.24427>.
- Cozza, Michela. 2021. *Key Concepts in Science and Technology Studies*. Studentlitteratur AB.

- Daume, Stefan, and Victor Galaz. 2016. "‘Anyone Know What Species This Is?’ – Twitter Conversations as Embryonic Citizen Science Communities." *PLOS ONE* 11 (3): e0151387. <https://doi.org/10.1371/journal.pone.0151387>.
- Davies, Sarah R. 2022a. "Science Communication at a Time of Crisis: Emergency, Democracy, and Persuasion." *Sustainability* 14 (9): 5103. <https://doi.org/10.3390/su14095103>.
- . 2022b. "STS and Science Communication: Reflecting on a Relationship." *Public Understanding of Science*, May. <https://doi.org/10.1177/09636625221075953>.
- Davies, Sarah R., Megan Halpern, Maja Horst, David A. Kirby, and Bruce Lewenstein. 2019. "Science Stories as Culture: Experience, Identity, Narrative and Emotion in Public Communication of Science." *Journal of Science Communication* 18 (5). <https://doi.org/10.22323/2.18050201>.
- Davies, Sarah R., and Maja Horst. 2016. *Science Communication : Culture, Identity and Citizenship*. London: Palgrave Macmillan. <http://search.ebscohost.com/login.aspx?direct=true&db=nlebk&AN=1242107&site=ehost-live>.
- Davis, Jenny L, and Nathan Jurgenson. 2014. "Context Collapse: Theorizing Context Collusions and Collisions." *Information, Communication & Society* 17 (4): 476–85. <https://doi.org/10.1080/1369118X.2014.888458>.
- Díaz-Faes, Adrián A., Timothy D. Bowman, and Rodrigo Costas. 2019. "Towards a Second Generation of ‘Social Media Metrics’: Characterizing Twitter Communities of Attention around Science." *PLOS ONE* 14 (5): e0216408. <https://doi.org/10.1371/journal.pone.0216408>.
- Edwards, Michelle L., and Caden Ziegler. 2022. "Examining Science Communication on Reddit: From an ‘Assembled’ to a ‘Disassembling’ Approach." *Public Understanding of Science*, January, 09636625211057231. <https://doi.org/10/gpbhgh>.
- Egher, Claudia. 2019. "Online Expert Mediators: The Rise of a New ‘Bipolar’ Stakeholder or Going Beyond Interactional Expertise in the Blogosphere," 22.
- Engelberts, Lernert, and Sander Plug, dirs. 2009. *I Love Alaska*. <https://submarinechannel.com/minimovie/minimovie-i-love-alaska/>.
- Epstein, Steven. 1995. "The Construction of Lay Expertise: AIDS Activism and the Forging of Credibility in the Reform of Clinical Trials." *Science, Technology, & Human Values* 20 (4): 408–37. <https://doi.org/10.1177/016224399502000402>.
- Faehnrich, Birte. 2018. "Digging Deeper? Muddling through? How Environmental Activists Make Sense and Use of Science — an Exploratory Study." *Journal of Science Communication* 17 (3): A08. <https://doi.org/10.22323/2.17030208>.
- Faehnrich, Birte, Michelle Riedlinger, and Emma Weitkamp. 2020. "Activists as ‘Alternative’ Science Communicators — Exploring the Facets of Science Communication in Societal Contexts." *Journal of Science Communication* 19 (6): C01. <https://doi.org/10.22323/2.19060301>.
- Felt, Ulrike, and Sarah R. Davies. 2020. *Exploring Science Communication: A Science and Technology Studies Approach*. SAGE.
- Fiesler, Casey, and Brianna Dym. 2020. "Moving Across Lands: Online Platform Migration in Fandom Communities." *Proceedings of the ACM on Human-Computer Interaction* 4 (CSCW1): 1–25. <https://doi.org/10.1145/3392847>.
- Fiesler, Casey, Jialun Jiang, Joshua McCann, Kyle Frye, and Jed Brubaker. 2018. "Reddit Rules! Characterizing an Ecosystem of Governance." *Proceedings of the International AAAI Conference on Web and Social Media* 12 (1). <https://ojs.aaai.org/index.php/ICWSM/article/view/15033>.
- Forlano, Laura. 2019. "Introduction: Materiality." In *DigitalSTS*, edited by Laura Forlano, Janet Vertesi, David Ribes, Carl DiSalvo, Yanni Loukissas, Daniela K. Rosner, Steven J. Jackson, and Hanna Rose Shell, 11–16. A Field Guide for Science & Technology Studies. Princeton University Press. <https://www.jstor.org/stable/j.ctvc77mp9.5>.
- franzke, aline shakti, Anja Bechmann, Michael Zimmer, Charles Ess, and the Association of Internet Researchers. 2020. "Internet Research: Ethical Guidelines 3.0." <https://aoir.org/reports/ethics3.pdf>.

- Freelon, Deen. 2018. "Computational Research in the Post-API Age." *Political Communication* 35 (4): 665–68. <https://doi.org/10.1080/10584609.2018.1477506>.
- Fuchs, Christian. 2017. "From Digital Positivism and Administrative Big Data Analytics towards Critical Digital and Social Media Research!" *European Journal of Communication* 32 (1): 37–49. <https://doi.org/10.1177/0267323116682804>.
- Fuentes, Claudio, Julian "Iñaki" Goñi, and Constanza Miranda. 2021. "Analytical Categories to Describe Deficit Attributions in Deep Disagreements between Citizens and Experts." *Public Understanding of Science*, June, 09636625211020474. <https://doi.org/10.1177/09636625211020474>.
- Galison, Peter. 1997. *Image and Logic: A Material Culture of Microphysics*. University of Chicago Press.
- . 2010. "Trading with the Enemy." *Trading Zones and Interactional Expertise: Creating New Kinds of Collaboration* 21 (1): 147–75.
- Geiger, R. Stuart, and David Ribes. 2011. "Trace Ethnography: Following Coordination through Documentary Practices." In *System Sciences (HICSS), 2011 44th Hawaii International Conference On*, 1–10. IEEE.
- Gerber, Alexander, Peter Broks, Markus Gabriel, Lars Lorenz, Lorke, Wolfgang Merten, Jennifer Metcalfe, Bernd Müller, and Nicole Warthun. 2020. "Science Communication Research: An Empirical Field Analysis." Edition innovare. <https://sagepubs.blogspot.com/2021/01/science-communication-research-past.html>.
- Gerlitz, C., and B. Rieder. 2018. "Tweets Are Not Created Equal: Investigating Twitter's Client Ecosystem." *International Journal of Communication* 12: 528–47.
- Gibbs, Martin, James Meese, Michael Arnold, Bjorn Nansen, and Marcus Carter. 2015. "#Funeral and Instagram: Death, Social Media, and Platform Vernacular." *Information, Communication & Society* 18 (3): 255–68. <https://doi.org/10.1080/1369118X.2014.987152>.
- Gibson, James. 1977. "The Theory of Affordances." In *Perceiving, Acting and Knowing: Toward an Ecological Psychology*, 62–82. Hillsdale, NJ: Erlbaum.
- Gieryn, Thomas F. 1983. "Boundary-Work and the Demarcation of Science from Non-Science: Strains and Interests in Professional Ideologies of Scientists." *American Sociological Review* 48 (6): 781–95. <https://doi.org/10.2307/2095325>.
- Gilbert, Sarah A. 2020. "'I Run the World's Largest Historical Outreach Project and It's on a Cesspool of a Website.' Moderating a Public Scholarship Site on Reddit: A Case Study of r/AskHistorians." *Proceedings of the ACM on Human-Computer Interaction* 4 (CSCW1): 19:1-19:27. <https://doi.org/10.1145/3392822>.
- Gillespie, Tarleton. 2010. "The Politics of 'Platforms.'" *New Media & Society* 12 (3): 347–64. <https://doi.org/10.1177/1461444809342738>.
- . 2018. *Custodians of the Internet: Platforms, Content Moderation, and the Hidden Decisions That Shape Social Media*. Yale University Press.
- Goulden, Murray, Christian Greiffenhagen, Jon Crowcroft, Derek McAuley, Richard Mortier, Milena Radenkovic, and Arjuna Sathiaseelan. 2017. "Wild Interdisciplinarity: Ethnography and Computer Science." *International Journal of Social Research Methodology* 20 (2): 137–50. <https://doi.org/10.1080/13645579.2016.1152022>.
- Gray, Jonathan, Carolin Gerlitz, and Liliana Bounegru. 2018. "Data Infrastructure Literacy." *Big Data & Society*, no. 2 (July): 1–13. <https://doi.org/10.1177/2053951718786316>.
- Gregory, Jane. 2020. "Engaging with 'Activists' and 'Alternatives' in Science Communication." *Journal of Science Communication* 19 (6): C02. <https://doi.org/10.22323/2.19060302>.
- Guenther, Lars, and Marina Joubert. 2017. "Science Communication as a Field of Research: Identifying Trends, Challenges and Gaps by Analysing Research Papers." *Journal of Science Communication* 16 (2): A02. <https://doi.org/10.22323/2.16020202>.
- . 2021. "Novel Interfaces in Science Communication: Comparing Journalistic and Social Media Uptake of Articles Published by The Conversation Africa." *Public Understanding of Science* 30 (8): 1041–57. <https://doi.org/10.1177/09636625211019312>.

- Gunnarsson, Andreas. 2012. "Unleashing Science Popularisation: Studies on Science as Popular Culture." <https://gupea.ub.gu.se/handle/2077/28928>.
- Gunnarsson, Andreas, and Mark Elam. 2012. "Food Fight! The Swedish Low-Carb/High Fat (LCHF) Movement and the Turning of Science Popularisation Against the Scientists." *Science as Culture* 21 (3): 315–34. <https://doi.org/10.1080/09505431.2011.632000>.
- Hagen, Sal, and Emilija Jokubauskaitė. 2020. "6 Dutch Junk News on Reddit and 4chan/Pol." In *The Politics of Social Media Manipulation*, 169. Amsterdam University Press.
- Hand, Martin. 2014. "From Cyberspace to the Dataverse: Trajectories in Digital Social Research." *Big Data? Qualitative Approaches to Digital Research*, Studies in Qualitative Methodology, 13 (November): 1–27. <https://doi.org/10.1108/S1042-319220140000013002>.
- Hara, Noriko, Jessica Abbazio, and Kathryn Perkins. 2019. "An Emerging Form of Public Engagement with Science: Ask Me Anything (AMA) Sessions on Reddit r/Science." *PLOS ONE* 14 (5): e0216789. <https://doi.org/10.1371/journal.pone.0216789>.
- Haraway, Donna. 1985. "A Cyborg Manifesto." *Socialist Review*. <https://sites.evergreen.edu/politicalshakespeares/wp-content/uploads/sites/226/2015/12/Haraway-Cyborg-Manifesto-2.pdf>.
- . 1988. "Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective." *Feminist Studies* 14 (3): 575–99. <https://doi.org/10.2307/3178066>.
- Hård af Segerstad, Ylva, Christopher Kullenberg, Dick Kasperowski, and Christine Howes. 2017. "Studying Closed Communities On-Line: Digital Methods and Ethical Considerations Beyond Informed Consent and Anonymity." In *Internet Research Ethics for the Social Age: New Challenges, Cases, and Contexts*, edited by Michael Zimmer and Katharina Kinder-Kurlanda, 213–25. New York: Peter Lang.
- Hicks, Diana, Paul Wouters, Ludo Waltman, Sarah de Rijcke, and Ismael Rafols. 2015. "Bibliometrics: The Leiden Manifesto for Research Metrics." *Nature News* 520 (7548): 429. <https://doi.org/10.1038/520429a>.
- Horst, Maja, and Sarah R. Davies. 2021. "Science Communication as Culture: A Framework for Analysis." In *Routledge Handbook of Public Communication of Science and Technology*, 3rd ed. Routledge.
- Horst, Maja, Sarah Rachael Davies, and Alan Irwin. 2017. "Reframing Science Communication." In *The Handbook of Science and Technology Studies*, edited by Ulrike Felt, Rayvon Fouché, Clark A. Miller, and Laurel Smith-Doerr, 4th ed., 881–908. United States: MIT Press.
- Ilten, Carla, and Paul-Brian McInerney. 2019. "Social Movements and Digital Technology:: A Research Agenda." In *DigitalSTS*, edited by Janet Vertesi, David Ribes, Carl DiSalvo, Yanni Loukissas, Laura Forlano, Daniela K. Rosner, Steven J. Jackson, and Hanna Rose Shell, 198–220. A Field Guide for Science & Technology Studies. Princeton University Press. <https://www.jstor.org/stable/j.ctvc77mp9.18>.
- Jacomy, Mathieu, Paul Girard, Benjamin Ooghe-Tabanou, and Tommaso Venturini. 2016. "Hyphe, a Curation-Oriented Approach to Web Crawling for the Social Sciences." *Proceedings of the Tenth International AAAI Conference on Web and Social Media (ICWSM 2016)*, 595–98.
- Jacomy, Mathieu, and Anders Kristian Munk. 2022. "Interfering with the Black-Box-Tradeoff Model: Gephisto, a One-Click Gephi for Critical Technical Practice." *Convergence*, November, 13548565221129052. <https://doi.org/10.1177/13548565221129053>.
- Jensen, Klaus Bruhn. 2012. "Lost, Found, and Made." In *The Handbook of Global Media Research*, 433–50. Wiley-Blackwell. <https://doi.org/10.1002/9781118255278.ch25>.
- Jones, Ridley, Lucas Colusso, Katharina Reinecke, and Gary Hsieh. 2019. "R/Science: Challenges and Opportunities in Online Science Communication." In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, 1–14. New York, NY, USA: Association for Computing Machinery. <http://doi.org/10.1145/3290605.3300383>.
- Joubert, Marina, Lars Guenther, Jenni Metcalfe, Michelle Riedlinger, Anwasha Chakraborty, Toss Gascoigne, Bernard Schiele, Ayelet Baram-Tsabari, Dmitry Malkov, and Eliana Fattorini. 2023. "Pandem-Icons'—Exploring the Characteristics of Highly Visible Scientists during the Covid-19

- Pandemic." *Journal of Science Communication* 22 (1): A04.  
<https://doi.org/10.22323/2.22010204>.
- Jullien, Nicolas. 2012. "What We Know About Wikipedia: A Review of the Literature Analyzing the Project (s)." <https://doi.org/10.2139/ssrn.2053597>.
- Keegan, Brian C., and Chenhao Tan. 2020. "A Quantitative Portrait of Wikipedia's High-Tempo Collaborations during the 2020 Coronavirus Pandemic." *ArXiv:2006.08899 [Physics]*, June.  
<http://arxiv.org/abs/2006.08899>.
- Ko, H. 2016. "In Science Communication, Why Does the Idea of a Public Deficit Always Return? How Do the Shifting Information Flows in Healthcare Affect the Deficit Model of Science Communication?" *Public Understanding of Science* 25 (4): 427–32.  
<https://doi.org/10.1177/0963662516629746>.
- Lagorio-Chafkin, Christine. 2018. *We Are the Nerds: The Birth and Tumultuous Life of REDDIT, the Internet's Culture Laboratory*. Hachette UK.
- Latour, Bruno. 1987. *Science in Action: How to Follow Scientists and Engineers Through Society*. Harvard University Press.
- . 1990. "Technology Is Society Made Durable." *The Sociological Review* 38 (1\_suppl): 103–31.  
<https://doi.org/10.1111/j.1467-954X.1990.tb03350.x>.
- . 2005. *Reassembling the Social: An Introduction to Actor-Network-Theory (Clarendon Lectures in Management Studies)*. {Oxford University Press}.  
<http://www.amazon.ca/exec/obidos/redirect?tag=citeulike09-20&path=ASIN/0199256047>.
- . 2017. "On Actor-Network Theory. A Few Clarifications, Plus More Than a Few Complications." *Philosophical Literary Journal Logos* 27 (1): 173–97. <https://doi.org/10.22394/0869-5377-2017-1-173-197>.
- Latour, Bruno, Pablo Jensen, Tommaso Venturini, Sébastien Grauwin, and Dominique Boullier. 2012. "The Whole Is Always Smaller than Its Parts—a Digital Test of Gabriel Tarde's Monads." *The British Journal of Sociology* 63 (4): 590–615. <https://doi.org/10.1111/j.1468-4446.2012.01428.x>.
- Latzko-Toth, Guillaume, Johan Söderberg, Florence Millerand, and Steve Jones. 2019. "Misuser Innovations: The Role of 'Misuses' and 'Misusers' in Digital Communication Technologies." In *DigitalSTS*, edited by Janet Vertesi, David Ribes, Carl DiSalvo, Yanni Loukissas, Laura Forlano, Daniela K. Rosner, Steven J. Jackson, and Hanna Rose Shell, 393–411. A Field Guide for Science & Technology Studies. Princeton University Press.  
<https://www.jstor.org/stable/j.ctvc77mp9.29>.
- Lave, Jean, and Etienne Wenger. 1991. *Situated Learning: Legitimate Peripheral Participation*. Cambridge University Press.
- Law, John. 2004. *After Method: Mess in Social Science Research*. London: Routledge.  
<https://doi.org/10.4324/9780203481141>.
- . 2016. "1 STS as Method." In *The Handbook of Science and Technology Studies*. MIT Press.
- Lindgren, Simon. 2019. "Hacking Social Science for the Age of Datafication." *Journal of Digital Social Research* 1 (1): 1–9. <https://doi.org/10.33621/jdsr.v1i1.6>.
- . 2020. *Data Theory: Interpretive Sociology and Computational Methods*. Cambridge ; Medford, MA: Polity.
- Lörcher, Ines, and Monika Taddicken. 2017. "Discussing Climate Change Online. Topics and Perceptions in Online Climate Change Communication in Different Online Public Arenas." *Journal of Science Communication* 16 (2): A03. <https://doi.org/10.22323/2.16020203>.
- Luka, Mary Elizabeth, and Mélanie Millette. 2018. "(Re)Framing Big Data: Activating Situated Knowledges and a Feminist Ethics of Care in Social Media Research." *Social Media + Society* 4 (2): 2056305118768297. <https://doi.org/10.1177/2056305118768297>.
- Maesele, Pieter. 2009. "NGOs and GMOs." *Javnost - The Public* 16 (4): 55–72.  
<https://doi.org/10.1080/13183222.2009.11009014>.
- Maier, Daniel, Annie Waldherr, Peter Miltner, Patrick Jähnichen, and Barbara Pfetsch. 2018. "Exploring Issues in a Networked Public Sphere: Combining Hyperlink Network Analysis and



- Topic Modeling." *Social Science Computer Review* 36 (1): 3–20.  
<https://doi.org/10.1177/0894439317690337>.
- Markham, Annette, and Elizabeth Buchanan. 2012. "Recommendations from the AoIR Ethics Working Committee," 17.
- Marres, Noortje. 2007. "The Issues Deserve More Credit: Pragmatist Contributions to the Study of Public Involvement in Controversy." *Social Studies of Science* 37 (5): 759–80.  
<https://doi.org/10.1177/0306312706077367>.
- . 2015. "Why Map Issues? On Controversy Analysis as a Digital Method." *Science, Technology, & Human Values* 40 (5): 655–86. <https://doi.org/10.1177/0162243915574602>.
- . 2017. *Digital Sociology: The Reinvention of Social Research*. John Wiley & Sons.
- . 2018. "Why We Can't Have Our Facts Back." *Engaging Science, Technology, and Society* 4 (0): 423–43. <https://doi.org/10.17351/ests2018.188>.
- Marres, Noortje, and Carolin Gerlitz. 2016. "Interface Methods: Renegotiating Relations between Digital Social Research, STS and Sociology." *The Sociological Review* 64 (1): 21–46.  
<https://doi.org/10/f8c2jr>.
- Marres, Noortje, and David Moats. 2015. "Mapping Controversies with Social Media: The Case for Symmetry." *Social Media + Society* 1 (2): 2056305115604176.  
<https://doi.org/10.1177/2056305115604176>.
- Marres, Noortje, and Richard Rogers. 2005. "Recipe for Tracing the Fate of Issues and Their Publics on the Web." In *Making Things Public: Atmospheres of Democracy*, edited by Bruno Latour and Peter Weibel, 922–35. Cambridge (Mass).
- Marsh, Oliver. 2018. "'Nah, Musing Is Fine. You Don't Have to Be 'Doing Science'": Emotional and Descriptive Meaning-Making in Online Non-Professional Discussions about Science." *Doctoral Thesis, UCL (University College London)*. Doctoral, UCL (University College London).  
<https://discovery.ucl.ac.uk/id/eprint/10044289/>.
- . 2020. "Science, Emotion, and Identity Online: Constructing Science and Selves on 'I Fucking Love Science.'" In *Exploring Science Communication: A Science and Technology Studies Approach*, by Ulrike Felt and Sarah R. Davies. SAGE.
- Martin, Brian, and Evelleen Richards. 1995. "Scientific Knowledge, Controversy, and Public Decision-Making." *Handbook of Science and Technology Studies*, 506–26.
- Marwick, Alice E., and danah boyd. 2011. "I Tweet Honestly, I Tweet Passionately: Twitter Users, Context Collapse, and the Imagined Audience." *New Media & Society* 13 (1): 114–33.  
<https://doi.org/10.1177/1461444810365313>.
- Massanari, Adrienne. 2017. "#Gamergate and The Fapping: How Reddit's Algorithm, Governance, and Culture Support Toxic Technocultures." *New Media & Society* 19 (3): 329–46.  
<https://doi.org/10.1177/1461444815608807>.
- McNeil, Maureen. 2013. "Between a Rock and a Hard Place: The Deficit Model, the Diffusion Model and Publics in STS." *Science as Culture* 22 (4): 589–608.  
<https://doi.org/10.1080/14636778.2013.764068>.
- Mede, Niels G., and Mike S. Schäfer. 2020. "Science-Related Populism: Conceptualizing Populist Demands toward Science." *Public Understanding of Science* 29 (5): 473–91.  
<https://doi.org/10.1177/0963662520924259>.
- Mendel, Jonathan, and Hauke Riesch. 2017. "Gadflies Biting Science Communication: Engagement, Tricksters, and Ambivalence Online." *Science Communication* 39 (5): 673–84.  
<https://doi.org/10.1177/1075547017736068>.
- Merrill, Samuel. 2020. "Following The Woman with the Handbag: Mnemonic Context Collapse and the Anti-Fascist Activist Appropriation of an Iconic Historical Photograph." In *Social Movements, Cultural Memory and Digital Media: Mobilising Mediated Remembrance*, edited by Samuel Merrill, Emily Keightley, and Priska Daphi, 111–39. Palgrave Macmillan Memory Studies. Cham: Springer International Publishing. [https://doi.org/10.1007/978-3-030-32827-6\\_5](https://doi.org/10.1007/978-3-030-32827-6_5).

- Metcalfe, Jennifer, Michelle Riedlinger, Martin W. Bauer, Anwesha Chakraborty, Toss Gascoigne, Lars Guenther, Marina Joubert, et al. 2020. "The COVID-19 Mirror: Reflecting Science-Society Relationships across 11 Countries." *Journal of Science Communication* 19 (7): A05. <https://doi.org/10.22323/2.19070205>.
- Metzger, Miriam J., Jennifer Jiyoun Suh, Scott Reid, and Amr El Abbadi. 2021. "What Can Fitness Apps Teach Us About Group Privacy?" In *Research Anthology on Privatizing and Securing Data*, 2135–57. IGI Global. <https://doi.org/10.4018/978-1-7998-8954-0.ch104>.
- Milan, Stefania. 2017. "Digital Traces and Bottom-up Data Practices." *AoIR Selected Papers of Internet Research*, October. <https://spir.aoir.org/ojs/index.php/spir/article/view/10085>.
- Møller Hartley, Jannie, Mette Bengtsson, Anna Schjøtt Hansen, and Morten Fischer Sivertsen. 2021. "Researching Publics in Datafied Societies: Insights from Four Approaches to the Concept of 'Publics' and a (Hybrid) Research Agenda." *New Media & Society*, June, 14614448211021044. <https://doi.org/10.1177/14614448211021045>.
- Moor, Joost de, Michiel De Vydt, Katrin Uba, and Mattias Wahlstrom. 2020. "New Kids on the Block: Taking Stock of the Recent Cycle of Climate Activism." *Social Movement Studies*. <https://doi.org/10.1080/14742837.2020.1836617>.
- Munk, Anders Kristian. 2019. "Four Styles of Quali-Quantitative Analysis: Making Sense of the New Nordic Food Movement on the Web." *Nordicom Review* 40 (s1): 159–76. <https://doi.org/10.2478/nor-2019-0020>.
- Munk, Anders Kristian, Axel Meunier, and Tommaso Venturini. 2019. "Data Sprints: A Collaborative Format in Digital Controversy Mapping." In *DigitalSTS*, edited by Janet Vertesi, David Ribes, Carl DiSalvo, Yanni Loukissas, Laura Forlano, Daniela K. Rosner, Steven J. Jackson, and Hanna Rose Shell, 472–96. A Field Guide for Science & Technology Studies. Princeton University Press. <https://www.jstor.org/stable/j.ctvc77mp9.34>.
- Murru, Maria Francesca, and Stefania Vicari. 2021. "Memetising the Pandemic: Memes, Covid-19 Mundanity and Political Cultures." *Information, Communication & Society* 0 (0): 1–20. <https://doi.org/10.1080/1369118X.2021.1974518>.
- Nabity-Grover, Teagen, Christy MK Cheung, and Jason Thatcher. 2022. "I'll (Not) Be Home for Christmas: The Impact of the Pandemic on Evaluation Apprehension and Self-Disclosure during the 2020 Holidays." In *HICSS*, 1–10. <https://doi.org/10.24251/HICSS.2022.067>.
- Nabity-Grover, Teagen, Christy MK Cheung, and Jason Bennett Thatcher. 2020. "Inside out and Outside in: How the COVID-19 Pandemic Affects Self-Disclosure on Social Media." *International Journal of Information Management* 55: 102188. <https://doi.org/10.1016/j.ijinfomgt.2020.102188>.
- Narayanan, Arvind, and Vitaly Shmatikov. 2006. "How To Break Anonymity of the Netflix Prize Dataset." *ArXiv:Cs/0610105*, October. <http://arxiv.org/abs/cs/0610105>.
- NESH, The National Committee for Research Ethics in the Social Sciences and the Humanities. 2019. "A Guide to Internet Research Ethics." Etikkom. 2019. <http://www.etikkom.no/en/ethical-guidelines-for-research/ethical-guidelines-for-internet-research/>.
- Nissenbaum, Helen. 2011. "A Contextual Approach to Privacy Online." *Daedalus* 140 (4): 32–48. [https://doi.org/10.1162/DAED\\_a\\_00113](https://doi.org/10.1162/DAED_a_00113).
- Norman, Don. 2013. *The Design of Everyday Things: Revised and Expanded Edition*. 2nd ed. New York, New York: Basic Books.
- Norman, Donald A. 1988. *The Psychology of Everyday Things*. The Psychology of Everyday Things. New York, NY, US: Basic Books.
- Okoli, Chitu, Mohamad Mehdi, Mostafa Mesgari, Finn Årup Nielsen, and Arto Lanamäki. 2014. "Wikipedia in the Eyes of Its Beholders: A Systematic Review of Scholarly Research on Wikipedia Readers and Readership." *Journal of the Association for Information Science and Technology* 65 (12): 2381–2403. <https://doi.org/10.1002/asi.23162>.
- Omena, Janna Joceli, Lorena Cano-Orón, Beatrice Gobbo, and Ana Marta Flores. 2022. "What Are Data Sprints For?" *Dígitos. Revista de Comunicación Digital*, no. 8: 9–30. <https://doi.org/10.7203/drdcd.v1i8.253>.

- Ooghe-Tabanou, Benjamin, Mathieu Jacomy, Paul Girard, and Guillaume Plique. 2018. "Hyperlink Is Not Dead!" In *Proceedings of the 2Nd International Conference on Web Studies*, 12–18. WS.2 2018. New York, NY, USA: ACM. <https://doi.org/10.1145/3240431.3240434>.
- Orlikowski, Wanda J. 2007. "Sociomaterial Practices: Exploring Technology at Work." *Organization Studies* 28 (9): 1435–48. <https://doi.org/10.1177/0170840607081138>.
- Orlikowski, Wanda J., and Susan V. Scott. 2008. "10 Sociomateriality: Challenging the Separation of Technology, Work and Organization." *Academy of Management Annals* 2 (1): 433–74. <https://doi.org/10.5465/19416520802211644>.
- Ottinger, Gwen. 2010. "Buckets of Resistance: Standards and the Effectiveness of Citizen Science." *Science, Technology, & Human Values* 35 (2): 244–70. <https://doi.org/10.1177/0162243909337121>.
- Özkula, Suay Melisa. 2019. "The Issue of 'Context': Data, Culture, and Commercial Context in Social Media Ethics." *Journal of Empirical Research on Human Research Ethics*, September, 1556264619874646. <https://doi.org/10.1177/1556264619874646>.
- Pearce, Warren, Sabine Niederer, Suay Melisa Özkula, and Natalia Sánchez Querubín. 2019. "The Social Media Life of Climate Change: Platforms, Publics, and Future Imaginaries." *Wiley Interdisciplinary Reviews: Climate Change* 10 (2): e569. <https://doi.org/10.1002/wcc.569>.
- Perrault, S. 2013. *Communicating Popular Science: From Deficit to Democracy*. Springer.
- Perriam, J., A. Birkbak, and A. Freeman. 2019. "Digital Methods in a Post-API Environment." *International Journal of Social Research Methodology*. <https://doi.org/10.1080/13645579.2019.1682840>.
- Pflugfelder, E.H., and A. Mahmou-Werndli. 2021. "Impacts of Genre and Access on Science Discussions: The New Reddit Journal of Science." *Journal of Science Communication* 20 (5): 1–21. <https://doi.org/10.22323/2.20050204>.
- Pielke, Roger A. 2007. *The Honest Broker: Making Sense of Science in Policy and Politics*. Cambridge University Press.
- Plantin, Jean-Christophe, Carl Lagoze, Paul N Edwards, and Christian Sandvig. 2018. "Infrastructure Studies Meet Platform Studies in the Age of Google and Facebook." *New Media & Society* 20 (1): 293–310. <https://doi.org/10.1177/1461444816661553>.
- Proferes, Nicholas, Naiyan Jones, Sarah Gilbert, Casey Fiesler, and Michael Zimmer. 2021. "Studying Reddit: A Systematic Overview of Disciplines, Approaches, Methods, and Ethics." *Social Media + Society* 7 (2): 20563051211019004. <https://doi.org/10.1177/20563051211019004>.
- Proferes, Nicholas, and Michael Zimmer. 2014. "A Topology of Twitter Research: Disciplines, Methods, and Ethics." *Aslib Journal of Information Management* 66 (3): 250–61. <https://doi.org/10.1108/AJIM-09-2013-0083>.
- Puschmann, Cornelius, and Christian Pentzold. 2020. "A Field Comes of Age: Tracking Research on the Internet within Communication Studies, 1994 to 2018." *Internet Histories* 0 (0): 1–19. <https://doi.org/10.1080/24701475.2020.1749805>.
- Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the Protection of Natural Persons with Regard to the Processing of Personal Data and on the Free Movement of Such Data, and Repealing Directive 95/46/EC (General Data Protection Regulation) (Text with EEA Relevance)*. 2016. <http://data.europa.eu/eli/reg/2016/679/2016-05-04/eng>.
- Rogers, Richard. 2013. *Digital Methods*. Cambridge, Mass: The MIT Press.
- . 2018. "Digital Methods for Cross-Platform Analysis." In *The SAGE Handbook of Social Media*, by Jean Burgess, Alice Marwick, and Thomas Poell, 91–108. 1 Oliver's Yard, 55 City Road London EC1Y 1SP: SAGE Publications Ltd. <https://doi.org/10.4135/9781473984066.n6>.
- . 2019. *Doing Digital Methods*. Los Angeles, California: SAGE.
- Rogers, Richard, and Noortje Marres. 2000. "Landscaping Climate Change: A Mapping Technique for Understanding Science and Technology Debates on the World Wide Web." *Public Understanding of Science* 9 (2): 141–63. <https://doi.org/10.1088/0963-6625/9/2/304>.

- Rohden, Frauke. 2022. "COVID ONLY ON THURSDAYS: DEALING WITH AN INFODEMIC IN LANGUAGE- AND REGION-BASED ONLINE COMMUNITIES." *AoIR Selected Papers of Internet Research*. <https://doi.org/20230412081748000>.
- Ruhleder, Karen. 2002. "Understanding On-Line Community: The Affordances of Virtual Space." *Information Research* 7 (3): 7–3.
- Ryfe, David, Donica Mensing, and Richard Kelley. 2016. "What Is the Meaning of a News Link?" *Digital Journalism* 4 (1): 41–54. <https://doi.org/10.1080/21670811.2015.1093269>.
- Schäfer, Mike S., Tobias Füchslin, Julia Metag, Silje Kristiansen, and Adrian Rauchfleisch. 2018. "The Different Audiences of Science Communication: A Segmentation Analysis of the Swiss Population's Perceptions of Science and Their Information and Media Use Patterns." *Public Understanding of Science* 27 (7): 836–56. <https://doi.org/10.1177/0963662517752886>.
- Schäfer, Mirko Tobias, and Karin van Es. 2017. *The Datafied Society : Studying Culture through Data*. Amsterdam : Amsterdam University Press.
- Schalkwyk, Francois van, Jonathan Dudek, and Rodrigo Costas. 2020. "Communities of Shared Interests and Cognitive Bridges: The Case of the Anti-Vaccination Movement on Twitter." *Scientometrics*, June. <https://doi.org/10.1007/s11192-020-03551-0>.
- Schmid, Philipp, and Cornelia Betsch. 2022. "Benefits and Pitfalls of Debunking Interventions to Counter mRNA Vaccination Misinformation During the COVID-19 Pandemic." *Science Communication*, October, 10755470221129608. <https://doi.org/10.1177/10755470221129608>.
- Schmidt, Jan-Hinrik. 2014. "Twitter and the Rise of Personal Publics." In *Twitter and Society*, by K Weller, A Bruns, J Burgess, M Mahrt, and C Purschmann. [http://www.schmidtmitdete.de/pdf/01\\_Schmidt\\_Twitter%20and%20the%20Rise%20of%20Personal%20Publics.pdf](http://www.schmidtmitdete.de/pdf/01_Schmidt_Twitter%20and%20the%20Rise%20of%20Personal%20Publics.pdf).
- Scott, Pam, Evelleen Richards, and Brian Martin. 1990. "Captives of Controversy: The Myth of the Neutral Social Researcher in Contemporary Scientific Controversies." *Science, Technology, & Human Values* 15 (4): 474–94. <https://doi.org/10.1177/016224399001500406>.
- Seaver, Nick. 2019. "Knowing Algorithms." In *DigitalSTS*, edited by Janet Vertesi, David Ribes, Carl DiSalvo, Yanni Loukissas, Laura Forlano, Daniela K. Rosner, Steven J. Jackson, and Hanna Rose Shell, 412–22. A Field Guide for Science & Technology Studies. Princeton University Press. <https://www.jstor.org/stable/j.ctvc77mp9.30>.
- "Seealsology." n.d. Accessed August 12, 2023. <https://densitydesign.github.io/strumentalia-seealsology/>.
- Severo, M., and T. Venturini. 2016. "Intangible Cultural Heritage Webs: Comparing National Networks with Digital Methods." *New Media and Society* 18 (8): 1616–35. <https://doi.org/10.1177/1461444814567981>.
- Sismondo, Sergio. 2011. *An Introduction to Science and Technology Studies*. John Wiley & Sons.
- solutioneering. 2021. "Evolving the Best Sort for Reddit's Home Feed." Reddit Post. *R/Blog*. [https://www.reddit.com/r/blog/comments/o5tjcn/evolving\\_the\\_best\\_sort\\_for\\_reddits\\_home\\_feed/](https://www.reddit.com/r/blog/comments/o5tjcn/evolving_the_best_sort_for_reddits_home_feed/).
- Soßdorf, Anna, and Viktor Burgi. 2022. "'Listen to the Science!'—The Role of Scientific Knowledge for the Fridays for Future Movement." *Frontiers in Communication* 7. <https://doi.org/10.3389/fcomm.2022.983929>.
- Squirrell, Tim. 2018. "Reddit Is the Best Social Media Site Because It Gets Community Right." *Quartz*, August 14, 2018. <https://qz.com/1309562/reddit-is-the-best-social-media-site-because-it-gets-community-right/>.
- . 2019. "Platform Dialectics: The Relationships between Volunteer Moderators and End Users on Reddit." *New Media & Society* 21 (9): 1910–27. <https://doi.org/10.1177/1461444819834317>.
- . 2020. "Interplay of Authority and Expertise in Online Self-Improvement Communities." The University of Edinburgh. <https://era.ed.ac.uk/handle/1842/37283>.

- Star, Susan Leigh, and James R. Griesemer. 1989. "Institutional Ecology, 'Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39." *Social Studies of Science* 19 (3): 387–420. <https://doi.org/10.1177/030631289019003001>.
- Stengler, Erik. 2015. "Studying Science Communication," September. <https://uwe-repository.worktribe.com/output/828476>.
- Suchman, Lucy. 1987. *Plans and Situated Actions: The Problem of Human-Machine Communication*. Cambridge university press.
- Sugimoto, Cassidy R., Sam Work, Vincent Lariviere, and Stefanie Haustein. 2017. "Scholarly Use of Social Media and Altmetrics: A Review of the Literature." *Journal of the Association for Information Science and Technology* 68 (9): 2037–62. <https://doi.org/10.1002/asi.23833>.
- Svensson, Patrik. 2010. "The Landscape of Digital Humanities." *Digital Humanities Quarterly* 4 (1). <https://www.proquest.com/docview/2555208348/abstract/73A97407841344D4PQ/1>.
- Trench, Brian. 2006. "SCIENCE COMMUNICATION AND CITIZEN SCIENCE: HOW DEAD IS THE DEFICIT MODEL?" *9th International Conference on Public Communication of Science and Technology (PCST)* Seoul, South Korea.
- Trevor Pinch and Wiebe Bijker. 1984. "The Social Construction of Facts and Artefacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other." *Social Studies of Science*, no. 3 (August): 399–441. <https://doi.org/10.1177/030631284014003004>.
- Utz, Sonja, Franziska Gaiser, and Lara N. Wolfers. 2022. "Guidance in the Chaos: Effects of Science Communication by Virologists during the COVID-19 Crisis in Germany and the Role of Parasocial Phenomena." *Public Understanding of Science*, May, 09636625221093194. <https://doi.org/10.1177/09636625221093194>.
- Venturini, Tommaso, Liliana Bounegru, Jonathan Gray, and Richard Rogers. 2018. "A Reality Check(List) for Digital Methods." *New Media & Society* 20 (11): 4195–4217. <https://doi.org/10.1177/1461444818769236>.
- Venturini, Tommaso, Mathieu Jacomy, and Pablo Jensen. 2019. "What Do We See When We Look at Networks."
- Venturini, Tommaso, and Anders Kristian Munk. 2021. *Controversy Mapping: A Field Guide*. Cambridge, UK ; Medford, MA, USA: Polity.
- Venturini, Tommaso, and Richard Rogers. 2019. "'API-Based Research' or How Can Digital Sociology and Journalism Studies Learn from the Facebook and Cambridge Analytica Data Breach." *Digital Journalism* 7 (4): 532–40. <https://doi.org/10.1080/21670811.2019.1591927>.
- Vertesi, Janet. 2014. "Seamful Spaces: Heterogeneous Infrastructures in Interaction." *Science, Technology, & Human Values* 39 (2): 264–84. <https://doi.org/10.1177/0162243913516012>.
- . 2019. "From Affordances to Accomplishments:: PowerPoint and Excel at NASA." In *DigitalSTS*, edited by Janet Vertesi, David Ribes, Carl DiSalvo, Yanni Loukissas, Laura Forlano, Daniela K. Rosner, Steven J. Jackson, and Hanna Rose Shell, 369–92. A Field Guide for Science & Technology Studies. Princeton University Press. <https://www.jstor.org/stable/j.ctvc77mp9.28>.
- Vertesi, Janet, and David Ribes. 2019. *DigitalSTS: A Field Guide for Science & Technology Studies*. Princeton University Press.
- Voss, Jakob. 2005. "Measuring Wikipedia." In *Proceedings of the ISSI 2005 conference*. <http://eprints.rclis.org/6207/>.
- Waldherr, Annie, Daniel Maier, Peter Miltner, and Enrico Günther. 2017. "Big Data, Big Noise: The Challenge of Finding Issue Networks on the Web." *Social Science Computer Review* 35 (4): 427–43. <https://doi.org/10.1177/0894439316643050>.
- Walsh, Melanie. 2021. "Introduction to Cultural Analytics & Python." Jupyter Notebook. <https://doi.org/10.5281/zenodo.4411250>.
- Ward, Alie. 2019. *Disinfectiology (BLEACH) with Evan Rumberger*. <https://open.spotify.com/episode/4SnlipyJWOLV7XWfDPPpq>.

- Weltevrede, Esther, and E Borra. 2016. "Platform Affordances and Data Practices: The Value of Dispute on Wikipedia." *Big Data & Society*, no. 1: 205395171665341. <https://doi.org/10.1177/2053951716653418>.
- WHO, World Health Organization. 2020. "Novel Coronavirus(2019-NCov) Situation Report - 13." <https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200202-sitrep-13-ncov-v3.pdf>.
- Wiles, Siouxsie, and Toby Morris. 2020. *English: Flattening the Curve*. Spinoff.co.nz. [https://commons.wikimedia.org/wiki/File:Covid-19\\_flatten\\_the\\_curve\\_-\\_cropped\\_version\\_%28no\\_cartoon%29.gif](https://commons.wikimedia.org/wiki/File:Covid-19_flatten_the_curve_-_cropped_version_%28no_cartoon%29.gif).
- Wilkinson, Clare. 2021. "Neglected Spaces in Science Communication." *Journal of Science Communication* 20 (1): C01. <https://doi.org/10.22323/2.20010301>.
- Windfeldt, Louise. 2020. "Activists as Alternative Science Communicators. The NGO 'Danish Seed Savers': Science Communicators and Activists but Questionably Alternative." *Journal of Science Communication* 19 (6): C05. <https://doi.org/10.22323/2.19060305>.
- Woiwode, Hendrik, and Anna Froese. 2020. "Two Hearts Beating in a Research Centers' Chest: How Scholars in Interdisciplinary Research Settings Cope with Monodisciplinary Deep Structures." *Studies in Higher Education* 0 (0): 1–15. <https://doi.org/10.1080/03075079.2020.1716321>.
- Wyatt, Sally. 2021. "Metaphors in Critical Internet and Digital Media Studies." *New Media & Society* 23 (2): 406–16. <https://doi.org/10.1177/1461444820929324>.
- Wyatt, Sally, Jess Bier, Anna Harris, and Bas van Heur. 2013. "Participatory Knowledge Production 2.0: Critical Views and Experiences." *Information, Communication & Society* 16 (2): 153–59. <https://doi.org/10.1080/1369118X.2012.746382>.
- Wynne, Brian. 1989. "Sheepfarming after Chernobyl: A Case Study in Communicating Scientific Information." *Environment: Science and Policy for Sustainable Development* 31 (2): 10–39. <https://doi.org/10.1080/00139157.1989.9928930>.
- Yang, Zheng. 2021. "Citizen Science Communicators, Boundary-Work and Scientific Authority: Struggle for Discourse Authority between Scientists and the Public in the Digital Media Environment of China." Phd, University of Sheffield. <https://etheses.whiterose.ac.uk/29311/>.
- Yearley, Steven. 2008. "Environmental Action Groups and Other NGOs as Communicators of Science." In *Handbook of Public Communication of Science and Technology*, 159–71. Routledge.
- Zimmer, Michael. 2010. "'But the Data Is Already Public': On the Ethics of Research in Facebook." *Ethics and Information Technology* 12 (4): 313–25. <https://doi.org/10.1007/s10676-010-9227-5>.
- Zook, Matthew, Solon Barocas, danah boyd, Kate Crawford, Emily Keller, Seeta Peña Gangadharan, Alyssa Goodman, et al. 2017. "Ten Simple Rules for Responsible Big Data Research." *PLOS Computational Biology* 13 (3): e1005399. <https://doi.org/10.1371/journal.pcbi.1005399>.

## **Appendix**

Paper 1: Experts, influencers, and amplifiers – Exploring climate movements' hyperlinking practices

Paper 2: A tale of three subreddits – community data practices shaping engagement with COVID-19 on Reddit

Paper 3: Moderating an infodemic – Platform dialectics in coronavirus-related knowing spaces on Reddit





## Experts, influencers, and amplifiers — Exploring climate movements' hyperlinking practices

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Frauke Rohden

### Abstract

While research shows different links between activism and science, little is known about activists engaging in science communication online. Demanding that decision-makers should “listen to the scientists”, the climate movements Fridays for Future (FFF) and Extinction Rebellion (XR) emphasize the role of scientific knowledge in democratic decision-making. Exploring the two movements' hyperlinking practices reveals a difference in the extent and selection of hyperlinks on their websites, pointing to influencer-based communication and focus on popularization of science by FFF and expert-based communication leaning on academic publications by XR, with both movements acting as amplifiers of existing science communication efforts.

### Keywords

Environmental communication; Public engagement with science and technology; Public perception of science and technology

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### Introduction

In 2018, two new climate movements emerged in Europe: the “Fridays for Future” (FFF) student protests initiated by Swedish high school student Greta Thunberg and the “Extinction Rebellion” (XR) civil disobedience protests originating in the UK. Both movements lean heavily on climate science, arguing that “the science is clear” [Extinction Rebellion UK, n.d.] and that policymakers should “listen to the scientists” [Fridays for Future, n.d.(c)]. The groups' use of digital and social media in combination with other protests has created much visibility online and in traditional media, both for the issue of climate change and for scientific studies thereof. This makes the movements interesting examples of activists as science communicators. Their almost zealous and in parts defensive, in parts idealized support of science in general and climate science in particular provokes questions on how the activists connect their demands to scientific knowledge production, and which sources and formats of scientific information they refer to and in turn make visible to their audiences. In this paper, I therefore explore the websites and hyperlinking practices of the FFF and XR movements to examine their role in communicating and amplifying scientific knowledge on the topic of climate change.

## *Two new climate movements*

Fridays for Future originated in August 2018 with the Swedish teenager Greta Thunberg going on a weekly “school strike” to demand climate action from the Swedish parliament. Other students joined, and the movement soon spread beyond Sweden. Students are joining protests and demonstrations on Fridays instead of attending school, pointing to the discrepancy between learning information about climate change in school and the lack of political action to reach agreed-upon climate goals. The movement is organized loosely on an international level and argues that it is the role of politicians and experts to figure out exactly what change is needed, refraining from commenting on policy themselves. The group’s demands are: “1. Keep the global temperature rise below 1.5°C compared to pre-industrial levels. 2. Ensure climate justice and equity. 3. Listen to the best united science currently available.” [Fridays for Future, n.d.(b)].

Extinction Rebellion originated in the United Kingdom in May 2018. The group uses nonviolent forms of protest. It received international media attention for elaborately orchestrated and highly visible acts of civil disobedience, for example blocking infrastructure or staging “die-ins” to point to issues of biodiversity loss, social injustices in relation to climate change, and the dangers associated with greenhouse gas emissions. Their demands are: “1. Tell The Truth — Government must tell the truth by declaring a climate and ecological emergency, working with other institutions to communicate the urgency for change. 2. Act Now — Government must act now to halt biodiversity loss and reduce greenhouse gas emissions to net zero by 2025. 3. Beyond Politics — Government must create and be led by the decisions of a Citizens’ Assembly on climate and ecological justice.” [Extinction Rebellion, n.d.].

The two movements were initially chosen for their similarities with an intention of comparing their practices. Both are European, both were established in 2018, both work with global online as well as local real-life activities, both emphasize science to establish the extent, urgency, and legitimacy of the issues they seek to address, and both see democratic decision-making processes as the most important lever to solving them. Both movements have received increased media attention especially throughout 2019, have gathered an international following on social media, and have managed to organize protests and demonstrations across Europe and the world. Both groups have sparked interest among researchers, for questions on studying these movements [e.g. Bevan, Colley and Workman, 2020; de Moor et al., 2020; Feldman, 2020] as well as questions on whether and how scientists should relate to the movements’ demands [e.g. Fraser, 2019; Hagedorn et al., 2019; Mahase, 2019; Mitchell, Rub and Wainwright, 2019; Shah, 2019]. Besides visible engagement with the topic in both mass media as well as scientific outlets, statements of support and scientist-led initiatives such as “Scientists for Future” and “Scientists for Extinction Rebellion” show the close connections to academia the two movements have built. They have in common that they have contributed to current narratives on climate change, providing narratives with a bigger sense of urgency [Bevan, Colley and Workman, 2020]. Both have managed to engage new participant groups in disobedience for political activism (although both are biased towards a more educated part of the population), and both have targeted local and national governments with their activism and the framing of ‘listen to the science’ [de Moor et al., 2020].

At a closer look, however, the groups reveal distinct characteristics, too. They differ in demographics with much younger participants in the FFF student protests. They use different modes of peaceful protest with XR emphasizing highly noticeable acts of civil disobedience to gain media attention and FFF using more traditional protest rallies and school strikes. And finally, the groups differ slightly in their messaging with XR adding the concern of biodiversity loss to the shared concern of climate change.

### *Activism and science communication*

Horst et al. define science communication as “organized, explicit, and intended actions that aim to communicate scientific knowledge, methodology, processes or practices in settings where non-scientists are a recognized part of the audiences” [Horst, Davies and Irwin, 2016, p. 883]. In environments of “post-normal science communication” where boundaries between journalism and science are increasingly blurry [Brüggemann, Lörcher and Walter, 2020], activism emerges as one of many “alternative” [Maesele, 2009] actors in science communication activities. These activities are no longer limited to scientists themselves or formal science communication practices within science journalism or science education. While activists’ use of science for their own sense-making [Fährich, 2018] and their potential role as knowledge-brokers in policy-making processes [Sardo and Weitkamp, 2017] have been explored, their role in public communication of environmental science has only recently come under scrutiny [Faehnrich, Riedlinger and Weitkamp, 2020; Feldman, 2020; Gregory, 2020; Rödder, 2020; Windfeldt, 2020]. NGOs working with environmental issues and environmental action groups can be especially prone to take on a role in communicating scientific information “because empirical claims about the state of the natural environment are core to their message” [Yearley, 2008, pp. 168–169], making them an interesting subject for studying alternative forms of science communication.

Considerations of alliances and blurry lines between science and activism are not new, for example with activists and patient organizations demanding and succeeding to gain influence over the scientific study of diseases [e.g. Epstein, 1996] as “emergent concerned groups” [Callon and Rabearisoa, 2007]. Similarly, grassroots citizen science or civic science movements have emerged around the topic of pollution [e.g. Ottinger, 2010], aligning themselves with selected scientific practices and practitioners to challenge standards and influence decision-makers. In exploring the roles of activists as science communicators, local NGOs acting as “alternative science communicators” have been described as working to reframe or contest the “science-industrial complex” [Maesele, 2009] and aligning with some parts of scientific knowledge production processes in order to challenge others. While similar forms of alliances between concerned groups and scientists exist in various constellations, XR and FFF present an interesting case in their emergence from and support of academic scientists. In contrast to an initial challenge of academic standards or practices as seen in other groups that successfully mobilize connections between scientists and activists, XR and FFF fully embrace and promote established scientific knowledge.

Their close alignment with science and especially climate science also raises questions on the involvement of researchers in these movements within the

scientific community at large. Pielke Jr. [2007] describes four idealized roles that scientists can take on in relation to politics (pure scientist, science arbiter, issue advocate, honest broker). While he sees all four as legitimate options depending on circumstances, he warns against taking on a role as a “stealth issue advocate” politicizing science. Climate scientists and other natural scientists increasingly find themselves facing a decision of whether or not they should join more radical climate movements demanding political changes — and whether ‘radical’ is actually a fitting term for describing them [Fraser, 2019; Shah, 2019]. Statements of support are being offered by academic communities, groups of scientists are publicly joining the movement [Hagedorn et al., 2019; Mahase, 2019], and supporting activist groups named “Scientists for Future” and “Scientists for Extinction Rebellion” have been formed. This indicates an increasing overlap between activists, science communicators, and scientists, with some individuals taking on different roles in different contexts. Interestingly, in this case the ties between activism and science are not motivated by outsiders’ challenges but by widespread support for political demands based on climate science from both within and outside of academic communities, inviting a closer examination of the new climate movements’ communication practices.

### *Social movements online*

Social movements aiming to influence political decision-making are increasingly relying on new communication technologies, in particular social media platforms, to organize themselves, to recruit new members, and to reach large audiences with their demands. Events with widespread social media activity, such as the Arab spring protests in 2011 or the viral spread of the #MeToo hashtag in 2017, have received attention both from the public and from scholars.

Social media platforms allow for “heterogeneous couplings” between scientific and nonscientific actors, objects, and interactions [Costas, Rijcke and Marres, 2020], not formally distinguishing between elements of different form, origin, or content and allowing users to seamlessly move between them. Similarly, hyperlinks can point to different types of contents and resources, and, despite a general turn to platforms, still offer valuable insights for social science research since they can move beyond the ‘gated communities’ of platforms [Ooghe-Tabanou et al., 2018]. However, what users do with this potential for heterogeneity across form, source, and content, can differ vastly between online spaces. An analysis of comments on two English-speaking climate blogs showed that commentators only engaged within like-minded groups and focused on one-way communication [Metcalf, 2020]. In an analysis of German climate change discussions online, generalization across different spaces proved difficult, revealing the presence of various “online public arenas” with overlapping but distinctly different interests and commenting practices [Lörcher and Taddicken, 2017].

Despite the growing interest in these types of online interactions, there is surprisingly little research on the use of digital information and communication technologies in activist movements for sustainability or environmental issues, as well as related online communities. In part, this might be due to some of these movements’ extreme focus on the local [Kenis and Mathijs, 2014]. In research on agricultural practices, Vallauri [2014] concludes that online communities might

enhance but not replace communal activities and quotes a website coordinator who wants participants “to switch off their laptops and come meet us in the neighbourhood!” Nevertheless, newer climate movements such as FFF and XR in Europe or 350.org in the U.S.A. increasingly rely on digital media to coordinate and communicate their efforts. While the movements have received some attention in the academic literature [Bevan, Colley and Workman, 2020; de Moor et al., 2020; Mitchell, Rub and Wainwright, 2019], their online presences have, despite being an important part of the movements’ abilities to gain public attention, not yet been explored as part of their science communication activities.

### *Aim and research questions*

Both FFF and XR engage in discussions about climate science as well as the role of scientific knowledge in democratic decision-making. Together with their highly visible online activities, this makes them interesting examples of alternative science communicators in online settings. The aim of this paper is to contribute to a better understanding of the two groups’ activities in the context of online science communication and to examine what sources these groups refer to as ‘the science’ emphasized in their demands. By exploring the online communication activities on the websites of both XR and FFF, I want to answer the following research questions:

1. What is the role of scientific information on the movements’ websites?
2. How do the movements make use of existing forms of science communication?
3. How do the movements act as alternative science communicators?

## **Methods**

Costas, Rijcke and Marres [2020] describe how social media platforms allow heterogeneous couplings between scientific and nonscientific actors, objects, and interactions. Similarly, hyperlinks remain an important part of web infrastructure even in the age of social media platforms [Ooghe-Tabanou et al., 2018]. They can point to different types of content online, allowing the curation of collections that refer to a wide variety of media formats, sources, and topics and making these available to other users. As climate movements create such collections of hyperlinks related to climate science on their websites, they build on a variety of existing formats and sources of science communication, selecting, assembling, and amplifying them to build their own communication strategy. To analyze the role and types of references to science used by XR and FFF, I have conducted a website analysis and a detailed analysis of hyperlinks found on the movements’ websites as described below. All data was collected on 2020-09-09 and analyzed in the weeks thereafter, with some additional analysis conducted on the collected materials in August 2021.

### *Website analysis*

To examine the referencing practices of new European climate movements, I explored the websites of the two movements ‘Fridays for Future’ (FFF) and

**Table 1.** Number of hyperlinks by website sections

Page sections	FFF	XR UK
contact information	400	290
events	135	
resources for members	7	208
about	18	29
issue — climate & biodiversity	7	871
issue — democracy		31
issue — finances		30
<b>Total hyperlinks</b>	<b>567</b>	<b>1459</b>

‘Extinction Rebellion’ (XR).<sup>1</sup> After examining the overall structure and appearance of the websites, I extracted xml sitemaps to get an overview of the sites’ pages and contained hyperlinks. These were then used to identify sections of the websites that contain more static content (as opposed to sections with frequent changes such as news or press releases) to capture core interests of the movements rather than short-lived campaigns or news items. In addition to the version of the websites scraped for hyperlinks, I explored the history of both websites using the Internet Archive Wayback Machine<sup>2</sup> to examine the development of the pages over time and to verify that the selected static website sections indeed remain stable over a longer time.

The central websites of the two examined climate movements only present a small glimpse into their online activities. For both XR and FFF, the websites serve as a hub to link to resources, ongoing events and campaigns, and most importantly contact information for local groups. Dynamic content on these websites, the change of the sites over time, content of social media activities, and content of local accounts or prominent supporters also are a large part of the movements’ online activities. This study was limited to an analysis of more static website content to capture core science communication activities of the movements that remain more stable over time, rather than more dynamic social media content or news or event pages with frequent changes. Neither the reasons behind the selection of certain links nor the sites’ policies of content creation were explored as part of this study, focusing instead on the results of activist movements’ science communication practices as they are visible online to both human and machine (e.g. search engine crawlers) visitors of the websites.

### *Hyperlink analysis*

After mapping the structure of both websites, I used the DMI link ripper<sup>3</sup> tool to harvest all hyperlinks from selected static content sections of the websites, collecting a total of 2026 hyperlinks. Table 1 shows an overview of the website sections with corresponding numbers of hyperlinks.

<sup>1</sup>Initially, the international websites (fridaysforfuture.org, rebellion.global) were considered; however, with more content and being the starting point of the movement, the UK website for XR (now extinctionrebellion.uk, previously rebellion.earth) was used for the study.

<sup>2</sup><https://archive.org/web/web.php>.

<sup>3</sup><https://wiki.digitalmethods.net/Dmi/ToolLinkRipper>.

I then explored the hyperlinks in detail, following a ‘haystack to needle’ approach [Hagen and Jokubauskaitė, 2020], considering and categorizing all domain names captured in the dataset instead of searching for known sources or relying on URL-names alone, in order to get a detailed picture of the content linked to by the two movements. I manually examined all collected links for the source (i.e., the person or organization providing the content), the media format, and the topic of linked webpages. When encountering broken links, I tried to find archived versions using the Internet Archive Wayback Machine.

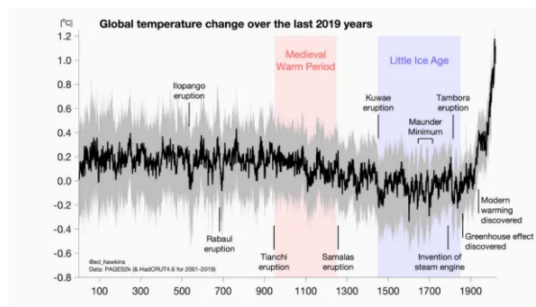
Subsequently, I grouped all links into categories in an inductive and iterative process considering sources, formats, and topics. I grouped the different formats into three overarching media types: text dissemination, multimedia dissemination, and interactive media. Since there was a significant overlap between the categories of formats and sources (e.g., most academic texts stem from academic sources), I chose to report the most frequently named individual sources instead of the categorizations. Additionally, six topics emerged from the categorization of links.

Duplicates were not removed from the results since they did not occur at a significant rate. However, some sources such as IPCC reports are cited more than once, and some sources were linked in different formats (e.g., a pdf document and a landing page for the same report, or a press release and the article page for the same scientific publication). Not removing these duplicates presents the weight of the hyperlinks as used on the page, results might differ slightly if only checking for unique content linked.

## Results

The Fridays for Future and Extinction Rebellion websites are similar and fulfill similar functions. For both Fridays for Future and Extinction Rebellion, the websites serve as a hub to point to resources, to link to social media accounts from global and local accounts, and to invite visitors to join national and local groups. While the movements overall are present on many different social media platforms, the smaller subgroups often use only one or a smaller selection of platforms, and do not necessarily have websites on their own, making the overarching international websites a key point of reference for them as well. Both groups offer information about the movement and their demands and provide materials to engage with politicians locally or start own branches of the movements and both offer scientific background information on climate change, although the amount, sources, and formats differ distinctly. The two groups’ websites are similar in their structure and visual appearance. The contact pages of both websites are among those with the largest amounts of hyperlinks. Many of the links in the contacts, events, and resources sections lead to social media platforms or pages internal to each group. They indicate the strong emphasis on local subgroups for both XR and FFF. Both movements also link up with dedicated partner movements by scientists (Scientists for Future and Scientists for Extinction Rebellion). Table 1 above shows a detailed overview of the websites’ structures and number of hyperlinks contained in each section.

The analysis of older versions of each website reveals that XR used a professional-looking web design from the start and gave detailed scientific information on a page labeled “the emergency” that was eventually split into several pages in the version of the website analyzed here. While the XR page has



Source:  
<https://www.climate-lab-book.ac.uk>

Each of the last three decades has been successively hotter than the one before, 19 of the top 20 hottest years have occurred in the last 19 years, and the past four years have been the hottest on record. 2016 was the hottest year ever recorded, whilst in 2019, nearly 400 temperature records were broken across 29 countries, June 2019 was the hottest on record, and July 2019 was the hottest month ever recorded. As of July 2020, January 2020 was the warmest January ever recorded in Europe, we saw the hottest May ever and we already have an 85% chance that 2020 will turn out to be the hottest year on record.



**Figure 1.** Part of the XR website archived at <https://web.archive.org/web/20200919230926/https://extinctionrebellion.uk/the-truth/the-emergency/part-1/>.

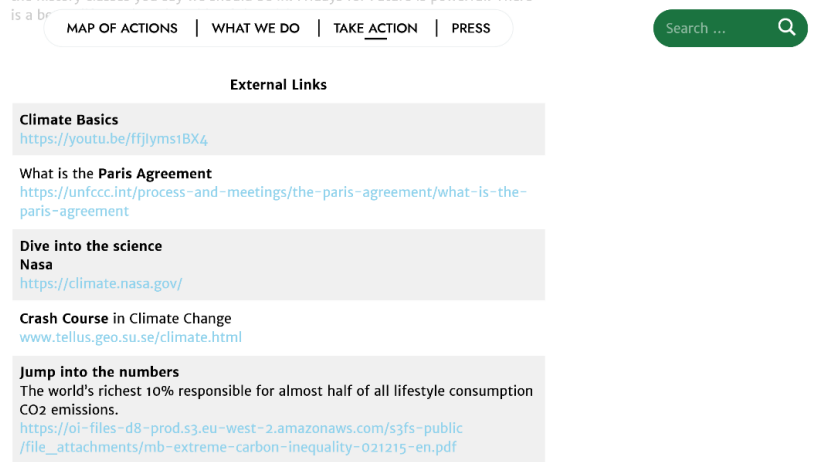
seen only slight changes and mainly additions to its content, the FFF website started out less structured and looking less professionally edited, with content spread out across different subpages and a menu-item called “more” containing much of the information through several layers of subpages. The navigation and layout of the page was changed completely from the original version to the version analyzed here, offering a more easily navigable menu structure with a section on “reasons to strike” similar to the “the emergency” section of the XR website. The following analysis refers to the websites at the time of data collection (September 2020).

### *The role of scientific information on the climate movements’ websites*

Notably, the XR website contains almost 900 links on their pages related to climate change and biodiversity loss, pointing to scientific evidence for the movements’ claims about the issues at stake and their urgency. These pages contain a lot of information, texts, graphs, and hyperlinks to sources about the issue of global warming, stating that “the science is clear” and quoting scientists and internationally known authority figures. Websites of national groups can be found through a map of “branches” in different parts of the world, and provide more content in other languages, still following the same design and similar structure as that of the main website, showing a structured organization and close links between the original group and local branches. The group demands the creation of citizen assemblies for democratic decision-making to curb the effects of global climate change [Extinction Rebellion, n.d.] and uses their website to expand on these demands and provide detailed background information on the issue. Large parts of the website contain graphs and long text elements with hyperlinks connected to sections in the text as a form of referencing (see Figure 1 for an example).

For FFF, the substantial number of contact information links indicates that the main





**Figure 2.** Part of the FFF website archived at <https://web.archive.org/web/20200919152312/https://fridaysforfuture.org/take-action/reasons-to-strike/>.

purpose of the website seems to be pointing visitors to relevant local subgroups. The website contains a prominently displayed large table of contact information and social media links to various subgroups in different countries. Fridays for Future also provides a lot of information in video format, and publishes speeches held by young climate activists including Greta Thunberg. The websites of national initiatives linked here have unique designs and structures, pointing to more independent, loosely connected groups in the different countries. In their frequently asked questions, the organization states “Fridays for Future does not have the capacity or the competence to evaluate solutions. If you have a solution, we therefore urge you to send your contribution to those who do, so that it can be put to use” [Fridays for Future, n.d.(a)] implying a responsibility of local, national and international policymakers and decisionmakers for evaluating and implementing solutions to climate change. Figure 2 shows an example of a collection of links from the FFF website.

### *Forms of science communication accessed and shared by the climate movements*

The hyperlinks collected from the two climate movements’ websites point to a wide range of different online resources. These were categorized for their affiliation with various sources, their media formats, and the topics they contained.

### Sources referred to

Both XR and FFF refer to a wide variety of sources. Appendix A contains a list of the most frequently referenced domain names by each organization. For XR, 28 domain names linked 10 or more times account for 62% of all outgoing hyperlinks. For FFF, 6 domain names linked 10 or more times account for 86% of all hyperlinks. This shows a higher concentration of links towards fewer sources for FFF, where social media platforms, e-mail addresses, YouTube videos, and references to the own website make up the bulk of all collected links, the main part of which refer visitors to local subgroups of the movement. XR, in addition to social media and

e-mail links, refers to a wide variety of sources including news websites, academic publishers and journals, popular (climate) science outlets, and many more, with many sources referenced only a few times.

Of the links not used for contact information purposes, for FFF, many links go to social media platforms and videos where categorizing the source is challenging. Many can be summarized as leading to “influencers”, with talks and presentations about climate change e.g., by Naomi Klein, a playlist of speeches by Greta Thunberg and other young climate activists, as well as popular science representations such as a video “Climate Science: what You Need To Know” produced for publication on YouTube by American public broadcaster PBS. Other sources include other activist movements and NGOs. One link goes to the climate section on the NASA website.

For XR, the picture is different, both in the much larger number of links to scientific information and the type of sources used overall: links to e-mail addresses and Facebook as well as XR’s own website are occurring frequently, linking users to local groups and resources of the movement. However, substantial amounts of links also point to academic sources such as academic journals or publishers. Additionally, links to governmental and large intergovernmental organizations, for example the UN and its different organs, national governments, or national offices and ministries occur frequently. Other sources include organizations dedicated to policymaking or research for political decision-making such as NASA and the IPCC but also think tanks and research alliances. One group of links points to various news organizations (including large international, smaller local, and special interest news organizations), organizations engaged in popular science and education (including Wikipedia, a range of blogs and education websites about climate change, museums, and popular science magazines). Finally, XR links to a small number of other activist movements and NGOs.

### Formats referred to

Both FFF and XR make use of a wide range of different communication formats in the links they refer to, making full use of the heterogeneity that hyperlinks permit. Nevertheless, some formats occur more frequently than others. I have grouped the different communication formats into three broad categories: text dissemination, multimedia dissemination, and interactive media. A detailed overview of the categories and subcategories is shown in appendix B.

The group named text dissemination refers to sources that focus on information in textual format, mainly comprised of academic articles and policy reports, but also including news, education, and popular science formats if they are text-based (e.g., blog posts). This category accounts for 4% (22 links) of hyperlinks from FFF and a majority of 58% (841 links) of hyperlinks from XR. Both groups also include links to crowdsourced texts such as shared documents or wiki articles, the majority of which stem from the organizations themselves and provide materials to support activists.

Multimedia dissemination comprises video and visual content as well as social media content (e.g., individual tweets or posts) and social media collections (e.g.,

links to a tag, topic, or playlist). For FFF, 16% (90) of the outgoing hyperlinks fall under this category. For XR, it covers 18% (261) of the outgoing links.

In both text and multimedia dissemination, interactive options such as commenting or sharing functions might be available but in each case the emphasis lies on relating information to the audience. In the third category, interactive media, the emphasis moves instead to interacting with the audience or getting the audience to take action. This includes explicit requests to volunteer or donate, calls to participate in specific campaigns, e-mail addresses and forms allowing viewers to get into contact with specific parts of the movements, and links to social media profiles implicitly requesting that users follow, befriend, or share content. For FFF, this category makes up 79% (446) of all outgoing links, whereas for XR it only accounts for 22% (326) of the links.

When referring to scientific information, FF mainly links to social media platforms and audio-visual content, with many links to YouTube videos. Extensive lists of links to national groups of the organization with different e-mail addresses and social media profiles make up the majority of hyperlinks on the page, indicating a less involved or less direct approach in communicating science from their website. Few academic texts are directly linked from the FFF website and dissemination of information makes use of various multimedia formats.

For XR, the largest group of formats is academic texts (mainly published journal articles, but also including pre-prints, working papers, or detailed data-analyses), closely followed by a large number of news texts (such as news articles and blog posts). Other text formats such as various reports and briefings as well as collaboratively created documents containing resources for XR members are also linked extensively from the website. Overall, dissemination of information through text makes up a large part of hyperlinks by XR. Multimedia dissemination seems less common for XR than for FFF. XR also provides contact information and social media profiles but these interactive media formats dominate less than they do for FFF.

### Topics referred to

General information about climate science, including information about emissions, temperatures, climate models, and extreme weather, is present on both XR's and FFF's websites but much more prevalent in XR's hyperlinks. For FFF, the biggest group of links leads to e-mail addresses and social media profiles, categorized as contact information. The second-biggest group of links leads to information about political action, including own and other NGOs' campaigns, requests for donation. Only few links point to information on climate science and the societal relevance of climate change and only one link refers to ecosystems. Information on ecosystems and biodiversity was almost exclusively linked to by XR. A large share of the hyperlinks by XR refer to societal issues related to climate change, such as migration or economic costs of climate change. A group of links in this category is concerned with agriculture and food, both as a threat to biodiversity if left unchecked, and a threat to humanity if disrupted. Some links lead to discussions of carbon capturing technologies that emphasize the difficulty and limited potential of such projects. Table 2 contains an overview of topics and categories linked from each site.

**Table 2.** Topics of sources referred from FFF and XR websites.

Topic group	Description	FFF	XR UK
[other]	<i>inaccessible links, rare topics</i>	4	25
Climate science	climate change, modelling, emissions, extreme weather events	7	371
Contact information	e-mail addresses and social media profiles of FFF and XR as well as related groups	470	337
Ecosystems	biodiversity, tipping points, water systems, ice loss	1	212
Political action	politics, sustainability transition, policy processes, activism (including supporting information for activists, own and other campaigns for climate action)	80	258
Societal relevance	Impact of/on climate change for/by society (including agriculture, food, water, health, inequalities, economy, pollution)	5	256
<b>Total</b>		<b>567</b>	<b>1459</b>

Notably, both XR and FFF refer mainly to the natural sciences and discussions of the issues at stake and their urgency, with few links to possible solutions (whether technical, social/behavioral, or political) or to contributions from the social sciences or humanities. Links that serve to establish the issue of climate change as relevant and urgent are more likely to go out to scientific publications (especially for XR) whereas links guiding activists on what to do frequently point to own resources or social media.

## Discussion

This study compared hyperlinking practices on the websites of two European climate movements both established in 2018. Contrasting the two movements' hyperlinking practices paints a picture of two similar interest groups with overlapping goals that have chosen two different styles of communicating about the science of climate change on their websites. While the hyperlinks on XR's website present a more technical, academic, and expertise-based style of communication, FFF employs a more accessible, popular style that relies on local subgroups and figureheads as "influencers". Despite different communication styles in detail, both groups emphasize sources and topics from the natural sciences, both groups act as amplifiers of existing science communication practices, and both groups show indications of being both alternative actors as well as alternative outlets for science communication.

### *What is the role of scientific information on the movements' websites?*

Both the FFF and XR websites contain information about climate science and the impact of climate change on social and ecological systems. And both movements emphasize the role of scientific knowledge in informing democratic decision-making in their demands. However, the role of scientific knowledge on the websites differs slightly between the two groups. For FFF, the bulk of the hyperlinks from the website refer to contact information for local subgroups in different countries and regions. The second-largest group of links contains

information on political action. A much smaller number of hyperlinks on the topics of climate science and climate change, together with the reliance on multimedia formats and well-known figures or 'influencers', indicates a more indirect science communication approach. Direct science communication efforts only make up a small part of the FFF website, the main purpose of which seems to be the collection of contact information for affiliated groups (who may be engaging in science communication as part of their online activities). The XR website also presents contact information for subgroups and information on political action, acting as a central information hub for the affiliated groups similar to the FFF website. Additionally, however, the XR website contains large numbers of hyperlinks on climate science, ecosystems, and the impact of climate change on societies, often linking directly to scientific publications or policy reports. These links occur as part of long and elaborate texts on the issues and represent a more direct science communication effort created by the group itself.

The content linked from the two movements' websites mainly refers to texts (for XR), and texts or multimedia content from authoritative sources, rather than databases, citizen science projects, or crowdsourced documents (which do occur but given the political ambitions of participation of the groups, might have been expected to play a bigger role). While links on the issue of climate change point to a range of prestigious academic sources, many links on political activism lead to other activist groups or collaborative documents by the movements. Discussions of potential ways to address climate change (technical or social), studies of existing or possible transition processes, knowledge about behavioral change, or other insights from a wider range of academic disciplines could have been underlined in a similar way by academic literature yet are largely absent from the examined websites.

Both movements provide only schematic answers to questions of which expertise should be involved in tackling global challenges, repeating the slogans of "Listen to the scientists" (FFF) and "The science is clear" (XR). Both XR and FFF refer to a generic image of "the science", that is unambiguous in the identification of the problem of climate change (along with biodiversity loss and problems of social justice) and seen as the correct group of experts to identify and characterize the problem. Interestingly, despite the movements' emphasis on 'the science', the IPCC reports considered the main source of academic consensus on climate change only feature as one of many sources with XR and are not directly linked at all by FFF. XR seem to undertake an own summary of different academic sources concerned with climate change, biodiversity loss, and the societal relevance of both on their website. FFF on the other hand refer to other forms of science communication, such as videos or training materials that in turn might reference the IPCC reports, indicating a reliance on more mediated sources of scientific information for FFF and a smaller role of this information on the website compared to XR.

Both groups demand that politicians should take the known threats seriously and plead that states should aim to reach agreed-upon climate goals. As for the expertise of evaluating potential strategies for dealing with climate change, FFF argues on their website that solutions to climate change should be evaluated by scientists giving input to established democratic decision-making processes, whereas XR pushes for the establishment of citizen assemblies to find and evaluate solutions. Neither of the two underline these approaches with further scientific evidence or claims like they do for climate science resources. Both groups attribute

expertise to a generic image of “the scientists”, arguing that this is the group of experts that political decision-makers ought to listen to but remaining somewhat vague [de Moor et al., 2020]. They delegate responsibility for evaluating potential ways of addressing climate change back to experts (FFF) or a citizen assembly to be established (XR). In a (possibly intended) contrast to frequently voiced worries about ‘fact-resistance’ and a perceived loss of trust in science, XR and FFF present a different picture about what they think the role of scientists should be, demanding that decision-makers should recognize the established scientific consensus about threats of climate change, biodiversity loss, and social injustice. At the same time, these movements do not only communicate the content of one area of science but also about the role of science, painting an image of science as giving input to democratic decision-making processes in a perhaps oversimplified way. Considering Pielke’s [2007] description of ideal types of scientists’ roles in political decision-making, many of the scientists linked directly or indirectly to both movements can be seen acting as outspoken ‘issue advocates’ demanding to be heard whereas the representation of science on XR’s and FFF’s websites paints an image closer to an ideal of a ‘pure scientist’ providing input to others’ decision-making as objective experts with little or no interest in the outcome — an idealized role difficult to argue for in the face of all-encompassing threats and urgent need of change in relation to global warming.

#### *How do the movements make use of existing forms of science communication?*

The websites of both XR and FFF can be considered a science communication effort themselves, curating and presenting information about climate science. More than that, however, they act as amplifiers linking to a variety of existing science communication efforts. In line with Yearley’s [2008] description of environmental groups likely taking on roles as science communicators on the state of nature, the links to scientific information by both XR and FFF mainly cover different aspects of climate change and biodiversity loss. Both movements refer to science to establish the extent and urgency of the issue of climate change (and biodiversity loss in the case of XR) and the vast majority of hyperlinks is closely connected to academic research on these issues specifically, amplifying science communication efforts across journalism, academia, activism, and policymaking in this area.

The use of hyperlinks to scientific knowledge on the websites of FFF and XR can be summarized as two distinct styles of science communication. XR engages in a more academically oriented, expertise-based use of hyperlinks, frequently and extensively pointing to academic heavyweight sources such as publications in *Nature* or *Science* or the IPCC reports, while also contributing with a long tail of links to other academic sources. There is a much larger amount of text sources by XR than by FFF. These links are embedded in long and detailed texts on the matter created explicitly for the XR website. FFF on the other hand, refers to more accessible formats, linking to videos and social media content rather than text and using well-known figures as “influencers” to establish trust and credibility of the presented information. FFF also has a more indirect style of science communication, linking less information directly and relying on existing formats as well as local subgroups rather than creating own new communication formats on their website. These different communication styles might align with the different participant demographics of the two movements. Nevertheless, there is an overlap

in the chosen strategies as well. While FFF relies on videos of “influencers”, XR also has a (text-based) section of well-known figures with links to their statements. The examined hyperlinks especially for XR lead to a vast range of formats and sources, covering a variety of academic texts and grey literature but also pointing to science communication formats that target wider audiences such as press releases, newspaper articles, videos, or webcomics.

The side-by-side use of different science communication formats and the different styles of communication by the two movements point to the value of a variety of science communication formats that alternative science communicators can access and share with wider audiences. The two movements use distinctive communication styles but both use their websites and the heterogeneity that hyperlinking allows as a way to contextualize scientific information and to amplify existing science communication formats.

### *How do the movements work as alternative science communicators?*

The activities of XR and FFF show two ways in which scientific research links to activism: firstly, activist groups can take up science to underline their demands, acting as amplifiers for other science communication channels. And secondly, scientists themselves can turn to supporting or establishing activist movements as an outlet of their research activities outside of academia.

Close connections between XR and climate scientists, and related movements of “Scientists for Future” and “Scientists for Extinction Rebellion” referred to by both websites indicate that some academic researchers are leaving behind ideals of neutrality or objectivity in relation to political decision-making and turning activism and science communication into processes that researchers (alongside with other participants) might choose to engage with as a result of their academic work or as outspoken “issue advocates” [Pielke Jr., 2007]. Boundaries between journalism and science are increasingly blurry [Brüggemann, Lörcher and Walter, 2020]. The analysis of the two climate movements’ websites shows that similarly, the boundaries between science, science communication, and activism are also blurring. The websites contain both scientific and political topics and use a variety of sources side-by-side. The heterogeneity of hyperlinks that creates the same visual appearance for links to different formats and sources may contribute to this blurring of boundaries. While XR and FFF might not necessarily consider or name their actions as science communication, they do engage in communicating (climate) science to wider audiences, showcasing how “alternative” [Faehnrich, Riedlinger and Weitkamp, 2020] actors can both make use of and share or amplify existing science communication efforts. At the same time, the movements’ highly educated demographics and the engagement of climate scientists in related and supporting movements suggest that some of these activities could also be characterized as alternative outlets for, rather than actors of, science communication.

The heavy use of academic journal articles and the text format using hyperlinks as references, especially on the XR-UK website additionally hint at an academic orientation of both site creators and intended audiences. This raises questions whether boundaries between “science” and “activism” can be drawn fruitfully. While many accounts exist of activist movements successfully using science, for

example in patient organizations [Callon and Rabearisoa, 2007; Epstein, 1996] or in citizen science projects on pollution [Ottinger, 2010], these accounts frequently see activists as outsiders challenging academic research who eventually gain access and influence in both scientific and political dimensions. XR and FFF on the other hand show close ties to academic communities and extensive efforts to communicate and promote the use of science in political decision-making.

Seen together with indications that these movements have successfully contributed to strategic narratives aimed at increasing support for policy measures to address climate change [Bevan, Colley and Workman, 2020], this points to a strong role of activists as science communicators as also indicated by a series of comments [Faehnrich, Riedlinger and Weitkamp, 2020; Feldman, 2020; Gregory, 2020; Rödder, 2020; Windfeldt, 2020].

## Conclusion

In this study, I have explored the websites and the use of hyperlinks by Fridays for Future and Extinction Rebellion. The two climate movements' online activities lie at an intersection of social movements, online communities, and science communication. I have found that firstly, the two groups engage in two distinctive styles of communication with XR employing an academic, expertise-based use of hyperlinks and FFF emphasizing influencer-based content accessible to general audiences and emphasizing options to interact with local subgroups of the movement through a variety of digital channels. Secondly, both groups refer to a vast range of different resources, mixing different formats and sources of scientific information with a focus on natural sciences and an emphasis on establishing the extent and urgency of the issue. Finally, the two groups retain close ties to academic science and can act as science communicators in two ways: on the one hand by giving scientists a non-academic outlet to draw attention to their research (as indicated by statements of support and scientist-led subgroups of both movements and a close orientation to academic formats especially of XR), and on the other hand by acting as amplifiers of various channels of science communication.

The audiences of the websites and hence the potential reach of these efforts have not been subject of this study. Research indicates that climate science communication efforts risk "chanting to the choir" [Metcalf, 2020]. Further research should examine whether the same applies to activist movements acting as alternative science communicators or whether they succeed in reaching alternative audiences, too. Future research on the use of science by activist movements should also consider the role of social media as another heterogeneous platform linking actors and content without clear demarcations of scientific and other sources and formats. The use of academic science side-by-side with other information and a variety of science communication channels employed by the two movements point to the importance of recognizing the diverse range of activities that science communication can encompass. How audiences of these sites view the presented content has not been part of this study but also deserves consideration. Finally, activism as an outlet for scientists to engage in science communication should receive more attention, for example by following the activities of organizations of scientists aligning themselves with climate movements such as Scientists for Extinction Rebellion, Scientists for Future, or Doctors for Extinction Rebellion.



**Appendix A.  
Most frequently  
referenced  
sources**

Most frequently referenced sources (domains linked to  $\geq 10$  times by either FFF or XR).

domain	FFF	XR UK	Description
mailto	107	88	E-mail addresses
facebook	80	100	Social media
twitter	157	19	Social media
instagram	108	6	Social media
nature	1	98	Academic journal
actionnetwork	2	80	Open online platform for organizing activism
rebellion		76	XR's own website
docs	3	62	Shared documents (Google docs)
youtube	21	30	Videos
ipcc		36	Intergovernmental Panel on Climate Change website
science		33	Academic journal
pnas		31	Academic journal
theguardian		31	News website
carbonbrief		30	Popular climate science
bbc		21	News website
agupubs		18	Academic journal (American Geophysical Union)
climate	1	17	Climate information by US government agencies (NOAA, NASA)
fridaysforfuture	16		FFF's own website
fao	2	13	Food and Agriculture Organization
sciencedirect	1	13	Academic Publisher (Elsevier)
advances		14	Academic Journal
forms		12	Google forms (used as contact forms)
iopscience		12	Academic Journal (Environmental Research Letters)
gov		12	UK-government websites
mckinsey		12	Consultancy
theconversation		11	Popular science/ news
un		11	United Nations websites
theccc		11	UK Committee on Climate Change
thelancet		10	Academic journal
skepticalscience		10	Climate Science Blog
<i>Other hyperlinks</i>	68	542	<i>Domain names referred to less than 10 times each</i>
<b>Total</b>	<b>567</b>	<b>1459</b>	

## Appendix B. Media formats of linked sources from FFF and XR websites

media type summary	media type group	FFF	XR UK
	[other]	9	31
<b>1 text dissemination</b>	academic	5	322
	news	3	225
	Policy (e.g. reports)	6	180
	Crowdsourced (e.g. wiki, shared documents)	8	70
	popular science		44
<b>2 multimedia dissemination</b>	own website (i.e. FFF, XR, including local groups)	38	113
	external website	3	67
	Video	11	44
	social media content (e.g. posts, tweets)	35	4
	Visual	3	33
<b>3 interactive media</b>	social media groups and profiles	328	125
	contact point (e-mail, forms)	108	181
	call to action (e.g. campaigns, donation requests, volunteer or join requests)	9	11
	Feed (e.g. newsletter, RSS feed)	1	9
<b>Total</b>		<b>567</b>	<b>1459</b>

## References

- Bevan, L. D., Colley, T. and Workman, M. (2020). 'Climate change strategic narratives in the United Kingdom: Emergency, Extinction, Effectiveness'. *Energy Research & Social Science* 69, p. 101580. <https://doi.org/10.1016/j.erss.2020.101580>.
- Brüggemann, M., Lörcher, I. and Walter, S. (2020). 'Post-normal science communication: exploring the blurring boundaries of science and journalism'. *JCOM* 19 (03), A02. <https://doi.org/10.22323/2.19030202>.
- Callon, M. and Rabeharisoa, V. (2007). 'The Growing Engagement of Emergent Concerned Groups in Political and Economic Life'. *Science, Technology, & Human Values* 33 (2), pp. 230–261. <https://doi.org/10.1177/0162243907311264>.
- Costas, R., Rijcke, S. and Marres, N. (2020). "'Heterogeneous couplings": Operationalizing network perspectives to study science-society interactions through social media metrics'. *Journal of the Association for Information Science and Technology* 72 (5), pp. 595–610. <https://doi.org/10.1002/asi.24427>.
- de Moor, J., De Vydt, M., Uba, K. and Wahlström, M. (2020). 'New kids on the block: taking stock of the recent cycle of climate activism'. *Social Movement Studies* 20 (5), pp. 619–625. <https://doi.org/10.1080/14742837.2020.1836617>.
- Epstein, S. (1996). *Impure Science: AIDS, Activism, and the Politics of Knowledge*. California, U.S.A.: University of California Press.
- Extinction Rebellion (n.d.). *About Us*. URL: <https://rebellion.global/about-us/> (visited on 1st September 2020).
- Extinction Rebellion UK (n.d.). *Introduction*. URL: <https://extinctionrebellion.uk/the-truth/the-emergency/introduction/> (visited on 4th September 2021).
- Faehnrich, B., Riedlinger, M. and Weitkamp, E. (2020). 'Activists as "alternative" science communicators — Exploring the facets of science communication in societal contexts'. *JCOM* 19 (06), C01. <https://doi.org/10.22323/2.19060301>.

- Fährnich, B. (2018). 'Digging deeper? Muddling through? How environmental activists make sense and use of science — an exploratory study'. *JCOM* 17 (03), A08. <https://doi.org/10.22323/2.17030208>.
- Feldman, H. R. (2020). 'A rhetorical perspective on youth environmental activism'. *JCOM* 19 (06), C07. <https://doi.org/10.22323/2.19060307>.
- Fraser, S. (2019). 'Extinction Rebellion: Who is The BMJ calling radical environmentalists?' *BMJ* 365, p. l2256. <https://doi.org/10.1136/bmj.l2256>.
- Fridays for Future (n.d.[a]). *Fridays for Future — About*. URL: <https://fridaysforfuture.org/about> (visited on 10th September 2020).
- (n.d.[b]). *Fridays for Future — Demands*. URL: <https://fridaysforfuture.org/what-we-do/our-demands/> (visited on 2nd December 2021).
- (n.d.[c]). *Fridays for Future — How Greta started a global movement*. URL: <https://fridaysforfuture.org/what-we-do/who-we-are/> (visited on 4th September 2021).
- Gregory, J. (2020). 'Engaging with 'activists' and 'alternatives' in science communication'. *JCOM* 19 (06), C02. <https://doi.org/10.22323/2.19060302>.
- Hagedorn, G., Loew, T., Seneviratne, S. I., Lucht, W., Beck, M.-L., Hesse, J., Knutti, R., Quaschnig, V., Schleimer, J.-H., Mattauch, L., Breyer, C., Hübener, H., Kirchengast, G., Chodura, A., Clausen, J., Creutzig, F., Darbi, M., Daub, C.-H., Ekardt, F., Göpel, M., N., H. J., Hertin, J., Hickler, T., Köhncke, A., Köster, S., Krohmer, J., Kromp-Kolb, H., Leinfelder, R., Mederake, L., Neuhaus, M., Rahmstorf, S., Schmidt, C., Schneider, C., Schneider, G., Seppelt, R., Spindler, U., Springmann, M., Staab, K., Stocker, T. F., Steininger, K., von Hirschhausen, E., Winter, S., Wittau, M. and Zens, J. (2019). 'The concerns of the young protesters are justified: A statement by Scientists for Future concerning the protests for more climate protection'. *GAIA - Ecological Perspectives for Science and Society* 28 (2), pp. 79–87. <https://doi.org/10.14512/gaia.28.2.3>.
- Hagen, S. and Jokubauskaitė, E. (2020). '6. Dutch junk news on Reddit and 4chan/pol'. In: *The Politics of Social Media Manipulation*. Ed. by R. Rogers and S. Niederer. Amsterdam, The Netherlands: Amsterdam University Press, p. 169.
- Horst, M., Davies, S. R. and Irwin, A. (2016). 'Reframing science communication'. In: *Handbook of Science and Technology Studies*. Ed. by U. Felt, R. Fouché, C. A. Miller and L. Smith-Doerr. 4th ed. Cambridge, MA, U.S.A. and London, U.K.: MIT Press, pp. 881–908.
- Kenis, A. and Mathijs, E. (2014). '(De)politicising the local: The case of the Transition Towns movement in Flanders (Belgium)'. *Journal of Rural Studies* 34, pp. 172–183. <https://doi.org/10.1016/j.jrurstud.2014.01.013>.
- Lörcher, I. and Taddicken, M. (2017). 'Discussing climate change online. Topics and perceptions in online climate change communication in different online public arenas'. *JCOM* 16 (02), A03. <https://doi.org/10.22323/2.16020203>.
- Maesele, P. (2009). 'NGOs and GMOs: a case study in alternative science communication'. *Javnost — The Public* 16 (4), pp. 55–72. <https://doi.org/10.1080/13183222.2009.11009014>.
- Mahase, E. (2019). 'Doctors for Extinction Rebellion: new group fights for planetary and public health'. *BMJ*, p. l2364. <https://doi.org/10.1136/bmj.l2364>.
- Metcalf, J. (2020). 'Chanting to the choir: the dialogical failure of antithetical climate change blogs'. *JCOM* 19 (02), A04. <https://doi.org/10.22323/2.19020204>.

- Mitchell, A., Rub, S. and Wainwright, T. (2019). 'Demanding disruption: Extinction Rebellion and changing psychology'. *Clinical Psychology Forum* 319, pp. 28–33.
- Ooghe-Tabanou, B., Jacomy, M., Girard, P. and Plique, G. (2018). 'Hyperlink is not dead!' In: *Proceedings of the 2nd International Conference on Web Studies*. ACM. <https://doi.org/10.1145/3240431.3240434>.
- Ottinger, G. (2010). 'Buckets of Resistance: Standards and the Effectiveness of Citizen Science'. *Science, Technology & Human Values* 35 (2), pp. 244–270. <https://doi.org/10.1177/0162243909337121>.
- Pielke Jr., R. A. (2007). *The Honest Broker*. Cambridge, U.S.A.: Cambridge University Press.
- Rödder, S. (2020). 'The ambivalent role of environmental NGOs in climate communication'. *JCOM* 19 (06), C03. <https://doi.org/10.22323/2.19060303>.
- Sardo, A. M. and Weitkamp, E. (2017). 'Environmental consultants, knowledge brokering and policy-making: a case study'. *International Journal of Environmental Policy and Decision Making* 2 (3), pp. 221–235. <https://doi.org/10.1504/ijepdm.2017.085407>.
- Shah, D. (2019). 'Viewpoint: Extinction Rebellion: radical or rational?' *British Journal of General Practice* 69 (684), pp. 345–345. <https://doi.org/10.3399/bjgp19x704357>.
- Vallauri, U. (2014). 'Transition Belsize Veg Bag scheme: The role of ICTs in enabling new voices and community alliances around local food production and consumption'. *Futures* 62, pp. 173–180. <https://doi.org/10.1016/j.futures.2014.04.008>.
- Windfeldt, L. (2020). 'Activists as alternative science communicators. The NGO "Danish Seed Savers": science communicators and activists but questionably alternative'. *JCOM* 19 (06), C05. <https://doi.org/10.22323/2.19060305>.
- Yearley, S. (2008). 'Environmental action groups and other NGOs as communicators of science'. In: *Handbook of Public Communication of Science and Technology*. Ed. by M. Bucchi and B. Trench. London, U.K. and New York, U.S.A.: Routledge, pp. 159–171.

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