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RESPONSIBLE SCIENCE COMMUNICATION ACROSS THE GLOBE

Towards the reflective science communication practitioner

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Abstract

The practice of science communication is fundamentally changing. This requires science communication practitioners to continuously adapt their practice to an ever-changing ecosystem and highlights the importance of reflective practice for science communication. In this study, we supported 21 science communication practitioners in developing a reflective practice. Our study shows that reflective practice enabled practitioners in becoming aware of their own stance towards science or assumptions regarding audiences (single-loop learning), underlying and sometimes conflicting values or worldviews present in science communication situations (double-loop learning), and facilitated practitioners to adapt their practice accordingly. Triple-loop learning, allowing practitioners to fundamentally rethink and transform their mode of science communication, was less observed. We argue that reflective practice contributes to opening-up public conversations on science — including a conversation on underlying values, worldviews, and emotions, next to communicating scientific facts.

Keywords

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

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Introduction

In the 2021 film 'Don't Look Up' the characters portrayed by Leonardo DiCaprio and Jennifer Lawrence are astronomers who discover an asteroid on a collision course with Earth. While preparing for his debut media appearance to bring this devastating news to the world, DiCaprio's character Dr. Randall Mindy is instructed: "You're just telling a story. Keep it simple. No math.", to which he responds confused: "but it's ALL math…". Of course, 'Don't look up' is a dramatised allegory, but the challenges DiCaprio's and Lawrence's characters face speak to many challenges that professionals are currently confronted with when trying to communicate science: how to deal with science denialism? How to deal with the politicisation of science? And how to balance complexity with a clear message?

The field of science communication is becoming increasingly dynamic and complex. Digitalisation and the rise of social media, commercialisation, including sensationalism of (scientific) information and the politicisation of science in public debates, have revolutionised the way in which science communication practitioners practice their work [Brüggemann, Lörcher and Walter, 2020; Alexander, 2015]. Firstly, science communication practitioners experience this as their work has become increasingly fast-paced — leaving less time for investigation, storytelling and curating what information should be disseminated [Massarani et al., 2021]. Secondly, the science communication ecosystem is more fragmented, with numerous interfaces which professional science communicators — and new science communication actors — interact with audiences in myriad ways [Bubela et al., 2009; Rutsaert et al., 2013]. As Trench already noted in 2008, there is an abundance of information about science online, often consumed from sources where traditional media's editorial oversight and fact-checking mechanisms are lacking [Trench, 2008]. At the same time, online public discussions of science are more explicit about the diversity of voices presented — all underpinned by their own values and worldviews [Roedema, Broerse and Kupper, 2021]. Moderating constructive public discussions on science is hard to put into practice, for science communicators indicate to have little insight into their audience, often referring to audiences as 'the general public', and with only 37% of science communicators indicating to receive occasional feedback from audiences on their outputs [Massarani et al., 2021]. This often leaves science communication practitioners guessing how their activities link to values of audiences and how they make sense of information put forward. Thirdly, scientific issues are increasingly drawn into political conflicts in a polarising society [Brüggemann, Lörcher and Walter, 2020].

This increasingly complex practice and continuously changing ecosystem, including wider societal transformations and post-normal situations, asks for *reflective science communication practitioners* [Brüggemann, Lörcher and Walter, 2020; Ramaker, van der Stoep and Deuze, 2015]. Current practice, such as 'fact checking' and 'gate keeping' of scientific information entering society, does not uphold in post-normal situations, for such situations require a practice capable of dealing with value questions and uncertainty [Brüggemann, Lörcher and Walter, 2020]. Many scholars have repeatedly pleaded for a shift in science communication roles as well as science communication modes, wherein they urge the field to move away from deficit-thinking and strengthen the relationship between science and society by two- or multi-way communication modes [Bubela et al., 2009; Davies, 2021; Fahy and Nisbet, 2011; Trench, 2008]. For science communicators, this means a constant rethinking is needed of their deployed mode of science communication, including reflection on the perspective or role they hold with regards to science-society interactions, goals and activities, and an awareness of how this addresses (or excludes) certain audiences [Roedema, Broerse and Kupper, 2021]. In this, reflection is essential to critically investigate the frames of thought deployed by the science communication practitioner, and to link this to science communication practice [Schön, 1983].

Reflective practice has mostly been operationalised in academic contexts, in practice-oriented fields such as management, nursing and social work [Askeland and Fook, 2009; Dubé and Ducharme, 2015; Jones and Stubbe, 2004], and for educational purposes to obtain certain professional skills or insights [Boud and Walker, 1998; Hesjedal et al., 2020; Karnieli-Miller, 2020]. More related to the

practice of (science) communication, scholars describe how work on reflection and reflective practices in journalism studies tends to be focused on formal education and to some extent the field of ethics, and not so much on the core journalistic practices of news gathering, selecting, editing, and publishing itself [Ahva, 2012; Niblock, 2007; Ramaker, van der Stoep and Deuze, 2015; Salmon, Priestley and Goven, 2017]. For example, Ramaker, van der Stoep and Deuze [2015] theorised how the concept of reflective practice could be essential for journalists, in terms of assisting them to cope with the constraints of current journalistic work. Salmon and colleagues described strategies and barriers to reflexivity in scientists 'specifically in relation to their outreach efforts' [p. 58] and showed scientists' reflections on science-society interactions [Salmon, Priestley and Goven, 2017]. This study aims to build on earlier work related to reflective practice in the context of science-society interactions. We propose that reflective practice can be valuable for practitioners who need to deal with complex realities or fast-changing communication environment, yet this mode remains understudied in daily science communication *practice* and for a wide variety of relevant actors in this field. As far as the researchers of this study could ascertain, this is the first empirical study that applies the 'doing' of reflective practice in daily science communication activities by different relevant actors in this field. We supported 21 science communicators, including science journalists, science communication practitioners in universities, research institutes and science museums and communicating scientists, in developing a reflective practice for their daily context and work — and explored ways in which this could help practitioners to deal with the challenges within the current science communication ecosystem. Through semi-structured interviews we set up reflective practice experiments together with participants, wherein they formulated activities that would enable them to adapt their practice to the complexities of the current science communication ecosystem. Participants kept track of their experiences in reflection diaries. We used the reflective cycle of Gibbs [1998] to help stimulate 'reflection-on' activities undertaken by participants and help create awareness of what happens in specific situations they experienced, as well as help practitioners to draw conclusions and make action plans for adapting their science communication practice to the complexities of the field.

Theoretical background for reflective practice

Reflective practice is generally understood as 'a process of continuous learning and gaining insights into how frames of thought, emotions, assumptions, worldviews, and values are linked to practices that are carried out by individuals, communities or institutes' [Finlay, 2008; Salmon, Priestley and Goven, 2017]. This involves mostly individual practitioners to critically assess one's own response to and in situations they encounter in their work. The concepts 'reflection' and 'reflective practices' are frequently used interchangeably in different fields of research and practice [Fook and Askeland, 2006; Niblock, 2007]. Therefore, it is first crucial to outline how we understand these concepts in the context of this study.

More than 100 years ago, the philosopher John Dewey articulated a concept of 'reflection' in his seminal book '*How we think*'. Dewey [1933] argued that reflection arises in moments of conflict or doubt about the experience of a particular situation. It is through reflection that one actively connects such an experience to other experiences and ideas, conceiving alternative courses of action to learn how to respond adequately. Schön has built on this notion of learning-by-doing in his book 'the reflective practitioner', where he fittingly mentioned 'the case is not "in

the book"' [Schön, 1983, p. 121]. According to Schön, reflective practitioners are professionals who are aware of their implicit knowledge and learn from their experiences [Schön, 1983]. They assess their own thoughts, emotions, worldviews, and values in specific situations, and directly link these to actions they undertook [Schön, 1983]. This helps practitioners to gain insights into the various ways their activities are influenced by perspectives, ideologies, institutions, or economic and political conditions [Finlay, 2008]. Schön [1983] distinguished two types of reflection, namely *reflection-in-action* and *reflection-on-action*. Reflection-in-action is doing the thinking *in the moment* of the encountered situation or experience, whereas reflection-on-action is the thinking or assessment of thoughts *after* a situation or experience has passed. Reflective practice is thus conceived as a dynamic process that is continuously modified by the changing context, rather than a permanent state, fixed process, or accumulation of thoughts. Different types of learning are useful in the context of reflective practice as a strategy to excite reflectivity [Hesjedal et al., 2020]. Single-loop learning is characterised as becoming aware of the problem or challenge in the, in this case, specific science communication situation; whereas double-loop learning 'includes a feedback loop that allows individuals' and organizations' experience to result in reconsideration and revision of the mental model' [Hesjedal et al., 2020, p. 1636]. Triple-loop learning is described as a processes wherein existing frames of thought are 'reopened', as to change the practice or undertaken activities more fundamentally [Tosey, Visser and Saunders, 2011].

Schön's work highly influenced models on reflection, such as the model of Atkins and Murphy [1993] on different stages of reflection, Gibbs' reflective cycle [1998] that highlights how reflection on experiences is essential in learning processes and gaining understanding of situations, and models that indicate how reflection might take place on different levels, from individual reflection, to a more reciprocal and shared reflection in communities, to reflective institutions [Atkins and Murphy, 1993; Chilvers, 2012; Finlay, 2008; Wynne, 1993]. A common theme amongst most models is the notion that reflection practice starts with an awareness of uncomfortable feelings and thoughts, followed by reflection on these feelings and thoughts, which results in newly obtained (action) perspectives [Atkins and Murphy, 1993, p. 1189–1190]. Gibbs' reflective cycle suggests that the continuous learning process happens iteratively when we encounter complex situations, for example, as awareness of feeling uncomfortable helps us reflect on what we feel, think, or how we act — and as such moves us to evaluate the experience, draw conclusions and make an action plan for future situations [Gibbs, 1998; Finlay, 2008]. In this study, we have used Gibbs' reflective cycle to help stimulate reflection-on-action and creating awareness in individuals of what happens in specific situations they experienced during their reflective practice experiments. Furthermore, Gibbs' reflective cycle was used to help practitioners draw conclusions and make action plans for similar science communication situations in the future — with the aim to also stimulate reflection-in-action in the future.

We argue that reflective practice may also benefit the work of science communicators. Science communicators draw on both practical experience and theory, as they need to think on their feet and improvise, as well as comply with scientific culture and practice. In this context, it is crucial to realise that reflective practice in science communication needs to be understood in terms of boundary work; practitioners in this field are driven by curiosity and creativity to translate

scientific information to wider audiences — and as such act on the boundary between science and society [Akkerman and Bakker, 2011; McGreavy et al., 2013; Roedema, Broerse and Kupper, 2021]. A reflective practitioner in this field should therefore not only question their own perspective or output with regards to science, or processes or dynamics in the science communication ecosystem, but also regard the common routines, values, worldviews, and cultures prevalent in society. Furthermore, science communication practitioners need to navigate the challenges related to 'post-normal situations', wherein they need to find ways to communicate uncertainties of science, value questions, a need to respond to calls-to-action, political pressures, and a polarised society [Brüggemann, Lörcher and Walter, 2020]. Reflection-in- and on-action allows science communication practitioners to regard these dynamics, and revise, modify and refine their practice accordingly — both in the moment as well as learn after they have deployed certain activities [Finlay, 2008; Schön, 1983].

Methods

This research is part of the European-funded RETHINK project (2018–2022). In this project, seven Communities of Practice (CoP) — so-called 'Rethinkerspaces' — were established in seven European countries: Italy, the Netherlands, Poland, Portugal, Serbia, Sweden and the United Kingdom. Rethinkerspaces act as testbeds and validation mechanisms for the reflective practice experiments developed and experimented with. Each Rethinkerspace consists of a heterogeneous group of approximately 10–15 science communication practitioners, varying from science communicators and science journalists, to communicating scientists, social sciences and humanities (SSH) scholars, policy makers and science funders.

3.1 Participant recruitment

All Rethinkerspace members received an invite to participate in this study, of whom three to four Rethinkerspace members were contacted to participate per country. Rethinkerspace members were selected for participation based on several characteristics. First, Rethinkerspaces members were asked to experiment with a reflective practice in their daily science communication activities. As such, it was a requirement for participation to be actively involved in the *practice* of science communication, meaning that participants had to produce science communication outputs or be involved with audiences more interactively. Second, these could be both online and offline activities, such as writing, tweeting, blogging or vlogging about scientific topics, moderating conferences, network events or discussion evenings in cultural institutes and museums, and many more. Participants needed to be actively involved in the practice of science communication at the time of data collection (in 2021). Lastly, an even distribution of practitioners over the seven Rethinkerspaces was strived for (see Table 1). In this, it was important for this study to gather as many diverse ways in which science communication practitioners experience and execute their practice.

Table 1. Overview of participants. (IT = Italy, NL = The Netherlands, PL = Poland, PT = Portugal, Sb = Serbia, Se = Sweden, UK = The United Kingdom).

	IT	*NL*	*PL*	*PT*	*Sb*	*Se*	*UK*	*Total*
Science journalist	1	2	2	2	3	2		12
Science communicator in university, research institute, science museum	1	2				1	2	6
Communicating scientist	1		3	1			1	6
Total	3	4	5	3	3	3	3	24

3.2 Data collection

This research followed different phases and used various research methods (see Figure 1), using interviews, reflection diaries and observations. Each phase is elaborated below.

Phase 1: Setting the stage. The main goal was to find challenging situations that could serve as an entry point for participants' reflective practice experiments, and to set up the experiment together. Researcher TR and research assistants conducted a first round of online interviews with 24 participants, inquiring about the experiences of participants in their science communication activities. Interviews lasted approximately an hour.

Phase 2: Reflection-in-action. Twenty-one participants (three had dropped out due to time constraints) experimented with reflection-in-action and kept track of their reflective practice experiment in a reflection diary. This diary followed a step-by-step approach, based on Gibbs' reflective cycle [Gibbs, 1998]. Participants listed a description of: 1) a science communication activity or situation; 2) related thoughts, emotions and assumptions; 3) related underlying values, perspectives, worldviews or other factors; 4) how underlying factors had influenced the science communication activity or situation; 5) an adapted science communication activity, strategy or practice for situations in the future. This led to a total of 79 science communication situations and activities on which participants reflected. Participants who completed multiple reflection diary entries received a small remuneration.

Phase 3: Reflection-on-action. The main objective of the third phase was to reflect-on-actions undertaken by participants, as to reach new understandings for the value of a reflective practice for individual participants. All 21 participants were interviewed (online) a second time to reflect-on-action, and together with the researchers develop new understandings regarding the value of a reflective practice for the individual practitioner. Furthermore, this interview was used as a check for the researcher to see if they had interpreted entries in the reflection diary correctly and to obtain more detailed clarifications. Interviews lasted approximately one hour.

Phase 4: Dialogue. The aim of the fourth phase was to gain insight into the value of reflective practice to the broader field of science communication. To this end, a multi-stakeholder dialogue was organised in each of the seven Rethinkerspaces,

wherein participants of this study presented their reflective practice experiment and reflected on the value. A total of 58 Rethinkerspace members attended dialogue sessions in seven European countries. Members discussed the potential broader value of reflective practice for science communication. Rethinkerspace dialogues were held online. Data collection took place via the online tool 'Miro', where Rethinkerspace members voiced their thoughts and reflections by posting sticky-notes on a virtual board. In every dialogue a reporter from the RETHINK project was present to take notes of conversations.

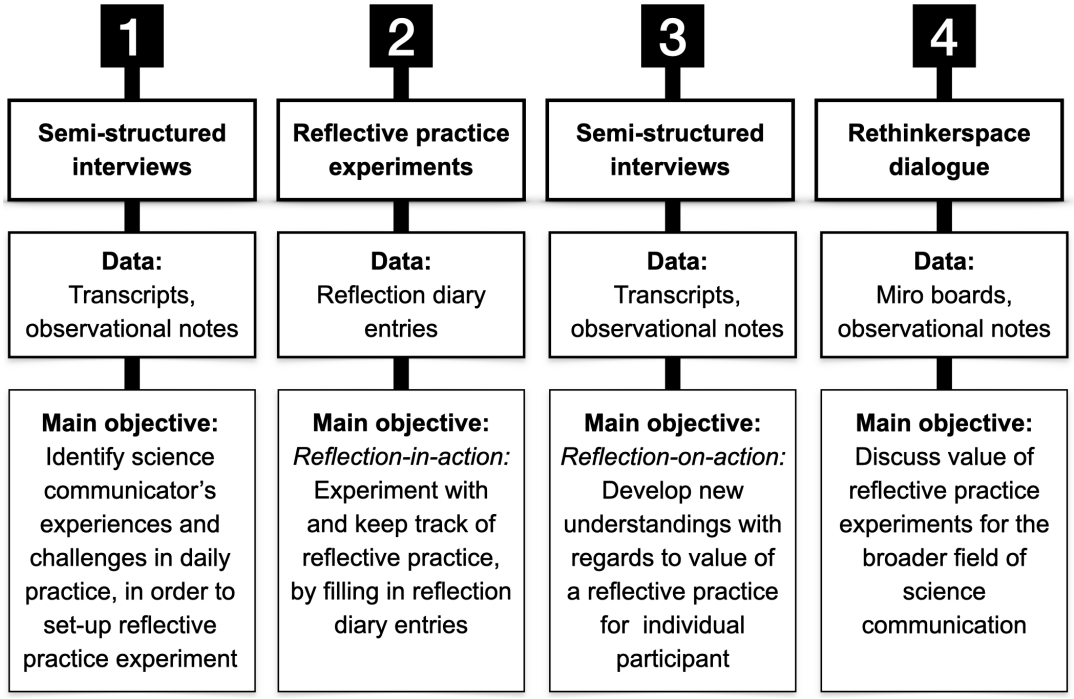

Figure 1. A schematic overview of the subsequent phases during this research, indicating methods used, data gathered and the main objective of each phase.

3.3 Data analysis

All interviews were audio recorded and transcribed verbatim. Interview transcripts and reflection diaries were coded on basis of the theoretical framework. Researchers VR and TR, and with help of multiple research assistants, coded the interview transcripts and reflection diaries. Open coding was used as a first step in the coding process — a process wherein the researchers developed their initial interpretations with regards to the value and process of the reflective practice experiments [Braun and Clarke, 2020]. This coding step was further informed by axial coding — or coding based on the theoretical framework of reflective practice — allowing the researchers to describe recurring themes and patterns present in the data. Lastly, VR and TR used observational notes of reflective practice experiments, taken during Rethinkerspace dialogue sessions and Miro boards, to further contextualise and check interpretations obtained through open and axial coding. As such, both inductive and deductive analysis strategies were applied in this study.

In an action-oriented research approach, researchers worked together with participants to identify challenges, shape the reflective practice experiments and

discuss their experiences. It is crucial for researchers who do action-oriented research to critically reflect on and be open about their own frames of thought — for they shape the way in which participants will experiment with their own reflective practices [Fergusson, van der Laan and Baker, 2019]. To this end, an extra check of researchers' interpretations of participants' responses were done in phase 3 and 4 of this research. A wide variety of stakeholders relevant to the theory and practice of science communication were present in the Rethinkerspace dialogues, encompassing practitioners, science enablers, science funders, science policymakers and SSH scholars. These diverse voices were used to challenge assumptions we had as researchers ourselves. Next, we applied triangulation of research methods and involved multiple researchers to shed light on the value of reflective practice for science communicators, from different perspectives and types of data. Lastly, researchers challenged each other on their individual coding and interpretations of data during this study. With this, we aimed to engage in critical reflection as researchers and cover our potential blind spots.

Findings

This section presents the experiences of participants in devising their reflective practice experiments. First, we discuss participants' context wherein their reflective practice experiments were situated and determined their entry points for reflection, in the form of challenging science communication situations as experienced by participants. On basis hereof, participants formulated new strategies to transform their practice. These reflections-in-action are discussed in the second sub-section. Lastly, participants looked back on their experiences with developing a reflective practice — or, in other words, 'reflected-on-actions'. Moreover, participants highlighted the broader value of a reflective practice for the field of science communication. These insights will be shared in the third section of the results. Quotes will be used to illustrate our findings.

4.1 Determining participants' context for reflection

Prior to devising the reflective practice experiments, we explored participants' science communication activities, experiences, and related viewpoints, which served as the participants' entry points for reflection. The participants perform a broad array of science communication activities, varying from public lectures and appearing on radio, podcasts or TV, moderating events in cultural venues, to writing blogs or articles. Through such activities the participants run into situations that prompt reflection, e.g., about the nature of their work, in terms of the desired or intended purpose of science communication in society, and their interactions with audiences. To this end, four themes emerged: an audience that is anonymous, hidden, or unknown to communicators; the wide diversity of communication channels; worries of participants regarding their (online) science communication abilities; and challenges for practitioners to communicate scientific information accurately where science is uncertain.

First, *the unknown audience*. Many participants mentioned that they only have a general idea of who their audience is. To quote participant 1, a British communicating scientist: *"we might be able to reach more people, but we don't know much about them"*. Concern existed about a lack of interest from 'the general public' and conversely, several participants experience to live in an academic bubble and

have the feeling that science communication practice only reaches people that already have an interest in science. Lastly, participants mentioned that online dynamics provide little in-depth feedback from audiences back to the science communicator. For example, some participants mentioned they received online feedback in the form of comments about the content of their output, but no detailed feedback was shared on the form in which the scientific information was presented or interpreted by audiences.

Secondly, several participants — of whom mostly communicating scientists who engage in science communication activities on top of their regular activities — indicated a general *discomfort with fragmentation of science communication interfaces*. Participants mentioned they are often overwhelmed by the abundance of communication channels to choose from and, consequently, the many different styles and modes of science communication practices they needed to get comfortable with. Thirdly, and relatedly, participants worried about their abilities to get the right message across in the right way. This especially concerned online science communication practices.

Fourthly, participants mentioned the importance of communicating about the scientific process to deal with uncertainty. A participant made the following observation about communication dynamics in relation to uncertainty during the Covid-19 pandemic:

> *"The pandemic has shown that people are being totally freaked out that scientists have different opinions. […]. 'Why do scientists say different things?!' But this is the scientific process. That you try some things, you find evidence for [your hypothesis], or if you must try something else and find new evidence."* — communication manager_Serbia (P19)

This participant illustrated concerns on how science communicators should deal with communicating uncertainty of the scientific process, including differing and sometimes contradicting stances within the scientific community and in wider audiences.

Lastly, many participants worry about *disinformation, misinformation, and fake news*. Participants experienced that many interactions elicited a wide variety of mostly negative emotions in them. For example, a science journalist from Portugal, mentioned to *"get very angry whenever I see pseudo-science"*. A communicating scientist from Poland expressed he did not know how to respond to such interactions online:

> *"I was confused (…). It would be very difficult to convince someone who already believes in [hoaxes], but I decided to write him a letter. […]. He thanked me but did not answer in any other way. Should I spend so much time just to answer one person? I could reach more people during this time, but that man was 'from the other side' — and maybe I could change his mind? I don't know. I often return to this situation with my thoughts and can't find answers."* — communicating scientist_Poland (P7).

Participants mentioned to struggle adapting their communication activities to a wide variety of persons that often hold viewpoints differing from their own.

Furthermore, participants in this study showed extensive worries regarding how science communication outputs can compete with misinformation or pseudoscience in the digital sphere. Lastly, participants indicated to often think about ways in which they should address such complex dynamics in the science communication ecosystem.

4.2 Reflection-in-action: reflective practice experiments

On basis of the previously described entry points for reflection, participants formulated reflective practice experiments they desired to undertake. The goal of these experiments was for practitioners to reflect-in-action. With this, participants examined how their — often implicit — thoughts, assumptions and emotions were linked to the way they addressed certain audiences. Each designed reflective practice experiment was tailor-made to the participant's experienced challenges, situations, needs and context. Participants undertook reflective practice experiments in roughly two categories: first, participants undertook activities to gain in-depth insights into their audience and how that audience made sense of the participant's science communication output, and second, participants experimented with conversational and writing strategies. All types of reflective practice experiments ultimately aimed at facilitating more constructive interactions between the science communicator and its audience, in light of the complexities of the current ecosystem.

4.2.1 Experiments undertaken to learn about audiences

Most participants felt that they lacked in-depth insights into the needs of audiences with regards to participants' science communication outputs — and as a result felt unequipped to adapt their practice to their audience. Therefore, many participants in their reflective practice experiment send out a questionnaire to audiences of their outputs, such as listeners of their own podcasts and radio shows. Other participants interacted with their audience through their social media accounts. These participants wanted to include the opinions of their listeners in composing questions for the podcast's guests. Others asked for feedback on how the scientific information was presented in the radio show.

These participants gained new insights into their audiences through their reflective practice experiments, particularly with regards to differing perspectives, values, and emotions that individuals can have with regards to science. Herein, many participants mentioned that assumptions they had about their own science communication output and the effect it would have in audiences was often incorrect. For example, a PhD student in immunology formulated this as follows:

> *"I acknowledged [in my podcast] that there is an infertility anti-vax rumour going around and mentioned that there is no evidence [to support that]. Now I realise that to pregnant women that is terrifying."* — PhD student in immunology and biomedicine_UK (P1)

Many participants mentioned that checking assumptions and learning about their audience is important to open-up conversations, get audiences engaged in the

story and adapt their activities to their audience. With regards to the previous quote, during the reflective practice experiments, participant 1 had realised she had not addressed the emotions of her audience with regards to the topic of Covid-19 vaccinations in her podcast explicitly, even though through her questionnaire she learned that her podcast had evoked many emotions in the listeners. Subsequently, she decided to experiment with these newly obtained insights. In her reflection diary, she explains how she opened-up the conversation on emotions, next to presenting the scientific facts:

> *"I think that I have tried to change my approach when I introduced a vaccine-related topic [in my podcast] to debunk misinformation. I now try to not go straight to the scientific information, but instead first acknowledge the valid reasons that people have for their hesitancy [to get vaccinated] and the fear that people have. Talk about 'why' people are scared. (…) I feel that people will be far more receptive to science if they feel that their emotions are being acknowledged too."* — PhD student in immunology and biomedicine_UK (P1).

Secondly, many participants mentioned that their reflective practice experiments *enabled them to see the people behind* the hesitancy or negative comments online. Participants stated their science communication activities felt more rewarding or meaningful. For example, a participant mentioned how he had confused doubt and a hesitant posture towards scientific information in one of his readers with being a conspiracy theorist:

> *"I was disappointed to see him vent his doubts with regards to science. I associated doubt with conspiracy thinking. But those doubts do not make him a conspiracy theorist. I realised he was being vulnerable and open to input. That made my perspective change. (…) Maybe the assumption I had was not strange, but it wasn't productive either."* — science journalist_Poland (P2)

Another participant highlights how, through a process of reflection-in-action, he was able to adapt his science communication activity towards finding common ground:

> *"I know that parents who don't want to vaccinate their children are not bad parents. They are just scared that something will happen. So, for me, the baseline here is that we all want to have healthy children. We agree on this. And when we have this agreement, it's easier to start the conversation. The next step is to ask [our doubting audience] questions."* — science journalist_Poland (P2).

As such, the reflective practice experiments were experienced by participants as valuable to gain new insights into their audiences. Moreover, participants mentioned to be more able in adapting their science communication activities to their audiences, in terms of incorporating uncertainty of science and audiences' underlying values, emotions and worldviews — next to a focus on the scientific facts.

4.2.2 Experiments undertaken to tinker with science communication activities

The other main category of reflective practice experiments concerned participants who experimented with new ways of writing and engaging in conversations. Related to entry points for reflection, participants experienced that they in some instances did not address or reach their audience in the intended way or with the intended goal. As such, these participants decided to change something in their own science communication activity to reach the audience the intended way. Participants decided to communicate their objective explicitly in certain activities with the goal to increase transparency and trust, wrote personal letters to science sceptics, interact actively with negative comments participants would normally ignore, and write articles to unpack how people come to the most common sceptical comments. In these experiments, participants specifically mentioned how suspending judgment, including more personal reflections and emotions next to scientific facts, and listening, had enriched the interactions they had with audiences. A Dutch science press officer describes this as follows:

> *"[The antagonistic citizen journalist] was actually very open, and I could tell that even though she had very little knowledge or expertise, it was clear that she had very real concerns about the disease and how to handle it. As the conversation developed, I let go of my science press officer persona, and talked from my own personal views. We had a long and open, respectful conversation [. . .]. I learned that it's not right to dismiss someone like her, but to listen to what she's saying. [. . .] Once you realize that scientists are occupied with the 'cause' of something, and most people with the 'reason' for it, it becomes easier to understand the misunderstanding."* — science press officer_The Netherlands (P16)

Reflecting on such communication situations gave many participants important insights into their own values and viewpoints; and connected that to science communication interactions they had. For example, when P16 had let go of his assumptions, and started to communicate from his "personal view", the dynamic of the conversation changed. With this, the reflective practice experiments made some participants realise they are not always as approachable as they thought — or when they were not flexible in adjusting their own point of view in light of new and valid arguments.

> *"The reflection diary helped me to think one step further. I had to consciously think about what happens daily in the interactions I have through work. It showed me that we are poorly informed [about our audiences] and disabled by our own thoughts and emotions about topics and people."* — science journalist_Poland (P10)

Some participants noticed that through use of the reflection diary, they started to reflect more *during* science communication activities. In other words, it appears that the reflection diaries facilitated reflection-in-action. For example, participants mentioned that the reflection diary facilitated active reflective thinking, which helped them to get new insights into their own perspective on science, their own emotions and values, and take opinions that were different from their own into consideration.

4.3 *Reflection-on-action: new understandings with regards to the practice of science communication*

In this sub-section we discuss how the participants reflected-on the experiments they had undertaken during this study, and new understandings they reached on basis hereof. Such understandings ultimately inspired participants in terms of possible directions for change of science communication practices — and provided opportunities to navigate challenges present in the science communication ecosystem. With this, participants mainly addressed the *disconnect* they felt with audiences. Overall, participants found they became more self-aware of their assumptions and displayed more openness about differing views and emotions in their activities.

> *"I would try to keep calm and allow myself to try to understand why somebody has a totally opposite opinion than mine. Even if that opposite opinion makes me angry, I will try to have more productive conversations. In that way, I will learn something from [the interaction], rather than just focus only on explaining my point of view."* — science journalist_Poland (P12)

Some participants also highlighted that tapping into personal feelings and establishing a more emotional connection on the otherwise more rational understood scientific topics had enabled common ground and facilitated mutual understanding. This was not always perceived as easy, and it took bravery and perseverance. For example, all participants mentioned they had interactions with people who believe in profound falsehoods in scientific information online. Participants mentioned these encounters led them to the 'automatic reaction' of defending science. Participants explained they felt to 'belong to the scientific community', for they believe that scientific information helps society navigate through complex problems, such as the Covid-19 pandemic — a perspective that was disputed by science sceptics online. After the reflective practice experiments, it appeared to many participants that it was better to deal with these difficult conversations by not immediately attacking or contradicting false claims, because people will always have their reason to believe or feel something towards scientific information, e.g.:

> *"Openness means being open to each person. Some of those people in the audience are totally anti-science. And they are not easy to talk to. Though, I feel that being open is to ask questions to those groups and address their questions as well. Because they are representatives of society. They do have a right to ask."* — communicating scientist_Poland (P3)

As such, most participants found through their reflective practice experiments that acknowledging the emotional side of socio-scientific topics and taking the critiques or other opinions on science seriously, is valuable to the practice of science communication. Almost all participants herewith expressed ideas to reorient their practical activities towards promoting dialogue, e.g.:

> *"What I could adopt for future encounters is the idea that being open and reflective should be the default mind-set. It helps to shed a light on the personality behind the doubts and questions, instead of all the associated characteristics that may or may not be present in someone."* — science journalist_the Netherlands (P13).

Hence, it was perceived to be more constructive to inquire *why* audiences believe something, or what underlying values and emotions give rise to online comments — and next, to take those reflections as the starting point of a conversation on science. Lastly, it felt refreshing to many participants to hold a conversation on the 'why', which included a conversation about values, perspectives, worldviews, and emotions related to science, next to merely discussing the scientific facts.

4.4 Observations with regards to types of learning in reflective practice experiments

Participants in this study displayed diverse types of learning in their reflective practice experiments. Participants displayed single- and double-loop learning to a large extend, yet triple-loop learning was not as often observed — and in some reflective practice experiments missing completely. Single-loop learning was displayed by all participants: they were able to identify 'mistakes' or indicated were interactions 'had gone wrong'. Many participants displayed double-loop learning when they reflected on underlying causes to why specific science communication situations had not had the intended effect. Triple-loop learning was less observed, for participants have not adopted fundamental changes in modes of science communication. For example, practitioners recognised they 'belong more to the scientific community', and as such had the corresponding practice to want to defend science (single- and double-loop learning) — yet such stances were rarely explicitly linked to a reorientation of their *goal*, or perspective on science, nor redefined how these underlying factors influenced their practice more fundamentally.

Participants who had displayed triple-loop learning in reflective practice experiments, were able to critically challenge how their own frames of thought had influenced the way in which they addressed audiences. Subsequently, they transformed their practice and opened-up the conversation on the plurality of perspectives, values, and emotions that people could have with regards to the displayed scientific information. They reoriented their goal and practice from 'convincing and educating' (e.g., 'scientific information is the universal truth that helps people in their daily lives'); to listening to audience's legitimate concerns, personal situations, and social contexts (e.g., 'science is not the only relevant type of knowledge in the lives of people') and transformed their practice accordingly to these newly obtained insights.

Discussion

This study engaged science communication practitioners in experimenting with reflective practice in their daily science communication activities. The science communication ecosystem has become an increasingly fragmented, dynamic, high-paced, and complex work environment for practitioners. Indeed, participants often indicated they did not know who their audience is, how these potentially diverse publics make sense of science communication outputs and how these audiences could be addressed. Many participants indicated they felt a need to 'defend' science and scientists' image — and educated audiences on 'the correct scientific information'. In line with what we observed elsewhere [see also Roedema, Broerse and Kupper, 2021], an overload of scientific information online and a vast number of interfaces where people interact on scientific topics, the feeling of being "just another voice in the void" and a lack of constructive feedback

mechanisms have resulted in a perceived disconnect between science communication practitioners and their audiences. Participants in this study set-up reflective practice experiments to find ways to adapt their practice to these challenging dynamics in the field of science communication. Their experiments were primarily focused on gaining insights into audiences, how audiences make sense of science communication outputs, and focused on how science communication practice could be adapted to fit the values, emotions, and worldviews of a wide diversity of audiences.

This study showed that by adopting a reflective practice, participants became more aware of their own assumptions, values, emotions, and worldviews; and how that connected to practitioners' activities deployed and audiences addressed. It should be mentioned that participants already displayed a lot of reflective thinking at the onset of this study, which most likely is a consequence of this research' approach in including participants familiar with the RETHINK project and enthusiastic about reflectivity. Most participants found that reflective practice allowed conversations to be shifted away from statements on scientific facts — where controversy arises — and steered conversations on contested science towards a search for common ground. Future studies could explore if reflective practice is also experienced this meaningful when participants have less prior interest for transforming science communication practice. The use of reflection diaries enabled reflection-in-action, meaning the 'doing' and learning happening in the moment of interactions, and adapting one's practice to that specific science communication situation. Multiple participants noticed they learned to reflect on their own stance and that of 'the other' in the moment of the interaction — and were able to experiment with a different science communication practice whilst the interaction happened. Participants prolonged this learning experience by reflection-on-action, when they reflected on how their adapted practice 'in the moment' had— positively or negatively — transformed their science communication practice.

This study showed many accounts wherein participants recognised when and why a particular interaction they had was challenging (single-loop learning) and how that stemmed from underlying differing values, emotions, stances towards the role of science in society and assumptions participants had about audiences (double-loop learning). This resulted in open and constructive interactions between science communication practitioners and their audiences on contested fields of science. However, triple-loop learning was not as often observed — and in some reflective practice experiments missing completely. Triple-loop learning — a form of reflection that is closely linked to the plea of Irwin for more third-order thinking — focuses on science communication practitioners to revisit goals, values, or stances they have towards science-society interactions; and re-evaluate if or why these were (or were not) the best goal, value or stance to adhere to [Hawkins, 1991; Irwin, 2008]. As such, even when practitioners realised that their differing opinions or disagreement on the scientific facts (single-loop) could originate from different or conflicting values, a different perspective or emotions with regards to the scientific content (double-loop), participants still did not always feel capable to re-evaluate if the value, perspective, or goal they adhered to with their science communication was indeed best fitting in that situation (triple-loop). With this, most participants displayed single- and double-loop learning, but were unable to critically address the more fundamental paradigms they operated in, such as, addressing deficit-thinking, or reorienting the goal of their activity away from

one-way or two-way modes of science communication and adapt a multi-way communication mode [Wynne, 2006]. Triple-loop learning is important in this context, for it could potentially elicit a more fundamental transformation of science communication modes and practice in a polarised and fragmented society — a practice that would allow for open conversations on the ambiguities, uncertainties and complexities related to science, and with a wide diversity of publics [Jasanoff, 2003].

These findings also point towards the importance of a shared responsibility to adopt reflective practices in networks, communities of practice and institutes. In interacting with researchers of this study and with other science communication practitioners in the Rethinkerspace dialogue sessions, participants displayed more critical thinking and triple-loop learning. This was notably a result of others being better able to 'hold-up a mirror' and provide participants with new insights into how their own frames of thought, assumptions or objectives were hidden in certain science communication situations, or how these underlying factors linked undertaken activities. Other scholars on reflection have pointed towards the importance of reflection as a social process [Ramaker, van der Stoep and Deuze, 2015; Boud and Walker, 1998; Salmon, Priestley and Goven, 2017]. For example, Salmon, Priestley and Goven [2017] mention the importance for setting-up collaborations when first engaging in reflective practice, for this is needed to come to new insights and challenge assumptions when 'doing' public engagement or outreach activities. Therefore, it might be valuable for future research to investigate the more social aspects of reflective practice, and how collaborations across professional or disciplinary boundaries could be of crucial importance in enabling more triple-loop learning.

With this our results show that reflective practices should not be the responsibility of individuals only, and, that the full potential of engaging in reflective practice is not met when this is done by individuals on their own. Already two decades ago, Webb [2000] pointed towards the risk of reflective practice: when done alone, it might enforce already present and persistent frames of thought in individuals — and it is therefore important for reflective science communication practitioners to seek and engage in dialogue with individuals who hold contrasting or conflicting beliefs [Webb, 2000]. Even longer ago, Wynne [1993] already plead for 'the case of institutional reflexivity' to improve science-society interactions, when he argued that science is not well equipped to reflect on frames of thought within the scientific community [Wynne, 1993]. Moreover, Chilvers [p. 305 2012] also highlights the importance of reflexive engagement through institutional learning, for this would make actors relevant to science-society interactions 'more responsive, responsible, and accountable to public values, social implications, and uncertainties of science and technology'. These points are especially important for participants in this study often mentioned to feel 'a belonging to the scientific community', and that this had impacted how they addressed and interacted with audiences. Against this background, it is interesting to note that our participants mentioned how they would like their institute to be reflective, for example when a science journalist in mentioned "I would like to organise a reflection day at my department, wherein we investigate and challenge our assumptions as an institute and find ways how to deal with those". A fine line should be sought after here, for literature suggests that focusing too much on reflectivity as a final outcome, results in a check box exercise for institutes [Platt, 2014].

Facilitating the science communication community to learn and help apply reflective practice within networks should be an important focus point for all who are concerned with enabling a constructive science-society relationship. Firstly, because reflective practice is not a responsibility of the daring or innovative individual on their own, but very much a responsibility that the science communication field should take up together. Secondly, because doing reflective practice together facilitates more rewarding experiences and may allow for more third-loop learning. Boundary crossing is essential in this, wherein actors outside of one's own community or with a radically different perspective on the same challenge, can really help individuals to challenge their frames of thought [Akkerman and Bakker, 2011; Salmon, Priestley and Goven, 2017]. In conclusion, a reflective practice for science communicators enables practitioners to connect with their audiences in a more profound way, and many shared that they would like to continue with experimenting with reflective practice in the future. Therefore, we invite all who operate at the boundary between science and society and those who are involved in public discussions on science, to engage in reflective practice.

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