An HCI Research Agenda for Online Science Communication

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Social media, blogs, podcasts, and other computer-mediated communication technology have become an integral way for the public to access and engage with research. However, despite the evolving challenges researchers face navigating these platforms, and the high stakes of online science communication, relatively little HCI research has focused on understanding and supporting online science communication through these participatory platforms. Through a review of the literature and a set of interviews with HCI researchers (n = 24), we identify challenges currently facing researchers who try to engage with the public about their work, and establish a research agenda for HCI to study, design, and evaluate technology to support science communication. Specifically, we advocate for the design of tools to support audience analytics, automated summary and outreach workflows, and providing quantitative and qualitative feedback about online outreach efforts, as well as additional research to elucidate the impacts of self-directed science communication efforts and the evolving roles of scientists on the participatory web. With shifting online platforms placing researchers in the role of advocates and participants in science communication, understanding and supporting these interactions is now more important than ever.

CCS Concepts: • **Human-centered computing** → *Empirical studies in HCI*.

Additional Key Words and Phrases: science communication, hci, chi, outreach, social media, blogs

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1 INTRODUCTION

As researchers, we have an ethical duty to share publicly funded research [103] and advocate for scientific knowledge [13]. This process of science communication often involves the use of various media, such as television, print media, social media, blogs, museums, talks, podcasts, and demos, to increase people's interest in, develop their opinions on, and promote their awareness, enjoyment, and understanding of science [16]. It involves the transfer of knowledge from researchers to their peers, the media, and domain non-experts, and can be beneficial to both researchers (e.g., by increasing visibility and citations [57, 60]) and their audience (e.g., by providing information [16] and inviting non-scientists into conversations around scientific issues [90]). It can help shape public debate and policy [28], both by informing relevant decision-makers about research results [16] and by empowering the broader public to engage in scientific topics [73] and setting scientific agendas [90].

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As social media, online communities, blogs, podcasts, and other computer-mediated channels provide new possibilities for science communication beyond traditional journalism, researchers now have more direct channels to connect with the public [78]. However, although the field of human-computer interaction (HCI) has engaged with some pressing science communication challenges (e.g. climate change [32]), and although communities like computer-supported cooperative work (CSCW) have shown increased interest in understanding the dynamics of science news and public scholarship on social media [41, 42, 98], relatively little attention has been paid to supporting public engagement through the above online channels by individual researchers. Most HCI research in this space has focused on collaborations with the media [81, 82, 94], so the dynamics of HCI researchers directly engaging with public stakeholders via participatory channels remains understudied. This is a crucial gap, given that the rise of these platforms has left researchers unsure how to navigate their evolving relationship with the public [13, 53]. By exploring these dynamics, we can inform future research and technology to support researchers in engaging with the public online. Such efforts can help them foster more productive connections, disseminate knowledge to communities that can use it, and make a greater positive impact with their work.

It has been argued that HCI is an "inter-discipline," which responds to the needs and challenges of other fields [9]. In that spirit, as a field focused on designing, developing, and studying sociotechnical systems, HCI should be well-positioned to investigate and address the challenges of these evolving forms of science communication. A recent large-scale analysis of trends in science communication research identified several such "grand challenges" and research gaps in the science communication literature [40], including a lack of longitudinal and experimental studies, a lack of large-scale studies of science communication on social media, a need for deeper breakdowns of specific stakeholder groups, a need for more cross-cultural work, a need for more systems-focused analyses, and a need for interdisciplinary efforts to build more rigorous theoretical foundations. We argue that HCI as a field is well-positioned to help address most—if not all—of these challenges, given its tradition of longitudinal research of sociotechnical systems (e.g. [2]), use of large-scale data-mining to investigate social media phenomena (e.g. [86]), trend toward more geographically diverse research [59], and its participatory focus to community-based research projects [93].

HCI is also a field that has the potential to spark people's interest in the technology that many of them use every day [94], shape debate about technology [74], and even get designers and practitioners thinking about the unintended consequences of their work [38]. So, while understudied compared to other fields [40], we argue that it is important to understand and support the direct public outreach that HCI researchers do.

In this paper, we report results from interviews with HCI researchers (n = 24) on their experiences with science communication and public scholarship through participatory web channels (e.g. social media), identifying current barriers and needs. We then discuss how these interviews can inform a research agenda to address some of the "grand challenges" of science communication research [40], advocating for the design of tools to support online science communication, as well as new research directions to better understand evolving challenges. Namely, we propose the following:

- The design of tools that provide deep insights into online audiences that are hard to keep track of, automate parts of the science communication workflow, and provide feedback on the efficacy of individuals' outreach efforts.
- Future research on the impacts of science communication, the evolving roles of researchers on the participatory web, the needs of different publics and stakeholders, and cross-cultural differences in science communication practices and needs.

By doing so, we hope to pave the way for HCI to help address these grand challenges in science communication research.

2 RELATED WORK

2.1 Science communication on the participatory web.

While science communication can be done through many different mediums—such as museums [6], television [76], radio [67], film, and magazines [35], to name a few—a growing body of work has examined the potential of social media and other online sources to connect researchers with the public. The participatory web (or Web 2.0) refers to the ecosystem of social media, blogs, reviews, video-sharing sites, podcasts, and other online platforms that center the user as a content creator [10]. As a result, researchers across different fields have become empowered to use these platforms to reach new audiences directly [70]. Partly as a result of these trends, the role of the scientist in the digital age has started to shift [13]. Rather than acting within their traditional communicative role as neutral, disinterested observers who only begrudgingly speak with stakeholders or journalists [63], online communication norms have shifted to something resembling the "post-normal," [37], where scientists act as advocates and participants rather than "pure scientists" [13]; they now write tweets, participate in Reddit ask-me-anything sessions (AMAs), write blogs, start podcasts, and otherwise engage directly with the public about their work. Researchers now have the capacity to write engaging public-facing pieces about their own work [5]. Because being on participatory web platforms can increase the visibility of their work [57, 60], and because this can in turn affect the public's perceived credibility of science as an institution [15], it has become important to understand how the affordances of these platforms affect how science is communicated and engaged with [78].

For example, Twitter has been shown to be useful as a way of sharing research with peers and colleagues prior to publication, in order to help quickly refine and develop ongoing work [27]. Blogs have been widely used as a way of engaging with diverse audiences, and science bloggers have developed a number of methods by which to tailor their message to these audiences [39, 49, 61, 75]. Video-sharing platforms like Youtube can also be used as a medium for science communication, and by using certain presentation and delivery techniques, individuals can develop videos that match or exceed the reach of corporate-generated content [97]. Online discussion forums, such as Reddit's r/science sub-community, also facilitate a range of science discussions between people with various levels of expertise in different disciplines [50]. In a survey of scientists' attitudes towards using online tools such as blogs, Twitter, and a variety of other networking sites to communicate their research, the majority agreed that communicating one's research through such social media channels benefits the public overall [103].

Beyond social media sites, recent research suggests that information sources such as science blogs are becoming an increasingly important means of engaging with expert and non-expert audiences alike [49], with about two-thirds of college students using blogs as a learning resource [45]. Some recent work has been done to better understand how to effectively tailor blog posts to these different types of audiences [39, 75], and given the large number of people who turn to blog posts for informational and educational needs [45], it appears as though blogging presents an opportunity for researchers to provide that information to the public. However, while a survey of humanities and social science (HSS) scholars found that about two-thirds of respondents reported using social media for "informal scholarly communication" (i.e. discussions between researchers outside of formal papers, conferences, and collaborations) [1], the majority of researchers across the medical sciences, natural sciences, and HSS never used social media or blogs to discuss their ongoing research or results [103], suggesting that these platforms may still be somewhat underutilized by academics for more public outreach.

2.2 Barriers to science communication on the participatory web

Of course, numerous barriers to effective science communication have been identified, such as the difficulty of explaining complex topics to a public with varying degrees of scientific expertise [31, 65, 77, 88, 103], the potential for miscommunication and misinformation on social media [24], the risk of having one's ideas stolen by other researchers [103], the danger of backlash and harassment [87], and the difficulty of reaching non-research audiences on social media [26, 54], particularly policy makers and other decision makers [51]. While others have provided advice for researchers trying to engage with public audiences [25, 69], the aforementioned challenges may present roadblocks for those trying to follow this advice. Because of the shifting relationship between scientists and the public [13, 53], and the high stakes of responsibly representing one's work in public discussion [15], it has become important to understand and support these online engagements between researchers and the wider public.

2.3 Science communication efforts and research in HCI

Some work has been done to investigate science communication and translation issues within HCI itself. Smith, et al [81, 82] examine the 'Media Production Pipeline", a process which involves both a communication flow through labs, communication departments, and news organizations to the general public, as well as a parallel flow through Web 2.0 platforms like social media, blogs, and organizational websites, noting a number of challenges including a lack of time, competing responsibilities, and difficulty collaborating with journalists. Vines, et al [94] also examined how HCI research is discussed in the news, and suggests that its easy contextualization into everyday life can lead to HCI research being mis-characterized. Finally, Spaa, et al [85] looked into how HCI can better engage with policymakers, a key audience for science communication [16].

HCI has also supported science communication around educational, environmental, technological, and health issues. For example, HCI researchers have long advocated for a focus on technology to promote sustainability [62], and have indeed devoted growing attention to the challenge of raising awareness of these issues [32], developing games [19, 68] and other artefacts [8, 11, 29] to support this goal. Vaccines are another important domain of science communication research, and HCI researchers have designed interventions to increase vaccine uptake [20] and understand social media users' values with regard to vaccines [52]. Other work has examined health communication between patients and physicians [7], as well as in informal settings [21]. HCI work has also focused on supporting education [80], including challenges related to teaching HCI concepts themselves [72]. Finally, the public's reaction to technology-related issues have also been examined [33], including their perception of online research practices themselves [34].

The translation of HCI research into design practice may be an issue of particular importance to the community. Colusso, et al [22, 23] provide a translational science model for HCI, describing existing gaps between research and practice. Watkins, et al [95] describes how HCI students carry knowledge between their education and later practice as UX designers, and Velt, et al [92] propose how different translations can help bridge this gap. As a field, HCI has examined issues of media-researcher collaborations, engagement with policymakers, and the translation of research knowledge into design practice, showing that our community has the interest and capacity to engage with important challenges for science communication.

Finally, despite the shifting roles of researchers on the participatory web [13, 15, 53], and the proliferation of science news on social media in general [78], relatively little HCI research has focused on how researchers engage with the public directly. Some work has focused on particular online communities like r/science, studying how users share information and discuss scientific topics [50], how technical language can serve as a barrier to entry for the community [3], and

how user-generated comments can affect users' expectations for and engagement with science news [98]. Similarly, other research has explored how moderation and public scholarship is carried out on r/AskHistorians [42], and how information seeking practices vary between this subreddit and the #AskHistorians hashtag on Twitter [44]. Instagram has also been examined as a means of sharing experiences at natural history musuems [96].

However, while these investigations provide insight into how the design of social media platforms affect engagement with science news and artefacts, there is less attention paid to the role of researchers themselves on these platforms. Gero, et al [40] do explore how researchers on Twitter explain complex topics in ways accessible to the broader public, but there is relatively little HCI research focused on understanding the challenges facing researchers who engage with the public on the participatory web, and how technology can be designed to support researchers who do this work.

To address some of these gaps, we set out to answer three primary research questions. First, we wanted to understand the perspectives of HCI researchers involved in science communication and public scholarship, as their experiences could be insightful in generating a research agenda around science communication on the participatory web:

RQ1: Why are researchers within HCI motivated to communicate their work to the public, and what do they expect to accomplish by doing this work?

RQ2: What challenges or opportunities do HCI researchers have when directly communicating their research to the public online?

Using this knowledge, we then wanted to understand how these insights could be combined with existing research in HCI and science communication, in order to define a research agenda:

RQ3: How can the experiences of HCI researchers help inform a research agenda for science communication and public scholarship on the participatory web?

3 INTERVIEWS WITH HCI RESEARCHERS

To answer our research questions, we chose to interview HCI researchers about their own science communication practices, motivations, challenges, and needs. We expected that—because of their expertise in the design of sociotechnical systems—HCI researchers could provide useful insights into how the affordances of various platforms affect their success in engaging with the public, and prompt future research directions to support researchers on these platforms. While we note that HCI researchers may not share the same challenges that other communities may face in science communication and public scholarship, we think their unique insights—combined with existing research on other fields—can help serve as a foundation for future directions in this space.

3.1 Interview Methods

Participants. An initial set of 20 participants were recruited via direct email solicitation to specific former CHI PC members (2016-2018). This group was chosen because CHI is the largest HCI conference and acts as an umbrella venue to smaller conferences, such as CSCW, GROUP, or UIST. Interviewing program committee members from various subcommittees allowed us to hear from community members that were active HCI researchers who have identified with the community for at least a few years, and who work in various subareas of HCI. Given the relative lack of early-career (i.e. PhD student and postdoctoral) researchers represented in the PC, we conducted a second round of recruitment where we expanded our pool to the students of former PC members from between 2016-2020, who had published at least one paper at CHI. We chose this last criterion to ensure they had published research to discuss online, expecting they would have insight into potential challenges therein, as well as to ensure that they had been active as members of the CHI community. Our final sample totaled 24 researchers.

Position	Full professor (or equivalent)	1
	Associate professor (or equivalent)	5
	Assistant professor (or equivalent)	8
	Postdoctoral researcher	2
	PhD student	4
	Industry researcher	4
Institution	North America	16
	Europe	3
	Asia	5
Subcommittee	Accessibility and Aging	2
	Design	2
	Engineering Interactive Systems and Technologies	4
	Games and Play	1
	Health	3
	Interaction Beyond the Individual	3
	Interaction Techniques, Devices, and Modalities	3
	Learning, Education, and Family	3
	Specific Application Areas	9
	Understanding People: Theories, Concepts, and Methods	8
	Visualization	1

Table 1. Aggregate summary of interviewee demographic information. Subcommittee is based on the CHI 2020 categories (we use closest equivalent for past years), and for PhD students is based on the subcommittee of their advisors. Total adds up to more than 24, as some participants served on multiple subcommittees.

Potential interviewees were contacted with a request for a 30-60 minute remote interview, via Skype, phone, Zoom, or another tool of their choosing. Participants' demographic data are aggregated to protect anonymity (see Table 2).

Interview Protocol. All interviews were conducted remotely by two authors and a research assistant, either solo or in pairs. The first three interviews and one pilot interview were done by all three interviewers to ensure consistency. All interviews were recorded and later transcribed.

The interview protocol was developed collaboratively by all authors. First, in order for us to better understand researchers' use of existing tools for science communication, participants were asked to describe what tools they most commonly used, how long they had used each tool, why they used them, whether they accomplished their goals, and what features are currently missing from them. They were also prompted about other areas that may present challenges, such as whether specific audiences were difficult to communicate with, potential challenges in their review process (if they had one), and how they advertise their outreach. We additionally asked about their motivations for doing science communication in general, what they consider their role to be, and how they judge the success of their communication. For the full set of questions, see Appendix A.

Analysis of the interview data was done using a thematic analysis approach [12]. The first interview was openly coded by four authors, who then met to develop the codebook. Two authors independently coded a subset of the interviews and used that data to develop the final version of the codebook. The first author subsequently re-coded the entire set of transcripts using the final codebook, which categorized the data into different types of barriers, motivations, strategies, resources, and tools, with 14 high-level codes across these categories. After coding the data, each

code was imported into the collaborative application Miro.com, where three authors met to affinity map the data and identify potential themes. All authors met twice more to discuss the findings and emergent themes.

In the following, interview quotes are not tied to individual pseudonyms to further preserve anonymity and are lightly edited for readability and clarity (e.g. removing "filler" words, pauses, stutters, etc.). All italicized sections have been added here for emphasis.

3.2 Results

3.2.1 Researchers' Motivations for Science Communication. Our sample showed a number of different motivations for communicating their work to various public audiences. A first class of motivations are concerned with **individual benefits and self-promotion**. Some interview participants suggested that public-facing communication can lead to more citations of their scholarly work:

> Even if your blog post isn't going to get 1000 hits from lay people, the audience of academics is also really important because, even if only a subset of academics are going to read your CHI paper, a larger percentage of them might take five minutes to skim a blog post, and then maybe decide to read your paper, and then maybe cite it.

This idea is backed up by relevant literature, which suggests that social media presence positively correlates with increased citations [57]. Another facet of self-promotion includes making connections (i.e. science communication as "dialogue" rather than one-way "dissemination" [90]). One such group might be prospective students:

> One reason for doing press work is to make yourself known to potential students who come here and want to get a PhD, and for that purpose it's kind of pointless to be on just some random paper. Being on the internet is actually where these people are.

By discussing their work via different public mediums, many participants felt they were able to make connections with potential students, participants, and collaborators, focusing on engaging with diverse audiences as well as disseminating information.

Similarly, some participants discussed the idea that public outreach can improve one's **funding opportunities**, particularly when they are picked up by the media:

> It turns out that some of the news media articles and so on are quite effective to persuade the funder...I show that this is what we have done, and it's pretty effective...We're giving the impression that we're actually quite serious about promoting the results.

However, self-directed efforts (e.g. blogs, social media) were not considered as effective by one of our participants: "I think anybody who thinks that blog posts are going to give them grants is sorely mistaken." Furthermore, other participants felt like there were no personal incentives to talking to the media, providing a competing perspective to the perceived funding benefits:

> I think it's really important that we are talking to the media, not just our academic community, but again, that takes time. Is that rewarded? You know, are faculty incentivized to do that kind of thing? And that's why maybe we all don't.

Past research has noted that public communication can provide some funding opportunities even as it incites backlash from other agencies; this backlash may be due to the perception that heavily popularized researchers are "substandard," or that their work is "overexposed" and therefore not deserving of grant opportunities [63]. Both our data and past research paint a complex picture of the potential costs and benefits of outreach.

Another class of motivations are based on broader societal benefits: to **increase public interest** in, and trust and understanding of, the scientific process. One participant discussed emphasizing the importance of science:

> As a scientist, I have a responsibility for maintaining the respect and the use of people who are doing science, and that one way to do that is to share the things that I do, and that my colleagues and other people do effectively, in a way that shows that utility for people who may not understand.

Others discussed the importance of teaching the public to better evaluate scientific claims:

> The thing that I'd most like to communicate is, I'd like to encourage the public not to believe everything they read. So, skills like, how to read a paper, how to make sure that you don't blindly trust scientific findings, how to form your own opinion.

Finally, a common motivation for communicating one's work is to **provide useful knowledge to the public**:

> Very few people are going to read your CHI paper, but you probably have something to say that's relevant to the wider world. Otherwise, why are we even doing this work, right?

This sense of responsibility was often directed toward the general public, and this type of outreach was seen as a way of making complex research accessible to a broad audience:

> If I can do something to take the complex stuff that we do here in the university world, and present it to somebody in a way that they can understand, if I can write a short article that explains to somebody precisely how [social media topic] works so that they don't have to read really long in depth articles about it...then I'm happy.

Sometimes the intended audience was more specific, with some participants targeting practitioners in various fields such as software engineering, design, and education:

> You talk to a software developer who's at Microsoft and has worked there 10, 15 years or whatever, they probably aren't actually reading research papers, they probably aren't reading the ones that have that STS and critical theory, and this is a format that just doesn't work well in their context. So, how can we take all of this interesting work that exists on inclusion in critical theory, things like data violence, and what does inclusion look like in tech that exists? And how do we bring it to people that are actually making this in the moment, they're sitting there, they're coding, and they have a choice to make a design decision that makes a difference in the world.

3.2.2 Pros and cons of online platforms. We identified six main themes related to the pros and cons of online platforms for science communication. The first theme showed that social media and blogs are commonly welcomed by researchers as a way of **communicating scientific results without traditional gatekeepers**. For example, one participant, who primarily used Medium blogs to communicate about their work, noted that "...my success rate from actually reaching out to journalists is exactly zero. Like they won't even reply." While several participants said their institutions' media specialists helped open them to traditional media channels, many others did not have access to these resources, communicating mainly through social media and blogs. Participants acknowledged that the increased control that resulted from directly communicating scientific findings themselves also helped them avoid their work being sensationalized

> ...as academics writing as science journalists, it's sort of within our value system to do that really carefully, right? To not over interpret our results and not ignore prior work...

Similarly, because there is no peer review, researchers had full control over what they wrote online. This provides researchers the freedom to discuss whatever they want, at the potential cost of reducing rigor:

> The blessing and the curse of doing this dissemination to the general public, is you can say whatever you want, right? Once you do this kind of add-on component, it doesn't have peer review. It doesn't have to be this rigorous set of strategies that are empirically validated, right?

Another advantage of maintaining a social media account or blog is to serve as an **archive of past communication activity**. Some participants mentioned Tweet threads and blogs as ways of providing a longitudinal record to help reflect on their interests or public behavior over time:

> The question of actually being able to save these things or have some collection of them is really interesting to me. At one point I started a blog...and one of the reasons why I wanted to do that was because I can have control over things like archiving...which is really useful if you want to be able to actually have something and refer to it later.

Beyond self-reflection, the idea of archiving one's work for public consumption was also appealing. One participant described using a combination of blogs and Twitter to provide a publicly-accessible repository of their work ("I'll like put everything there in case people are wanting to find it, and then of course like I'll promote them on Twitter.").

In general, although participants used social media platforms like Twitter and Facebook to broadcast their research to a wider audience (echoing the advantages stated in the above section), several interviewees identified limitations to their use for science communication. For instance, there can be a **diverse mix of audiences on social media**, with some researchers struggling to balance the platforms as both personal and professional channels ("It's your family life, it's your work life, it's your academic life. So I have to play all these roles all together, and then the audience is all messed up too"). This may be especially difficult given the constant shifts in how platforms are structured and who uses them:

> It keeps changing, the way I perceive Facebook as a channel for communicating my research. I think the dynamics are continuously changing because the audience changes, because how other people use Facebook changes as well, so I think I tend to somewhat adapt to what I think is more appropriate.

Researchers may also **lack metrics and feedback** about who is engaging with their work. While platforms like Medium and Twitter provide certain metrics of engagement, they may not allow for more fine-grained insights about the diverse mix of audiences interested in HCI work:

> I would like to know who the identities of the people who are reading these things, who is re-tweeting it and know more about them. And in some ways all of that data's just there. It's just not curated in a way that's easy for me to see at a glance.

This uncertainty relates to another point of tension: despite difficulties in knowing who one's audience is, many participants emphasized the importance of understanding their audience to best contextualize and communicate their work. One participant pointed out that this lack of audience visibility can also prevent researchers from receiving useful feedback:

> If somebody reads a blog post and replies to me or talks to me about it, I know that they're engaged in that work, but I don't know if somebody didn't read it, I don't know if somebody read it and didn't like it because most people are not going to like email you and say, "this is stupid" or whatever. You don't really know why something didn't succeed.

Thus, using conventional metrics, it may be difficult to incorporate available user engagement data into productive feedback. Some participants suggested that knowing more about the impact, such as through tools that could visualize or summarize how science communication spreads, would be useful:

> So maybe that would be like a metric of success. Getting deeper into the community, or seeing people actually take things on or hearing them tell you about what they did or what they're going to think differently. Just being able to visualize the ripple effect.

Another related challenge was that, beyond the need to juggle diverse audience interests, researchers often had difficulty accessing these audiences in the first place, due to a **lack of targeting mechanisms**. For example, when writing blog posts on Medium, some participants were unsure how to target specific audiences ("It shows up, and then it just kinda sits there...There's no targeting you can do past just putting it in a specific bucket of a publication and just hoping people see it.").

Another participant echoed this concern around targeting blog posts, discussing possible technological features that may help:

> If I could know that a blog post was actually going to be added to like some aggregation service, that journalists actually check, I would be like much more likely to blog and I would put more time into my blogs and I would think about them slightly different. Like I would write more for the general audience.

In some cases, participants mentioned using services such as Slack channels or email lists to target specific groups of academics or industry professionals. However, as other participants noted, reaching the non-expert public may present additional challenges, as they may not be accessible via the same channels that more specialized audiences are, a concern that is somewhat supported by the existence of academic filter bubbles for other fields' Twitter presence [26, 54].

Finally, while previous research has noted that some researchers turn to Web 2.0 channels to gain greater control of their narratives than they might have working with mainstream media [82], the affordances of platforms like Twitter ("Explaining my [work] takes more than 280 characters") can **make contextualizing one's work difficult**, allowing those narratives to spin out of control and damaging their ability to engage with the public:

> [Twitter is] not great for conversation, it's not great for debates. It's certainly good at like generating all kinds of miscommunication, right? You can enter in an argument with somebody and spend like 50 replies trying to clarify what you meant because your original 280 characters wasn't clear enough. So sometimes what I broadcast turns into those things and sometimes that leads to interesting conversations, but oftentimes it's just a whole bunch of really broken communication.

The way conversations are displayed can also make it difficult to track conversations, either leading to misunderstandings or impairing the ability to follow conversations:

> Twitter is fine for browsing through these short bursts of comments that could be funny, or has this one interesting idea in it in very short sentences, but I wouldn't really call it an in-depth discussion, per se. You know, sometimes people try to have an in-depth discussion, and I sometimes see good-quality discussion happening, but from the user's point of view, it's really hard to track what exactly is happening, because of the way the thread is visualized and displayed.

3.2.3 Platform non-specific challenges. We also identified three platform non-specific challenges that are specific to, or exacerbated by, the nature of HCI. As a highly interdisciplinary field, HCI research contributions may include empirical studies (quantitative and qualitative), built systems and artifacts, data sets, and new methods or theories [99], and several of our interview participants

described challenges related to effectively **communicating different types of research across diverse media**. For example, research on built artifacts may necessitate video communication, which may have the advantage of being accessible to broad audiences:

> For almost every project we create these days, we create a video for it. And that video is often in support of the publication proper, but honestly it often gets a lot more play than other kinds of communication, just because they're easy to consume, and because it's a form of communication that people really like nowadays.

However, our interview results echoed past literature [81] in that some participants discussed a lack of video skill, especially among students. In some cases, participants suggested that complex systems may be difficult to capture. Moreover, this format may not be equally appropriate for all contribution types. For those projects that are highly visual, the process may be relatively simple ("We just show what we're doing, and people get it, right?"), whereas empirical or methodological contributions may be more difficult to capture in this way:

> If you're doing a study where the story is all about some kind of careful evaluation and statistics, I mean what kind of video is that? That's going to be crap, nobody's gonna care, unless you're Hans Rosling, but I don't have quite that kind of magic.

Of course, other options for dissemination formats may be applicable to empirical and visualization based contributions, such as those similar to what is provided by Distill, which offers interactive online publication for machine learning research [30], which one participant suggested can help make research articles more engaging. However, this may not be as easily applied to theoretical or qualitative papers, which are not inherently visual.

A final consideration is in selecting one's intended audience. Beyond some media being more appropriate for different contribution types, certain platforms may be more suitable when trying to communicate to different groups, highlighting the need for an in-depth understanding of what types of people one is trying to reach:

> Unless you know who your audience really is then it's really hard to write something that's compelling. So I think that it's more of like figuring out who your audience is, if you can reach them through that particular format or platform and then write for them.

Thus, because fields like HCI involve a wide variety of contribution types, there is an initial challenge in determining what is the most effective medium for scientific outreach for any given project. Furthermore, even if one knows what media to use in disseminating their research, they must then cultivate the required skills (e.g. video, visualization...) to do so effectively, which may present a particular challenge for those whose research spans multiple contribution types. Finally, these considerations also interact with who the intended audience is, and whether they are reachable via any given format or platform.

While several participants described the desire to self-promote and grow their audience, having a larger audience online also came with certain risks, leading to **discomfort with public outreach**. One major risk may be harassment:

> I have colleagues who write about very controversial issues, and if you're writing papers about say, GamerGate, or harassment of women in tech, then you posting about your work publicly might just be inviting harassment onto yourself.

Many of our participants were part of marginalized communities (e.g. women, trans/non-binary, racial/ethnic minorities in their countries), and found that discussing such topics online made them especially prone to backlash and harassment ("There are definitely academics, particularly women, who face harassment depending on what they're writing about."). There is a disproportionate

risk for researchers from these backgrounds, and as several participants mentioned, the fear of negative reactions itself can provoke anxiety when interfacing with the public: While increasing one's social media presence may have real benefits, this fear may interfere with the goals of science communication, a potentially significant problem given how much of the CHI community's public outreach is done using sites like Twitter.

Beyond topics of harassment, CHI research may be otherwise politically charged:

> I'm just saying that some of my work might actually cause a scandal... sometimes it's okay to probe those ideas in academic contexts where you can think them through, where you try to find out where these gaps are in design and also how active you are within society, right? But you know, if you don't have some kind of safe environment to do that...

Thus, while HCI's focus on sociotechnical issues may motivate and facilitate public communication (given a perceived broad relevance by our participants), it may also touch on topics that invite negative reactions and even harassment. Beyond fearing negative reactions from the public, some interviewees also discussed a general discomfort with self-promotion on social media (building on similar findings from past literature [63, 81]):

> I don't have a particularly big Twitter presence, and so it's a little bit weird for me to use it only as an advertising source. I find that somewhat awkward, even though it may not be that way. Many of my colleagues, that's all they do it for. And the other thing is, there's a certain level of self-evangelism that I just find awkward.

One participant further mentioned that disseminating one's own work may draw attention away from others', and it is not always clear whether one's own work should be widely propagated:

> Everyone else's science output is also interesting and relevant, like why should yours dominate all of the conversation? Like, if mine's getting all the attention, maybe that's not good. Maybe climate change is more important, and we should be seeing climate change papers everywhere, you know what I mean? Like, I think it's good for my career, but I don't know if I can say that this is good generally.

However, some participants offered strategies for dealing with this discomfort. In some cases, it may be easier for others to promote one's work rather than oneself: "It's easier if other people come and say this has been so cool. And then I go forward and say, this person says, by the way, this is cool."

Our respondents also indicated difficulty **communicating with researchers in other disciplines**:

> So, recently I went to the EE department at another school in their graduate seminar, with like 50 graduate all in EE. That was one of the toughest crowds to deal with. I mean they all have their own deep interests, so it's really hard to get them excited about the stuff that I do

Some also mentioned that HCI may not be well regarded by certain other faculty, making it more difficult to justify the importance of one's work:

> You hear a little bit about how other faculty members are saying, "Oh, this guy is doing strange stuff." So, HCI is in a way negatively perceived by some other people...

One reason that was offered was based on the broader computer science community regarding HCI as less serious or rigorous:

> And so, when I take them and try to bring them together, I notice a lot of people over in the CS community are like, this isn't even research. Where's the math? Where's the numbers? And on top of that I do qualitative research, which is a whole problem in

> computer science because they like numbers. And so, a lot of these little things come together to get this vibe from computer science researchers where they're like, are you sure you're really doing research? Like, this is fun, but really?

4 DISCUSSION OF INTERVIEW FINDINGS

Based on members of the CHI community, we described a number of specific challenges and opportunities for science communication of HCI research, and insights into how different platforms support (or fail to support) science communication on the participatory web. We found that our sample are highly motivated to publicly discuss their work, and many have adopted online platforms to do so. In their view, the lack of gatekeepers leads to better access and control compared to mainstream media channels, providing a means to disseminate and archive their work for diverse public audiences. However, we also uncovered a number of challenges facing HCI researchers communicating about their work. Our results echoed previous findings indicating that a lack of time [100], fears of negative perception [18, 63], challenges using multimedia [81], and a sense of public misunderstanding [36] can impede outreach efforts. Beyond, this, we found that HCI work has particular challenges to communication. Even though HCI work is often very applied, making it relevant to the general public, we found that can also be a disadvantage; HCI research can be emotionally or politically charged, meaning that researchers who discuss these topics may risk backlash and harassment. It also means researchers need to navigate various overlapping audiences of other researchers, relevant practitioners, and other interested publics, requiring a high degree of skill to communicate various contribution types to these different groups. This can be especially challenging to navigate if science communication is not considered a priority or supported within a researcher's institution. Building these skills takes time and effort, and without adequate support or motivation, may be too difficult for many researchers to take on, highlighting the need to better support researchers in doing this work.

Taken together with previously-identified barriers to online science communication, this work describes a field where many researchers have made attempts at online science communication, but who face numerous challenges doing so. Although social media platforms are gaining interest as alternatives to mainstream media for public outreach [82], HCI researchers' use of social media highlight limitations with current technologies, such as difficulty tracking ongoing conversations, a lack of insight about one's audience, a lack of feedback mechanisms, and a lack of targeting mechanisms for specific groups. These point to numerous directions for future research to support science communication on the participatory web.

5 AN HCI RESEARCH AGENDA FOR SCIENCE COMMUNICATION ON THE PARTICIPATORY WEB

Here, we discuss how our interview results can inform research directions to support researchers who seek to engage with the public, and to address existing gaps in the science communication literature. See Table 2 for a list of proposed research directions.

5.1 Designing tools to support science communication

5.1.1 Audience analytics and framing strategies. One challenge our participants faced was in navigating the mix of audiences on participatory platforms; it wasn't easy to frame their work when dealing with multiple overlapping audiences, especially when they don't know who those audiences are. Moreover, we found that without adequate targeting mechanisms, it can be hard to reach specific audiences when one's work calls for it (e.g. a blog post on web design should reach web designers). Effective science communication relies on knowing one's audience [25], but given the ever-changing demographics on sites like Facebook [43] and Twitter [71], it can be difficult to

Type	Direction	Description
Tool support	Audience Analytics	Provide information about invisible online audiences
	Outreach Incentives	Reduce the burden on researchers who reach out to the public
	Feedback Tools	Provide feedback on researchers' science communication efforts
Empirical	Evaluating Impact	Elucidate the impact of science communication on both researchers and various publics
	Role of Researchers	Explore how researchers can navigate evolving digital landscapes
	Identifying Stakeholders	Determine unique considerations of different fields for science communication
	Global Research	Cross-cultural research to assess science communication impact on a global scale

Table 2. Summary of our proposed research agenda for science communication in HCI.

determine what the right platform is when trying to reach a specific audience. To provide better insights on who one is reaching, researchers will need tools that provide an overview of their audience. These tools could use analytics on sites like Twitter to help estimate what broad groups (e.g. researchers, practitioners, domain non-experts) are being reached by any given tweet, post, etc. This could be done by building on the keyword-matching techniques used in previous science communication work, to predict whether a given Twitter user is a researcher or not [26, 54], or what domains they have expertise in.

However, even knowing who one is reaching may not be enough; researchers must still determine how to frame their work for these audiences. To that end, strategies to automatically identify science communication writing guidelines [4] could be leveraged to provide writing suggestions for tweets or other posts. For example, if a tool like this finds that one's Twitter audience is largely domain non-experts, it could also recommend using metaphors or relating one's research to current events, to more effectively engage with that audience. Our participants sometimes found it difficult to reach out about certain contribution types, so providing suggestions based on existing guidelines or others' strategies could help when navigating this issue.

5.1.2 Incentives for promoting outreach. Another significant challenge for our participants was a general discomfort with public outreach, which manifested in three key ways. We found that researchers in our sample are often uncomfortable with self-promotion, due to lack of confidence, fears about coming off as too much of a self-promoter (fears which may not be unfounded based on the persistence of the Carl Sagan Effect [63]), and gendered expectations of modesty around one's accomplishments (a known challenge for self-branding in other contexts [58, 79, 84, 89]). There is a tension here, where the need to self-present as a confident scholar and expert may be incongruous with their backstage personas in online spaces [46]. Researchers found this can be uncomfortable and difficult to navigate.

Because some participants noted that receiving endorsements from others may feel less awkward, providing mechanisms and/or incentives for community members to broadcast each other's work could help reduce this discomfort. One possibility would be to provide automated dissemination tools whereby researchers could write blog-posts and/or short blurbs about their publications and

broadcast them to Twitter, Reddit, etc. While as of the time of writing, the ACM provides free use of the communication service Kudos [55] to its authors (which provides users with templates to write and generate shareable one-page PDFs about their work), authors must still share the work themselves. An automated system could take this one step further, broadcasting such templates and easing the burden of self-promotion from researchers themselves, perhaps by posting to social media accounts branded by specific conferences or journals.

5.1.3 Tools for providing feedback. A related issue brought up by several participants was a lack of feedback mechanisms, meaning that researchers have a hard time judging what constitutes a successful blog or post. So, future tools or platforms could be designed with consideration for deeper feedback mechanisms. At a high level, this might include aggregating quantitative engagement data to compare with various aspects of one's outreach, such as topic, length, channel, time of day, to reverse-engineer the qualities of a successful post. For more specific feedback, perhaps platforms could encourage more (productive) user commentary, allowing researchers to more clearly see why their science communication succeeded or failed. The current lack of these comments on Twitter may indicate a need to incentivize 'upstream engagement' [14], whereby non-researchers are drawn into the research process as participants and stakeholders. By signalling that researchers value the perspectives of the broader public, it may be possible to encourage relevant stakeholders to follow, comment on, and discuss with researchers about their work, providing a more direct avenue for dissemination and engagement while simultaneously providing useful feedback for how researchers conduct and frame their work for the public.

5.2 Empirical research on the evolving digital landscape

5.2.1 Evaluating the impact of science communication for all stakeholders. One important direction for future work will be to elucidate the personal advantages of science communication. Our participants shared conflicting perspectives on how this work may affect their funding prospects, and the literature appears similarly divided [56, 63]. Thus, confirming whether or not online science communication actually lead to increased funding would help clarify the uncertainty we have uncovered, and help researchers in HCI and beyond make more informed decisions about how to prioritize this work. Furthermore, we found that HCI researchers use a variety of dissemination media when communicating about their research. However, while some participants expressed an interest in emerging platforms like Distill, which support interactive visualizations, such publications may require significant time and skill to properly utilize. Thus, in order to determine how to best support the most effective communication of different research contributions, future research should examine how effective these various media are in discussing different types of results, in order to ensure that researchers at different career stages, and with different goals and skill levels, can make the most effective use of their time.

Moreover, there is little existing science communication research focused on social media and other participatory channels, and most research focuses on the "general public" rather than breaking it down into specific publics [40]. What effect does scientists participation on Twitter and other social media have on the visibility of their work to non-scientists? What effect does it have on different publics' trust in science? What effect does it have on public discourse or policy decisions? Who is missing from these online conversations, and how might they be engaged? If we can better understand the downstream effects of science communication and public scholarship on the participatory web, perhaps individual researchers can make more informed decisions about whether to do this work.

This line of inquiry could also help inform how science communication is valued at an institutional level. Recent calls have been made for academic departments to consider science communication as

an integral part of academics' responsibilities and consider them for tenure promotion [64]. If new tools and research can help clarify the positive effects of public engagement by researchers, institutions may start to value these activities more formally, providing more space and encouragement for researchers to do this work. Additionally, tools to identify and track science communication efforts could help make this invisible work visible, making it easier to advocate for this work as an important component of research.

Of course, such incentives would need to take into account the potential exclusion of women and minorities in mainstream news reporting or discrimination on social media [64], and should be crafted so as not to unfairly discriminate against those who may have difficulty gaining broad public exposure. Given the examples of harassment our participants brought up for researchers working in certain domains, this is an important consideration, and should be measured against the potential unintended consequences of such an institutional shift. Additional qualitative work, combined with large-scale quantitative studies to surface the challenges faced by these groups, could help in determining how such a shift might affect these researchers, how to reduce the burden on them, and whether such expectations should be made at all.

5.2.2 Understanding the evolving role of scientists in the post-normal era. Our interview participants often struggled to navigate conflicting personal and professional identities on social media. Recent science communication research has explored how scientists grapple with their shifting roles on social media, and the line between professionalism and sensationalism can be blurry [53]. Some scholars call for a more playful, carnivalesque approach to break up the more sterile outreach efforts of scientists online [66], and indeed using language with stronger sentiment has been shown to predict success on Twitter [48], an important domain for science communication in our sample. However, straying too far from professionalism may have negative effects on publicly-visible researchers' credibility due to expectancy violations on how scientists should act [101, 102], further confusing the path forward for scientists as communicators.

There are several questions to tackle here. How have evolving media ecosystems affected the public's expectations for how scientists should act, and how do these expectations vary across online contexts? What are the effects of different engagement styles for science communicators on social media, both in terms of immediate credibility perception and longitudinal effects on outcomes like people's trust in science? What are the relationships between shifting platform affordances, audience demographics, expectations, and researchers' roles and behaviors? These are important questions in today's media landscape, and are questions HCI likely has the tools to help answer.

5.2.3 Understanding the needs of different fields and their relevant stakeholders. There is currently little science communication research on fields outside of ecology and biology [40], but as our results illustrate, other fields have their own considerations when engaging with various stakeholders. Moreover, these fields have their own sets of overlapping publics who approach research for different reasons, and their needs must be taken into account when setting agendas for science communication and engagement. Communication practices on social media vary widely between fields [47], but more work needs to be done to identify and address the challenges involved in engaging the public around different research topics. For example, what are the considerations other fields must account for when engaging with the public? Who are the important audiences and stakeholders for different research domains, and what are their needs? How can technological interventions support members of those fields in doing the work of science communication? Large-scale, longitudinal analyses, as well as more community-specific approaches, could both be useful directions for this line of inquiry.

5.2.4 Large-scale, cross-cultural research on science communication and its effects on global attitudes. Finally, more large-scale, global, cross-cultural research is needed to better establish theoretical foundations for science communication research [40]. HCI's trend towards more global studies [59], its mixed-methods focus [91], and its interdisciplinary nature [9] clearly position it to tackle such a challenge. How do the practices of science communication vary across countries and cultures? How can we assess the efficacy of science communication across different cultural contexts? How can relevant knowledge from diverse disciplines like communication, psychology, and sociology be synthesized? As a methodologically diverse inter-discipline [9], we argue HCI has the capacity to respond to these important challenges.

6 LIMITATIONS AND FUTURE WORK

While we attempted to include as many diverse perspectives as possible when recruiting participants, our sample was still somewhat limited. Although we surveyed and interviewed researchers across North America, Europe, and Asia, our sample did not include any researchers from Central and South America or Africa. Given region-specific science communication challenges and opportunities in certain South American [17] and African [83] communities, further research may be needed to better integrate global perspectives into our understanding of science communication in HCI. Furthermore, although we focused on core members of the CHI community, CHI does not necessarily reflect the worldwide HCI community overall, so while we provide a number of unique challenges and motivations for science communication based on our sample, explorations of other communities within HCI may uncover further considerations for public outreach.

Finally, our sample only included people who have published papers before, and who have actively communicated about their work. Science communication is not limited to discussing one's own research or publications, but can also include discussing the work of others. This may be an important direction for future work, examining the perspectives of researchers who curate, discuss, and translate larger bodies of research on participatory platforms.

7 CONCLUSION

In this paper, we sought to explore how HCI as a field could help respond to evolving challenges in science communication. Through a review of the literature and a series of interviews, we identified a number of potential challenges for science communicators on the participatory web, including a lack of feedback mechanisms to tell researchers how their work is being received and who is reading it, difficulties juggling the diverse media needed to communicate interdisciplinary research contributions, and difficulties managing conversations on social media, particularly when discussing easily-misunderstood or sensitive research results that come up in fields like HCI. We concluded by setting out a science communication research agenda for HCI, and by doing so, we hope to encourage further work in understanding how we as a field can more effectively support researchers in bringing their work to the public.

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