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RE-EXAMINING SCIENCE COMMUNICATION:
MODELS, PERSPECTIVES, INSTITUTIONS

"Who is going to believe me, if I say 'I'm a researcher?"' — Scientists' role repertoires in online public engagement

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Abstract

This article contributes to reflective practice amongst scientists who engage with citizens in the digital public sphere, by exploring the scientists' experiences and underlying perspectives on their role repertoires in online science-society interactions. Semi-structured interviews were held with 26 European scientists to investigate their focus and contribution in boundary interactions, perspective on appropriate model of science communication, and activities, outputs and addressees in the digital public sphere — together comprising a role repertoire. The intended role of scientists often did not match with their deployed repertoire in online interactions with citizens. Participants were left with the feeling that the digital public sphere provides hollow interactions, devaluates scientific expertise or even represents a hostile environment. In order to capitalise on the promise of the digital public sphere for constructive interactions with a diverse public, a reflective practice is needed that aligns scientists' intended contribution to science-society interactions with the scientists' perspective and deployed online repertoires.

Keywords

Public engagement with science and technology; Representations of science and technology; Science communication: theory and models

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Introduction

Digitalisation and the rise of social media platforms have revolutionised the way in which scientists interact with diverse non-scientific publics [Bubela et al., 2009; Rutsaert et al., 2013]. A wide range of digital communication platforms such as sites for social networking, video- and picture-sharing, blogs, and microblogs, give scientists new means to share scientific insights with citizens directly, but also allow audiences to generate information themselves [Bubela et al., 2009; Hara, Abbazio and Perkins, 2019; Rutsaert et al., 2013]. This has extended the range of actors involved in the production and use of scientific knowledge to artists, activists, bloggers, amateur enthusiasts and social media influencers — all with their own values, perspectives and worldviews. In past decades, science is being

opened to society in many ways, pushing both the production and scrutiny of scientific knowledge out of the traditional scientific communities into the public arena [Nowotny, Scott and Gibbons, 2001]. Digitalisation has only intensified this development. The myriad of online and public discussions about science have been characterised by Schäfer [2016, p. 3] as 'the digital public sphere', an interface where scientists openly blog about their results and instantly post adaptions or updates to research findings; and where citizens can directly respond and interact with the author.

The digital public sphere has been indicated by some as a promise to boost this trend of science opening-up to citizens, for they provide level playing field platforms and enable scientists and citizens to 'enter active conversations' [Regenberg, 2010]. Indeed, social media have offered scientists positive experiences, such as the opportunity 'to give knowledge back to society', engage with questions from the public on online discussion websites and social media, and helped inform scientists on the societal relevance of their research [AbiGhannam, 2016; Dermentzi and Papagiannidis, 2018; Hara, Abbazio and Perkins, 2019; Jones et al., 2019]. Contrastingly, authors have also pointed at both lingering and newly introduced challenges that come with the promise of an open and more interactive science system. For example, as Davies and Hara pointed out, in this newly emerging online science communication ecosystem it is "not as simple as digital technology enabling multivocal discussions of science or making science more widely accessible; and engagement cannot be taken for granted" [Davies and Hara, 2017, p. 564–565]. In several studies, scientists indicated that they are wary of interacting with citizens in the digital public sphere, for example for fear of criticism and personal attacks, and being framed by suggestive questions and potentially receiving low-quality comments from citizens; which could in turn lead to a decline of trust in scientists among other users on the platform [Dermentzi and Papagiannidis, 2018; Hara, Abbazio and Perkins, 2019; Jones et al., 2019; Sajeev et al., 2019].

While science communication literature displays a common plea for communication models that move away from 'deficit-thinking' and towards more dialogue or interactive models [Bubela et al., 2009; Nisbet and Scheufele, 2009], what is observed is that scientists primarily fall back to the persistent assumption that deficits in citizens' knowledge of science are the origin of misunderstandings and conflicts [Besley and Nisbet, 2013]. It means that although some scientists happily took-up on the invitation and promise of the digital public sphere to engage in active dialogue with citizens on science, others may not have been prepared for citizens to talk back. This is ever more challenging in a digital public sphere where 'traditional' science journalists can no longer act as gatekeepers of the quality of scientific information that enters the digital realm, nor moderate public discussions on science online [Bubela et al., 2009; Fahy and Nisbet, 2011; Trench, 2008]. Without the mediation of 'traditional' science journalists, scientists themselves now need to facilitate how public discussions on science are held [Chilvers, 2013; Fahy and Nisbet, 2011]. This is especially important — yet complex — in fields where science is publicly contested, where there are high levels of uncertainty, scientific processes are complex and sometimes difficult to make transparent, and where the digital public sphere presents a widely diverging array of viewpoints on science [Brüggemann, Lörcher and Walter, 2020; Davies and Hara, 2017; Miah, 2017; Schäfer, 2016]. Constructive and open public discussions on

contested areas of science, such as climate change or the current Covid-19 pandemic, prove to be difficult to realise — for they involve many different scientific fields as well as political, social, economic, cultural and ethical dimensions that often remain hidden in the interaction.

Previous research has pointed towards the importance of reflection of scientist communicators on their role in order to enable effective communication and engagement activities [Baram-Tsabari and Lewenstein, 2017; Davies, 2021; Salmon, Priestley and Goven, 2017; Wynne, 2006]. For example, Salmon, Priestley and Goven [2017] encourage scientists to become "a 'reflexive scientist', one who is familiar with critical Public Engagement with Science (PES) literature; thoughtful and clear about the goal of his or her public engagement activities; and capable of critically analysing the relation between those activities and the politics of his or her own field, the relevant institutional context, and his or her own personal assumptions" [Salmon, Priestley and Goven, 2017, p. 66]. Recently, research has been done into scientists' perspective on their role and factors that determine willingness to engage in (online) science communication or public engagement activities [Besley, Dudo et al., 2018; Davies, 2021; Davies and Hara, 2017; Dudo and Besley, 2016; Loroño-Leturiondo and Davies, 2018; Miah, 2017]. However, these studies raise the need of further conceptualization of the experiences and perspectives of scientists on the use of digital media — for the production, consumption and analysis of these online interactions is complex and involves both insights into individual perspectives as well as systemic, contextual, cultural, political and ethical dimensions [Davies, 2021]. Appropriate analytical frameworks or theories that untangle how individual scientists reflect on their role and how these connect to personal experiences or worldviews remain less described; nor are they placed in the context of relevant institutional or societal contexts and (online) media dynamics [Besley and Nisbet, 2013; Jia et al., 2017; Salmon, Priestley and Goven, 2017]. Therefore, this article aims to gain insights into the experiences of individual scientists who interact with citizens in the digital public sphere, their underlying perspectives on their role and the repertoires they deploy in science-society interactions in the public digital sphere. These insights could contribute to reflective practice among scientists who engage with publics online — with the overarching goal to contribute to a more constructive dialogue on contested science in the digital public sphere.

Analytical framework for researching role repertoires of scientists

Scientists who interact with different stakeholders and publics operate on the boundary between science and society. In the digital public sphere, this boundary has become increasingly permeable, dynamic and controversial. If boundaries are impermeable, no meaningful communication can take place. If they are too permeable, scientific findings get mixed with personal opinions and strategic interests, and the value of scientific knowledge fades away. Attention to boundaries and boundary work is therefore essential to the research and practice of science communication. The central idea of boundary work is that tensions arise at the interfaces between different communities with different views of what constitutes relevant, useful or trustworthy knowledge [McGreavy et al., 2013]. Most of the research into boundary work has been performed in the context of science-policy interface, knowledge management and sustainability science. We believe that also in the context of science communication and public engagement, insights into the complexity of boundary work may help scientists to establish a

Table 1. Analytical framework for roles and repertoires of scientists' online engagement (based on Bauer and Kastenhofer [2019], Spruijt et al. [2013] and Turnhout et al. [2013]).

Category	*Dimension*	*Description*
Role	Focus	What scientists try to achieve with respect to boundary interaction; the effect the scientists aim to achieve with their engagement activities, e.g. informing, educating, awareness-raising, critiquing and democratising
	Type of contribution	What scientists add to boundary interaction; the contribution scientists want to make, e.g. knowledge, understanding, meaning, agenda, empowerment, connections and perspectives
Repertoire	Perspective on science-society	How scientists perceive and frame the status of scientific method and knowledge and its implications or use in society; how scientists perceive and frame the appropriate model of science communication in terms of direction, framework and nature of communication
	Activities and outputs	What scientists do to address boundary interactions and the form they take, e.g. science writing, video-making, deliberative processes and capacity-building
	Addressees	The scientist's intended and target audiences
	Interaction patterns	The way practitioners identify, engage, connect the public, stakeholders and scientists; boundary strategies scientists use, e.g. supplying, demarcating, bridging, facilitating and blurring
	Boundary challenges & opportunities	Boundary interaction problems and opportunities available to scientists, including scientists' interactions with addressees in the digital public sphere and in the context of organisations, institutes, science systems and cultures

reflective practice that is crucial for constructive and effective engagement [Davies, 2021; Salmon, Priestley and Goven, 2017].

This study takes a boundary work perspective to explore scientists' understanding of their role in the digital public sphere, related to the activities they undertake. This requires an in-depth understanding of the assumptions, values and routines that shape their interactions with citizens in the digital public sphere. The literature on science policy and knowledge management comprises several different typologies of the roles of scientific experts in policy, politics and public interaction [Bauer and Kastenhofer, 2019]. Further empirical work in those fields has demonstrated how scientists put this variety of roles into practice by means of different action repertoires [Spruijt et al., 2013; Turnhout et al., 2013]. In our study, we draw on these conceptual and practical insights to articulate the roles and repertoires of scientists navigating the digital public sphere (Table 1). In the next paragraph, we operationalize these concepts in the context of science communication to develop an analytical framework to examine scientists' perspectives on online engagement.

In our analytical framework the concept of 'role' refers to a scientist's focus and desired contribution to science-society interactions. In the current more networked

and digitalised science communication landscape, scientists may play different roles in the interactions with wider audiences online. Recently, Besley, Newman et al. [2020] described six contributions or foci that scientists have with science communication activities, which were ensuring that policymakers use scientific evidence, society values science, adequate funding for scientific research is obtained, helping citizens make better life decisions based on scientific knowledge, fulfilling a duty to society and helping to establish a professional reputation [Besley, Newman et al., 2020]. Similarly, in a study by Davies [2021], scientists indicated six clusters of potential roles that science communication plays in society, which were the value of accountability, i.e. science communication activities being a responsibility or duty, provide society with relevant scientific knowledge deemed necessary for making better life decisions, enhancing democracy, fulfilling a cultural role and is used for marketing or promotion purposes [Davies, 2021].

The concept of 'repertoire' emphasizes that roles are not static but depend on context, situation and an individual's values, views and styles [Turnhout et al., 2013]. 'Repertoires' link scientists' underlying perspective on science-society interactions to the activities they deploy. In other words, the concept of 'repertoire' reveals how an implicit science communication model-in-use shapes boundary work. Along the lines of conceptual distinctions well-known in the science communication field, these models-in-use may range from dissemination models, characterised by the assumption of a knowledge deficit within the public, to more dialogical and participative models, emphasising the legitimacy of different sources of knowledge and ways of knowing and the inseparable role of values and ideals in complex societal issues [Trench, 2008]. Dissemination models typically centre on one-way interaction and demarcation of the boundaries between science and public. Dialogical and participative models typically centre on two- or multi-way interaction and blurring or spanning of boundaries [Turnhout et al., 2013]. Adherence to a certain perspective on science-society interactions subsequently informs the activities scientists undertake and addressees or audiences they intend to reach. Moreover, it elicits certain interaction patterns and boundary challenges that scientists experience.

Scientists may deploy various roles and repertoires. Rather, we see these role repertoires as dynamic, especially considering the various situations, contexts and space-times scientists may find themselves in when engaging with audiences in the digital public sphere. By making explicit and untangling scientists' roles and repertoires in the complex digital interspace, the conflicts that may arise or are experienced between their roles, perspectives and repertoires will become explicit — thereby contributing to the reflexive practice of scientists who interact with citizens on contested science in the digital public sphere.

Methods

The research reported here was part of the EU-funded RETHINK project. In seven EU countries, RETHINK has set up transdisciplinary communities of inquiry and learning that bring science communication scholars and practitioners together to re-examine the role of science communication in a digitalized and blurred science communication landscape. The study draws on semi-structured interviews, which allowed the interviewer to steer these into a direction relevant for the research without interfering with the interviewees' perceptions. Twenty-six semi-structured interviews were held with a range of different scientists from each of the seven

countries. Role repertoires were explored in various contexts, ranging from the individual context of the scientist, to organisational, institutional and societal contexts.

For the purpose of this study, we selected scientists from three fields of science and technology that are currently contested in society: climate change, healthy diet and artificial intelligence. These areas are characterised by high stakes, potentially significant impacts, high levels of uncertainty and a multitude of social, ethical, political and economic dimensions that may challenge communicative practices [Brüggemann, Lörcher and Walter, 2020]. Scientists in these fields of research are the subject of intense online public debates wherein facts and authorities are faced with scepticism. In addition, we see the emergence of new players such as bloggers and social media influencers in these debates. Scientists were invited to participate if they worked in one of these fields, their daily activities comprised research and teaching at universities or research institutes, and they regularly deployed engagement practices as a secondary or voluntary activity. Scientists were selected and first contacted for potential participation by local RETHINK partners. Based on their suggestions, the first author invited 53 scientists to participate in this study, of whom 26 were available within the timeframe. Subsequently, 26 scientists were interviewed, of whom 12 women and 14 men. Eight participants work in research fields related to healthy diets, nine in climate change and nine in AI-related research fields. Scientists at different stages of their academic career were interviewed, among whom there were two Ph.D. students, three post-doctoral researchers, five assistant professors, six associate professors and six full professors. Four researchers were categorised as 'senior researcher' because they worked in a research institute that did not distinguish academic levels. Geographical diversity was sought from across Europe: northern (Sweden, $n = 6$), western (the Netherlands, $n = 6$; United Kingdom, $n = 3$), southern (Portugal, $n = 3$; Italy, $n = 1$), and eastern (Poland, $n = 2$; Serbia, $n = 5$).

All interviews were held via video conference software, lasted one hour on average, and were recorded and transcribed verbatim. In order to interpret the meaning of the data as emerged from the transcripts, some transcripts were first coded by use of open coding. All transcripts were further analysed by axial coding — i.e. coding on basis of a coding book that was constructed on basis of the previously described analytical framework. Newly emerging themes or interactions between themes that emerged were added to the analysis process [Boeije, 2010]. As such, both deductive and inductive analysis strategies were used. Analysis and coding of the interviews was conducted by and discussed with multiple researchers. Data analysis software ATLAS.ti was used.

Results

The following section describes the experiences and role repertoires of scientists in interaction with the digital public sphere. It provides an empirical reconstruction of the roles and repertoires practiced by the participants, structured accordingly to the analytical framework. As such, it describes participants' focus and contribution with regards to the boundary interaction, perspective on the boundary interaction, and subsequently, participants' addressees, activities and outputs. Lastly, the challenges and boundary interactions that arise around role repertoires in the digital public sphere, related to the individual, scientific and societal context are discussed.

4.1 *Focus and contribution*

All scientists who participated in this study professed huge personal motivation for public engagement, often connected to a deep passion for science. Their contribution to boundary interactions was said to be closely connected to 'giving back to society', which took various forms. For example, all scientists mentioned feeling a huge responsibility, sense of duty, or even the obligation, to communicate about science online. A majority of 23 participants believed that their role in public interactions online involved some form of dissemination of scientific knowledge in society. Specifically, participants indicated a focus on informing, providing "a better understanding of the severity of social problems", creating awareness of societal issues or telling citizens how they can use scientific knowledge to "better their lives". Scientists felt that much research in their contested scientific field was misrepresented or misunderstood online. Therefore, participants' aimed contribution to the boundary interaction online was to resolve confusions, questions and misconceptions that people have about science.

> "*AI will influence everybody in society. We see a lot of misconceptions online, and also a lot of anxiety as a result — and I think a lot of this is based on a lack of understanding*." (Associate professor, AI, Sweden)

Next to participants' focus on information provision, participants mentioned they wanted to raise awareness of societal problems where science could offer a solution, and subsequently, change behaviour of addressees. In their view, scientists' crucial contribution to boundary interactions is that they can better interpret scientific results in the context of society and so direct public discourse towards opportunities for social change.

Only few scientists in this study were inclined towards a focus and contribution to boundary interactions that aimed at collecting or displaying of a wide range of ideas, values and perspectives present in the digital public sphere. A professor from the U.K. in climate change research mentioned that "online [platforms] open-up the space for deliberation with citizens". Furthermore, a professor from Sweden in AI mentioned that educating the public through online media is not the most important contribution of scientists in boundary interactions, since complex problems society is faced with cannot wait for citizens to be educated about the latest scientific knowledge. According to this participant, the focus and contribution of scientists with respect to boundary interactions should not be to represent scientific expertise, but rather to have a public dialogue on all forms of expertise necessary to solve pressing social issues.

4.2 *Perspective on science-society interactions*

In line with the focus and contribution envisioned by the majority of participants in this study, participants mainly displayed a one-way perspective on boundary interactions. As the previous sub-section shows, the majority of participants felt their role in boundary interactions was to inform on research results and educate audiences. Similarly, many participants displayed a linear perspective on science-society interactions. These participants engaged with citizens in the digital

public sphere on the basis of their scientific expertise and deeper knowledge of the research content and experience with advanced education activities. As such, their repertoire centred around the perspective that knowledge is a key factor currently missing in public discourse.

> "*I feel that the public opinion in my country is still not well-informed on the issues and the danger posed by climate change. As a scientist I feel the responsibility to spread correct information that will lead to action. With my online activities the ultimate goal is in fact to change behaviour or induce some kind of action.*" (Assistant professor, climate change, Italy)

Participants with this perspective emphasized the value of science in society, for example as scientific information could lead addressees to make "better life decisions" or contribute to societal change. They did not tend to see the value of public knowledge in science. As such, participants' one-way perspective was clearly linked to the informing role that these participants envisioned for themselves in boundary interactions.

Other participants adopted a more two- or multi-way perspective on the relationship between science and society. These participants saw the value that science has in society and vice versa. This was connected to the perceived role participants assigned themselves — and as the following quote illustrates, this was connected to the realisation that collaborations beyond the scientific community are important in order to realise societal change.

> "*It is valuable to have face-to-face deliberations, yet at the same time, there is only so much that can happen on local level. We need global scale discussions amongst the public. [. . .] Going online means reaching a broader and potentially more diverse range of people. [. . .] It opens-up the space for deliberation with audiences. [. . .] More often than not, it triggers people to get in touch with us.*" (Professor, climate change, United Kingdom)

As such, the digital public sphere not only offers scientists the option to reach out to audiences, but also provides citizens the option to contact and deliberate with scientists. Herein, adhering to a two- or multi-way perspective resulted in more equal and diverse boundary interactions between scientists and citizens.

4.3 Activities, outputs and addressees

Roughly 20 participants practised their activities on Social Networking Sites (SNS), blogs, and in online publications of scientific news outlets and newspapers. Participants specifically mentioned to use Facebook, Twitter, Instagram and LinkedIn. In addition, some participants had started their own blog in order to share research results. The participants' activities, outputs they produced and addressees they aimed to reach were heavily informed by their underlying perspective. Most participants in this study believed that the role of scientists is to educate or raise awareness; and consequently, undertook dissemination activities such as translating from 'complex and technical information' to 'information and output that is understandable for the general public'.

Based on their underlying perspective, participants identified relevant audiences and adjusted their output or activities accordingly. Participants holding a one-way perspective believed that deficits in knowledge are the basis of public misunderstandings. They did regard "the general public" as a relevant audience for dissemination and education but not for multi-way exchanges such as deliberation or negotiation. For example, a professor in AI in Portugal stated to delete comments to his output if they "*are wrong from a scientific point of view*", because he felt these comments would confuse other people. As such, he did not actively engage in a dialogue or two-way interactions with his addressees. Participants with a one-way perspective did engage in two-way activities with addressees they deemed valuable. As such, participants with a one-way perspective mentioned they often used Twitter to connect and interact with scientific peers, politicians or journalists. Similarly, participants with a two- or multi-way perspective on boundary interactions displayed active interactions in the digital public sphere with both scientifically and non-scientifically literate audiences. Herewith, the role and perspective of participants were linked to the activities deployed, outputs produced and addressees they expected to find on a specific platform.

> "*Especially regarding Twitter, I know that it is very much used by two very particular categories of people, namely journalists and politicians. And so, by using Twitter I more have in mind these audiences, rather than for example Facebook or Instagram, where I think more about a general public.*" (Assistant professor, climate change, Italy)

Furthermore, this quote illustrates the notion that participants often referred to citizens as 'the general public'. As such, participants did not thoroughly define their addressees. Rather, participants seemed to think in dichotomy regarding addressees they aimed to reach online, for participants made a distinction in audiences between the scientifically literate and non-literate citizens. With this, participants distinguished between science-oriented audiences, such as other scientists, politicians, journalists and individual citizens with a pre-existing interest in science; and 'the general public' of whom participants thought as less scientifically oriented or literate.

4.4 Interaction patterns and boundary challenges

Untangling the participants' role, perspective and associated activities revealed that a participant's role repertoire could easily clash with the characteristics of the platform she used or the interactions she engaged in. This resulted in boundary patterns emerging and participants experiencing various boundary challenges. This included conflicts that scientists experienced within their role repertoire, between role repertoires and the digital public sphere, and lastly, between role repertoires and the scientific sphere.

4.4.1 Conflict within role repertoires leads to frustrating boundary interactions

Many participants described feelings of frustration in their boundary interaction with citizens online. A discrepancy within the role repertoire of individuals was found that lied to the basis of boundary challenges experienced by participants in

the digital public sphere. Firstly, participants held on to a frame or perspective that did not match the intended role in the boundary interaction. For example, these participants indicated they aimed to engage in a diverse and active interaction online; but tried to realise this interaction dynamic with a repertoire that more matches a homogenous conversation with scientifically like-minded addressees. Secondly, participants did not adapt their repertoire to match their intended role in boundary interactions online. For example, these participants wanted to inspire people and aimed to change individuals' behaviour to better society, but deployed a repertoire that informs or educates addressees. The following participant described this as follows:

> "*I started with online writing because I really like science stories. I am pushed by a desire to induce the same sense of marvel and curiosity in people that drove me to become a scientist in the first place.*"

However, for this scientist, interaction with audiences online often resulted in disappointments, as he mentions:

> "*Comments or replies are either from people that already know very well what I am talking about or from people who just want to reinforce their knowledge and own opinion.*" (Assistant professor, climate change, Italy)

Here, this assistant professor notices that his intended focus or contribution with regards to the boundary interaction — i.e. to inspire and change behaviour — was not realised by the repertoire he deployed in the boundary interaction. With this, participants experienced a conflict between adhering to their desired role and perspective with regards to boundary interactions, and later found out that their repertoires did not lead to such interactions with citizens in the digital public sphere.

4.4.2 Conflict between role repertoire and the digital public sphere — scientific expertise is "just another voice"

There was a conflict between participants' role repertoires and characteristics in the digital public sphere, wherein it appeared that scientists did not feel the worlds of science and the digital public sphere are compatible. Firstly, participants' role repertoires seemingly did not match with the nature of the medium. For example, role repertoires were rooted in participants' scientific environment and culture. Subsequently, participants indicated that it was hard to be someone who functions as an intermediary between the world of science and the general public online. Participants perceived scientific processes and the development of ideas take whole careers, while in the digital public sphere, ideas where formed spontaneously and interactions were more fast-paced.

> "*I deliberately decided not to use Twitter. Just because it was too quick for me. I didn't manage to deal with that. It results in more difficult debates for scientists. You are not allowed to [take time to] read and people just post punch lines — and that can win over good arguments.*" (Senior researcher, climate change, Sweden)

> *"I do not have Twitter, because I think it is a shallow way of communicating. You can be very easily misunderstood, with only 150 characters. [...] We have this kind of pattern in society about everything being entertainment. Our personal lives, our private lives, but also climate change, the coronavirus. [Social media] shallows discussions."* (Assistant professor, climate change, Portugal)

Many participants suggested that science should be described extensively and nuanced in order for the content to be correctly interpreted, and that scientific knowledge or information cannot be cramped into brief interactions online. They reported that the scientific processes with which they are familiar are not compatible with practices that are common in society. Participants' personal belief in this was that science should be taken seriously. However, participants noticed that scientific expertise is less recognised or more anonymous. For example, the following participant mentioned that it was not salient to present herself as scientist, or disseminate scientific knowledge, for she would 'just be another profile' in the digital public sphere.

> *"[Online public engagement activities] are behind this curtain of anonymity, so who am I on an online discussion forum? If I say I'm a researcher, who is going to believe me?"* (Assistant professor, AI, Sweden)

As such, by entering the digital public sphere, these participants referred to their voice being "just one of the many voices", which made them feel anonymous and reduced to the same level as any other opinion. For many participants, not being recognised as scientific expert in the digital public sphere or not holding a conversation on basis of scientific expertise, increased their sense of vulnerability.

4.4.3 Conflict between role repertoire and the digital public sphere — demarcating strategy provides poor boundary interactions

Participants experienced demarcation challenges in the digital public sphere. Following from their role repertoires, participants wanted to engage in boundary interactions on basis of scientific knowledge — whereas interactions in the digital public included public knowledge as well. The majority of participants in this study felt a responsibility or need to demarcate between scientific knowledge and public knowledge. However, participants often felt that demarcating between scientific and non-scientific knowledge in the digital public sphere led to frustrating interactions with non-scientific audiences. For example, the majority of participants in this study adopted a role repertoire focused on educating or informing audiences, wherein they would emphasise or refer to scientific processes, expertise or knowledge — and as such distinguish 'the scientific' from the more experiential or public forms of knowledge.

> *"It is very important to be specific in that the knowledge of a patient is something else than scientific knowledge. I don't instruct nor give advice on online platforms to patients. Never. Because these stories on Instagram or blogs, they are what we call anecdotic evidence. And that cannot be translated to the general public, because we cannot check what these social media influencers have done."* (Associate professor, healthy diets, Sweden).

However, in the digital public sphere such different forms of knowledge and expertise are blurred, mixed and maybe not always explicit or easily recognisable. Participants therefore experienced that bridging between different forms of knowledge, as such, might be especially challenging online. For example, this participant held on to a role repertoire that focused on getting scientifically correct information to patients with obesity. Consequently, she demarcated between scientific knowledge and practice, versus anecdotic or personal knowledge and practice. However, in the digital public sphere, this participant experienced that this boundary strategy would not have the intended effect in audiences:

> "*I communicate the science. But when my scientific knowledge does not correspond with their personal opinions, then they think I attack them as a person. But I'm not!*" (Associate professor, healthy diets, Sweden)

Since the majority of participants in this study demonstrated a one-way perspective on boundary interactions, it appeared to be difficult for participants to adapt their repertoire and try to bridge between different types of knowledge in the digital public sphere. Herein, a conflict was seen between the factual, distant or knowledge-based characteristics of the scientific world, where participants felt comfortable with, versus the more personal interactions that were present in the digital public sphere. For example, participants mentioned that commenters on online platforms would respond to their persona or image as a scientist, rather than the scientific content they would present online. These participants found it difficult to bridge between the scientific and more personal characteristics.

> "*I am known as someone who is a reliable scientist and who communicates science — and not my personal views. I have understood that if you are on Facebook, Twitter and Instagram, or other platforms like that, that it is very hard to communicate science or have a scientifically based dialogue. [. . .] When I [conduct public engagement activities] I do not want to do that as me, the private person, but as a professional, a researcher.*" (Associate professor, healthy diets, Sweden)

As such, participants indicated that they struggled with fulfilling a role repertoire that would function as mediator in boundary interactions in the digital public sphere. This meant that participants felt unable to highlight the personal or emotional aspect of doing research in addition to displaying themselves as "a professional researcher".

Participants were familiar with a role repertoire grounded in the scientific sphere, and consequently displayed repertoires that included informing or educating audiences. Participants indicated they missed a mediator in the digital public sphere, who would bridge between the participants' scientifically-focused output and the more emotional or personal characteristics of the boundary interactions that participants encountered online.

> "*The difference with social media today is that it has democratised journalism. I can post whatever I want on Twitter and Instagram. Because there is no editor online, anyone can say whatever they want.*" (Associate professor, healthy diets, United Kingdom)

> *"I feel like the people with rage and frustration are overpowering others. A lot of posts are over-commented with very negative and hating comments. I wonder, can [online interactions] ever be constructive?"* (Assistant professor, AI, Sweden)

The constructive interactions that participants were looking for, required a two-way perspective on boundary interactions, wherein participants' role repertoire would be aligned with the frame of reference of addressees. However, the role repertoire of many participants in this study was focused on a one-way interaction, wherein the scientists' mainly focused on disseminating scientific knowledge, and were not always equipped to engage with audiences that perceived the participants' output from a different frame of reference. The digital public sphere permits interactions that go in multiple ways, and includes the open confrontation of different worldviews, cultures and emotions next to 'the scientific'; and as such participants who entered the digital public sphere were sometimes caught by surprise that their scientific expertise was not recognised.

Discussion and conclusion

In the digital public sphere, the differences between scientists' expectations of interactions with audiences and their actual experiences have become more explicit. For scientists that deploy engagement practices online, the digital public sphere provides opportunities as well as challenges. Publics who originally resided deep in society, far away from the realm of science, are now one click away [Bubela et al., 2009; Rutsaert et al., 2013]. Similarly, scientists are increasingly more visible and directly approachable in the digital public sphere, and as such can be more openly criticized on their online activities, communication style and personality. Scientists responded to these dynamics by restating their scientific expertise and demarcate between scientific and personal or experiental knowledge. At the same time, scientists feel more anonymous in the digital public sphere, and are not necessarily approached on basis of their scientific expertise. Lastly, by taking a boundary work perspective it was revealed that participants had difficulties in mediating different forms of knowledge or practices in interactions with non-scientific 'general publics' in the digital public sphere. Scientists' experiences in the digital public sphere, therefore, often did not live up to their expectations of online public engagement activities — which left a feeling that 'the online' provides hollow interactions, anonymises scientists and devaluates scientific expertise. Furthermore, the role repertoire of the majority of scientists focused on dissemination of scientific information, rather than connecting to citizens' underlying values, emotions or worldviews on science or building a transformative online community. As Loroño-Leturiondo and Davies [2018] described, when scientists feel solely responsible for disseminating knowledge towards publics or draw the responsibility to do engagement towards themselves, the result may very well be that the activity of engagement will be separated from the public [Loroño-Leturiondo and Davies, 2018]. Moreover, there is a gap between this finding and the grand narrative of the science communication field, wherein public engagement tries to move away from a perspective on science-society interactions that include public understanding of science and instead adds repertoires of public engagement and public participation with science [Davies, Halpern et al., 2019].

Moreover, in scientists' role repertoire it became apparent that participants' one-way perspective and focus on informing or educating audiences, resulted in

participants rarely defining their audiences. For example, participants did not necessarily display a felt need to know more of their audience than the assumption that 'the general public' has a limited knowledge of science. This finding is in line with Besley and Nisbet's observation that scientists seem to see the public as homogeneous or categorise publics in terms of being up-takers or more 'against' science [Besley and Nisbet, 2013]. Science communication literature reports on audience segmentation and analysis [Füchslin, 2019; Hine et al., 2014; Metag and Schäfer, 2018]. Herein, scholars emphasize that 'the public' or 'citizens' should not be seen as monolithic categories, for different people have different interests, behaviours and perspectives on scientific information [Metag and Schäfer, 2018; Schäfer et al., 2018]. Our finding may point towards an underlying cause of interactions online not being constructive. If scientists have a limited understanding of the perspective that audiences have on science, it may be difficult to adjust a specific role repertoire accordingly. For example, participants indicated to struggle with mediating between the scientific knowledge and perspective they were familiar with, and the more personal or emotional approach that 'the general public' took in the digital public sphere. In some cases, it seemed surprising for scientists to notice the different emotional responses citizens tended display with regards to scientific information at all. Familiarising with these various approaches or perspectives with regards to how different individuals make sense of science, might therefore be a first step towards establishing meaningful connections online.

It is of vital importance to further investigate how constructive interactions between scientists and general audiences could be facilitated — especially given that participants in this study repeatedly indicated that interactions in the digital public sphere led to alienation between scientists and the general public. On the one hand, scientists may not have been capable in establishing constructive interactions, for they approached 'the general public' as one monolithic category, and as such not always recognised the value that individual citizens could bring to the boundary interaction. On the other hand, scientists increasingly are subject to personal attacks, and as such, the digital public sphere sometimes represents a hostile environment [Lewandowsky, Ecker and Cook, 2017; Lewandowsky, Oreskes et al., 2015]. This study showed that scientists feel very responsible for making interactions valuable to both the communicator as well as the receiver of the scientific information. However, it is not the question *if* scientists feel responsible, but rather *how* scientists feel responsible for interactions with citizens online.

To this end, it is of vital importance that scientists find out *how* to feel responsible, and as such adopt role repertoires that facilitate meaningful online boundary interactions. The concept of 'role repertoire' and the boundary work perspective could help scientists gain insights into their experiences and the boundary interactions they have with audiences in the digital public sphere. Our findings show that the default focus of most scientists is to inform or educate their audiences, and with this adhere to a boundary strategy that demarcates between scientific knowledge and public knowledge. However, the way in which citizens make sense of science is more dependent upon values, worldviews and the personal situation or context of individuals [Rerimassie et al., 2021]. As such, a desirable role repertoire facilitates scientists to recognise and listen to underlying values, perspectives and ideas that shape the public's perspective on science. This provides ground for an interaction with citizens that is based on mutual respect

instead of scientists telling the 'other' what they should know [Nisbet and Scheufele, 2009]. The concept of role repertoires is valuable to this end, for it provides scientists with insights into their own role in and perspective on boundary interactions is, and subsequently, how that shapes the way in which scientists think of their audiences. Secondly, it provides scientists with an important understanding of how their role repertoires interact with the perspectives of their addressees, and how role repertoires or boundary interactions work out in the context of the digital public sphere. With such insights, scientists could adapt their practices to align with the perspective of their addressees.

We therefore propose that scientists who engage with publics online need to adopt a reflective practice. One of the progenitors of this was Schön's [1983] work on 'the reflective practitioner', wherein he described reflection as a continuous learning process of reflection-in-action and reflection-on-action. Reflection-in-action is an integrated process of thinking about ones actions and at the same time executing them, whilst reflection-on-action is an evaluation exercise on the effect of undertaken activities and taking actions towards a pre-set goal [Schön, 1983]. In the context of communicating science in the digital public sphere, a reflective practice would first of all require an understanding of the many different 'others', and second, require an openness of scientists with regards to ambiguities, uncertainties and complexities present in their field of science [Brüggemann, 2017; Jasanoff, 2019]. The latter becomes especially relevant in relation to contested science discussed in the digital public sphere. Double-loop learning is particularly useful here, for this allows individuals to revisit their model-in-use and adapt it to what is required in the boundary interaction [Hesjedal et al., 2020]. Therefore, and following the idea of reflective practice, scientists who experience challenges in interacting with publics online should learn to ask themselves during interactions with citizens: 'How do I regard my interaction with publics online, and how does this perspective influence my actual engagement practices? And, with this, do I achieve what I want to achieve?'.

However, improving science-society interactions should not be a responsibility that is laid upon individual scientists themselves — if anything, scientists in this study already felt a tremendous obligation to do so. Moreover, in interviews participants repeatedly mentioned public engagement activities to be voluntary activities, for which little time or resources was provided. This suggests a shared responsibility of both academia as well as society should be realised, in order to explore new directions in which role repertoires could be carried out constructively by scientists online. Moreover, support structures should be established that may help scientists become reflective practitioners in the digital public sphere. Teaching and training of early-career researchers may provide a valuable first step to this regard [Hesjedal et al., 2020; Salmon, Priestley and Goven, 2017]. It is important to emphasise a need for diversity in roles repertoires rather than searching for a single best role repertoire in the digital public sphere — be it that these role repertoires are aligned to the scientists' intended contribution and expectations of online science-society interactions.

In conclusion, given the presence of widely-ranging and alternative perspectives on science, and the directness towards and anonymity of authors in the digital public sphere, it is not hard to imagine that scientists must feel exposed when interacting online. We belief that reflective practice can bring a valuable learning

opportunity here, for it makes explicit underlying conflicts or differing values and worldviews, and reveals possible directions for change. As such, the digital public sphere might actually present an opportunity, for online interactions provide valuable opportunities for scientists to be exposed to numerous social, economic, political or cultural perspectives on their contested field of science — and might stimulate participants to rethink their existing assumptions and activities [Hesjedal et al., 2020]. As such, the digital public sphere can facilitate and elicit appreciation of reflective practice, for it may provide scientists with insights into why their interaction with citizens is unfulfilling, experienced as hollow or even hostile; and instead provide directions for learning and rewarding interactions with citizens online.

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