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Science stories: researchers' experiences of writing science communication and the implications for training future scientists

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ABSTRACT

This study investigates tenured academics' experiences of science communication—popularization of science, dissemination of scientific knowledge, and collaboration outside academia. Specifically, the study spotlights the written aspect of science communication and explores how scientists approach writing addressing audiences 'beyond academia'. Adopting an ethnographic narrative interview approach, we explore what four researchers in different STEM fields write, how they do it and why, their perceptions about the value and the role of science communication, and the place and space it takes in their career. After presenting their individual experiences, we discuss the common themes that link their personal 'stories' of science communication. First, their motives align with the notion of scholarship of engagement: as a means to educate and share scientific knowledge, science communication has a democratic value. Secondly, they engage in a wide range of writing practices and genres, based on the nature of their work and their field of expertise. Additionally, while they personally value writing science communication, this engagement takes time away from their academic writing and other types of scientific work. We conclude with suggestions for further research and the development of training programs for future scientists that build on established writing pedagogies.

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Introduction

Science communication – dissemination of research-based knowledge to the public, and scientists' engagement with society in a variety of communicative forms (Baram-Tsabari & Lewenstein, 2017) – is an increasingly important aspect of academic work. In many countries, scientists are expected to communicate science outside of academia as part of their job as scholars. Yet, despite scientists' central role, their experiences and motivations have been under-researched in the science communication scholarship (Llorente et al., 2019), which has typically examined societal dynamics at the intersection between academia, policymaking, the media, and the public (Bucchi, 2019). Therefore, this study investigates science communication from the point of view of the scientists, with a focus on written genres.

The purpose of science communication has been conceptualized in various ways in the social sciences (Davies, 2020; Kappel & Holmen, 2019); there is a consensus that it is vital in a democratic

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society. This perspective echoes the definition of scholarship advanced by Boyer in the 1990s: in addition to scientific research (scholarship of discovery), scholarship should entail interdisciplinarity (scholarship of integration), application of knowledge to society (scholarship of application), and teaching (scholarship of teaching). The concept of *scholarship of engagement* (Boyer, 1996), introduced later, specifically identifies the range of ways in which academics take an active role in society and is thus useful to conceptualize science communication. We argue that the written dimension is often overlooked in science communication studies, yet as applied linguistics studies show (Luzón & Pérez-Llantada, 2019; Pérez-Llantada, 2021a), scientists nowadays are producing a great deal of writing (including digital genres) for purposes other than publication.

Therefore, we examine the writing practices of scientists, investigating the experiences and motivations of established academics. Using their own science communication texts as starting points in interviews ('episodes', Flick, 2000), we adopt an ethnographic approach to lift their own narratives (Barkhuizen, 2015). Our research questions are: what is science communication for these scientists? Why do they do it? How do they do it? Based on their experiences, we discuss the common themes which emerge from their stories and highlight some implications for further research and for the training of scientists' communicative skills, especially at the post-graduate level.

Science communication in the modern university

As neoliberal, public management models for universities have emerged (Deem & Brehony, 2005; Miller, 2013), the 'job' of being an academic has become increasingly regulated, requiring a complex balancing act between attracting research funding, publishing in high-impact outlets, carrying out academic service, teaching, and engaging with society outside academia (Defazio et al., 2022; Kim & Kim, 2020; Roumbanis, 2019). In this scenario, the motives driving science communication in the modern university have been questioned (Davies, 2020): is it a strategic tool, used for marketing purposes in an increasingly competitive global educational offering? A recent overview of university practices in more than 2,000 institutions across eight countries shows that country, disciplinary culture, and local institutional resources (including professionalized staff) result in high levels of public communication, but casts doubt on whether these efforts aim at a long-term promotion of engagement in science rather than visibility (Entradas et al., 2020; see also Priest, 2018 about strategic vs. democratic forms of science communication).

The Swedish situation is particularly interesting because of its long historical tradition of science dissemination and collaboration between academia and social actors (Hetland et al., 2020). Swedish legislation (cf. SFS, 1977:218 to SFS, 2021:317) has reflected this tradition through terms such as *sprida* (dissemination), *samverka* (collaboration), *nytta* (utilization) and most recently *ömsesidigt utbyte* (mutual exchange). Both the Swedish Research Council and non-profit organizations actively promote and coordinate efforts across a variety of governmental, academic and industry actors. Yet, Swedish universities also operate in a public management/neoliberal model of productivity and excellence: since 2005, research funding has been increasingly directed to the main state funding agencies rather than being distributed to universities for normal operations (Åmossa, 2021). As a consequence, Swedish academics are pressured to publish internationally and compete for research funding (Schimanski & Alperin, 2018), leaving little time for other forms of scholarship – as documented by Bohlin and Bergman (2019) in the report *I want to but I do not have time.*[1] The tension between Sweden's tradition of democratization of knowledge and the current neoliberal model of university management invites a closer examination of scientists' experiences: the form, role, and space that science communication takes in their work life.

Understanding academics' experiences and challenges should also be the starting point in developing effective science communication training. As emphasized by Baram-Tsabari and Lewenstein (2017), science communication training is in need both of a clearer articulation of what exactly is being taught – acknowledging that science communication means different things (cf. Renwick et al., 2020) – and of learning goals that 'draw fully from the range of fields that comprise public

communication of science' (p. 286). Science communication practices are in constant flux, and 'While many institutions are offering courses in communicating science, there is little evidence about the content these courses should include' (Bray et al., 2012, p. 24). In this perspective, evidence from scientific and academic writing research should not be overlooked.

Why the focus on writing? As Emerson (2017) states, scientists' writing practices have been rather neglected by research, despite the wide range of rhetorically demanding genres in which they produce work. Science communication specifically requires advanced abilities to adapt register, content, and form to a variety of readers and purposes (Kim, 2021; Vitikka, 2021; Yonai & Blonder, 2020), via genres that diverge quite considerably from the publication genres that scientists may be more comfortable with, especially early-career researchers (Mason & Merga, 2021). Recent applied linguistics research has emphasized the variety of non-academic genres that are part of scientific written output (Luzón & Pérez-Llantada, 2019; Pérez-Llantada, 2021a, 2021b), including social media and digital genres.

Research in science education has shown that scientists' writing ability is largely self-taught or implicitly acquired through processes of enculturation, such as mentoring and collaborative practices (Florence & Yore, 2004; Wickman & Östman, 2002; Yore et al., 2002). While the value of this type of social learning is crucial, it poses two issues. First, this type of learning often leads to implicit knowledge, which is difficult to articulate and pass on (McGrath et al., 2019). Secondly, not all doctoral students have equal access to a supportive network and helpful mentors (Silander et al., 2021). Considering the range of writing that scientists seem to produce, it is thus crucial to include theory and research on scientific/academic writing pedagogies in communication training in science education, to prepare future generations of scientists to face the communicative needs of their profession (Emerson, 2017).

With the aim of deriving experience-grounded insights, we elicit the 'stories' of four established scientists at a major university of technology in Sweden. We ask what science communication is for them, why they do it, and how.

Methods

Participants and setting

Participants were carefully selected: they needed to have extensive experience of the phenomenon under study – written science communication. Our approach combined purposive sampling based on a preliminary study[2], and snowball sampling (Russell Bernard, 2013). Purposive sampling is relevant when, like in our case, the aim is to understand a specific social phenomenon and the experiences of individuals that play a key role in this phenomenon: 'you decide the purpose you want your informants … to serve, and you go out to find some' (Russell Bernard, 2013, p. 164). Therefore, we first selected a pool of scientists particularly productive based on our preliminary mapping. Through snowball sampling, we then identified additional relevant individuals by asking colleagues in key roles until no new suggestions were made and our sample was saturated (Russell Bernard, 2013). We then compiled a list of eight potential participants with extensive science communication experiences in different fields, and invited them to an interview via email. The results below summarize the interviews with four participants from different fields in STEM: tenured academics at the senior level. Their scientific backgrounds encompass applied areas of engineering and technology, traditional sciences, and applied science/social science.

Prior to the interview, participants were assigned a participant code, and were given the interview protocol and the informed consent note[3] with details about the project – which they signed and returned. In preparation, they were asked to bring to the interview 1–3 examples of written science communication they produced, and to respond to a brief background questionnaire. Notably, in the preceding twelve months, all our participants had been interviewed because of their scientific expertise (including on national television and radio); most of them had written either

for popular science or professional outlets, and all had written on scientific topics on social media and/or web forums.

Data collection and analysis

The interview protocol (see Appendix) was developed over a few months and was designed to optimize the connection between theory and research, research questions, methodological choices, and the interview questions.

As Figure 1 illustrates, after deriving research questions from existing literature we opted for an ethnography-inspired approach. Protocol design was based on narrative interviewing, which focuses on 'personal stories' (Barkhuizen, 2015), and specifically episodic interviewing, which uses the participants' own experience of an episode as a starting point for the interview (Flick, 2000). We adapted our questions to the topic of investigation and episodic interview phases (Flick, 2000), organizing the interview in three parts: (1) the scientists' own experience of science communication; (2) the *bigger picture* – the scientists' perspective on the meaning and value of science communication in academic life and in society; and (3) their social context and story – including collaborations and learning experiences. To stimulate the participants' recollection of their experiences (Gass & Mackey, 2000), we started the interview from the examples of science communication they had written themselves. The interview protocol was piloted with a volunteer, leading to small wording adjustments.

Interviews were approximately 90 min long, were conducted digitally (due to Covid-19), recorded, and were either in Swedish or English, as per participant preference. During the interview, notes were taken by two of the researchers while a third asked the questions. The audio recording was then transcribed by a professional service.

Data analysis followed a constant-comparative approach (Miles et al., 2014) and grounded theory methodology (Charmaz, 2006). Since our aim was to foreground the participants' own stories, we analyzed the data inductively rather than applying pre-established codes. To this end, after each interview we drafted first analytic memos or think pieces' (Saldaña et al., 2011, p. 98) and then a summary of the participant's narrative. In parallel, we drafted an ongoing description of the themes that emerged (see Figure 2). Importantly, the process of analysis and interpretation was not done *a posteriori* after data collection but proceeded in parallel with the process of interviewing, to ensure that the derived results – narratives and themes – remained grounded in the participants' perspectives, emerging cumulatively and consistently across interviews. To ensure systematicity and reflexivity, a shared Analysis Log was kept throughout the progress of the project.

Following each interview, three analysis tasks were carried out independently by the three authors (Figure 2): (1) drafting a summarized interview narrative based on the transcript and the interview notes; (2) inserting the participant's answers in a grid document, organized by interview question; (3) deriving a preliminary description of emergent themes from the notes and the grid. After each interview, we debriefed and verified our interpretations in the transcripts, to ensure the accuracy of the narratives and the description of the themes. Finally, drafts of the narratives

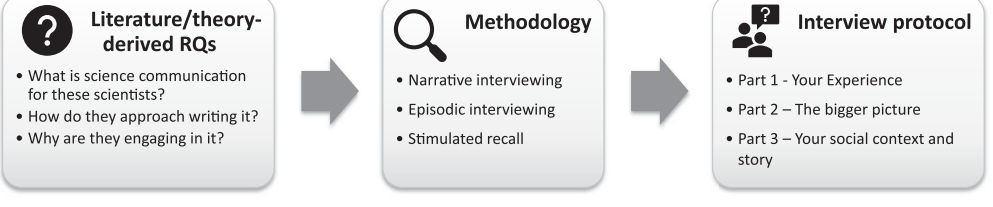

Figure 1. Methodological development: from theory to interview protocol. A detailed table with references to relevant literature is available as supplementary material.

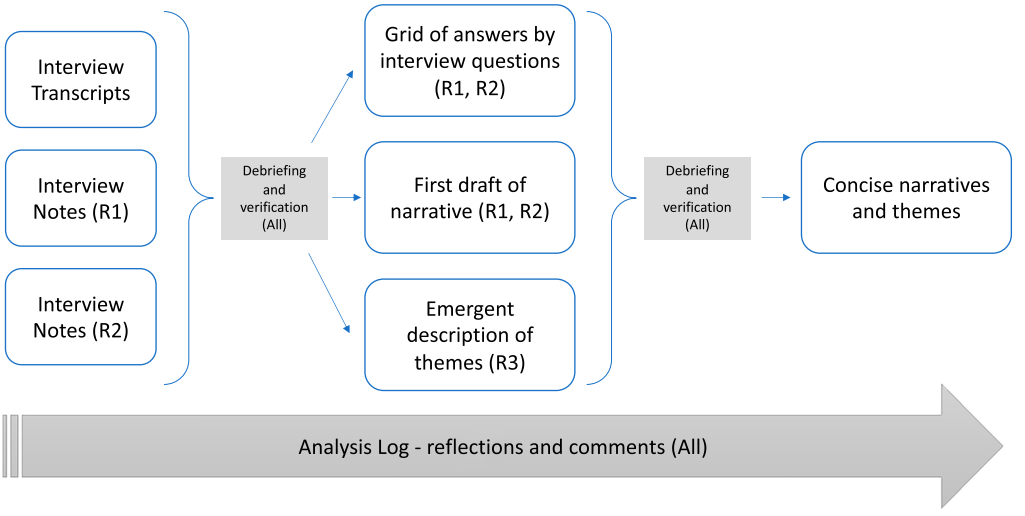

Figure 2. Diagram of data analysis process. R1, R2, R3: Researcher 1, 2 and 3. Numbering is random and does not reflect authorship order.

were shared with our participants to avoid misinterpretation and to ensure anonymization: all were approved.

In the Results section, we present four narratives that summarize the interviews with our participants. Reflecting the methodological intent to preserve their own story, we limit our commentary to brief meta-text facilitating readability. An analysis of the themes that emerged across the interviews is presented in the Discussion section.

Results

R2D1

Together we develop knowledge around these projects.

In response to the question of what science communication is to them, our first participant emphasizes the central role that it has in a practice-oriented field:

For me, science communication is something driven by research funders and transdisciplinary research projects. In my field, we have a lot of seniors who never do any scientific publication, only write books, chapters, or more disciplinary papers, towards a community of researchers and practitioners. We are judged against it being a practice-based field. Industry and public sector actors are often involved in this communication; they may even finance part of the project. Funders request that you spread more practical publications; participants in the industry may request popular reports from us. Whether these are diffused to the wider public, I don't know; it's available at least.

In relation to this variety of purposes, R2D1 describes the different categories of science communication they engage in: their audience, objectives, and characteristics:

I write within different categories of science communication, like the three examples I have here: *guidelines*, a book that instructs a specific audience on how to do things well; *anthologies*, kind of small popular science chapters that provide insights more than guidelines – I've been part of the editorial team where we push authors to write together with a practitioner from a project to develop the text together; and *trade media articles*, which I usually try to write at least once a year. We also write catalogues for the exhibitions we hold.

All these differ from the scientific publications I write; the guidelines are the furthest away: they need an attractive layout, with pictures, instructions, and bullet points. We work with professional

designers on this. A popular science article can be like a summary, 'translated' from a scientific article, so more or less the same text type, but without methods and such. The anthology chapters can be the opposite way around; they can be like a 'first draft' and then be developed into a paper. But the popular science articles relate most closely to my scientific publications; the largest difference is that we don't include any previous research in the field, any literature review or theoretical perspective. The focus is on the empirical results, so it's much less work than a scientific journal article.

To the question of how they perceive their impact, R2D1 lifts both the value of science communication to educate and the indirect impact it has on society:

Does my scientific work influence society? Yes, it does, both directly and indirectly. Someone said to me that they learned by working with me because academia is not teaching them; instead, together, we develop knowledge around these projects, which bring in people, and we have discussions and workshops. This is a direct [learning] influence on people. Indirectly, the word is spread via some guidelines, some well attended seminars … it can spread beyond.

It's rewarding to see that what you're doing has an impact. Over the years, I've been invited to hold seminars, lectures, be on television, and even to meet with government agencies to see how they make use of the knowledge in writing new policy. I like science communication because I like the response I get from the users of the knowledge. And I don't only write it myself but get contacted for input. Some journalists or magazine editors call me up regularly – they know I'm doing things. The questions they pose help me see what is of interest and how to build on it.

In describing their strategies and the process of writing, R2D1 then lifts the importance of catching the reader's attention, of language choices, and their interest in writing:

With writing science communication, I think it's important to catch a reader's attention. I think about what punchline to have, what heading, maybe ask the reader some questions. Of course, these articles are much shorter, so you need to know your limits. I also think about which words to use, whether people will be acquainted with them. I try to use simple language. One colleague of mine said 'When you write popular science reports you have to be even more attentive to language, because these reports are actually read'! But for the different texts, I don't think the process of writing is so different. And I only write the popular texts in Swedish. I can't think of any I've written in English. But I don't think that affects the way I approach the writing either.

I would like to write much more than I do. I became a doctoral student because I wanted to write; I was interested in words and writing, but I never really developed it to become a really good writer! To like to write is a good start though. I'm not the best, but I like it. I'd like to go on courses to develop my writing, but we don't have time to do this. There were some workshops as a doctoral student and I did do one really good writing-related course here, but we have little faculty money which would allow for this.

Coherently to the description of science communication given at the beginning of the interview, R2D1 emphasizes the central but demanding role that science communication has in their work life, at the expense of scientific publication:

I write a couple of science communication pieces every year, which takes some time. Funders sometimes ask for this kind of writing, and I have to deliver. As a consequence, my scientific publication, which takes more effort, more time, suffers. Some of the popular science reports take a lot of time, but you have to do it. It also takes time to work with people, have all the meetings, workshops, and gather a lot of material. I really don't have time to analyse and do something with it. Chapters can take a while. Some short popular science pieces are, however, quick, while many agencies want a final report, which, again, takes a lot of time. Once a report is done though, it's usually possible to make an article of it quite easily. But, in my experience, the project is then over and you're running into the next project! Some of the studies we've done should really have been published and yet they're not. I would like to publish more; we should publish more. We have something to contribute to this scientific discourse.

To do science communication and scientific publication at the same time, you have to be really efficient. The university wants us to teach, disseminate knowledge and be excellent researchers. It's

almost impossible! Instead, you have to take a lot of vacation and write your papers. I would like to write much more if I had time. Maybe I'd have to get a scholarship and go away for three months to really have time to get into something. Because it's really funny, when you start writing articles, you say, 'oh, this is why I chose this career. I really want to do this'. And then you are stuck in learning platforms, admin and discussions with students. The latter is nice. Admin not so much!

In relation to that, R2D1 suggests the potential of providing concrete incentives and training in science communication:

I think it's good that the funders emphasise science communication. But it is also the responsibility of individual researchers to make time in the budget. Otherwise, it will take time from other activities. We have compulsory pedagogy credits here, why not also in science communication? Some people might react negatively to this, but if it's part of the career, if you have to have that training to get an associate professorship for example, then people would do it. The university needs to be clearer about how they value these activities. Only scientific publications are getting merits and financial rewards. It has to be made an activity that we want to engage in. Give some financial reward to the departments who engage in these things. And then departments can make it possible for people to do more of this kind of communication.

R2D2

I want to educate others, in particular those who seek education themselves.

The educative value of science communication was foregrounded by R2D2, who sees it as an opportunity to engage people outside of academia intellectually:

To me science communication is about educating. I write for people who are interested in science. A lot of people who might have chosen another path in life are able to understand science. I think that readers could really learn something from science communication, instead of us just showing off what happens at the university. There must be more than just telling people that this example of science is good or important and that it can be applied: the reader should have the opportunity to learn. If you have an audience and they don't learn something, that is a lost opportunity. I want to educate others, in particular those who seek education themselves. You shouldn't be afraid to write about things that are complicated: keeping it too simple, to make sure that everyone is onboard, means that it becomes boring for those who know more and if you try to oversimplify your explanations, it becomes more difficult to explain. I don't believe that you can communicate if you don't know what you're talking about, even if some people seem to believe it's possible.

In this perspective, science communication is seen as another facet of writing, which in turn is described as enjoyable and an integral part of being a scientist:

I enjoy writing. I started out when I was a doctoral student writing an article about my research in a magazine, which I received an award for. It was a while before I wrote something again, mainly due to the total lack of incentives. I started collecting stories and trying to get published and that's how it begun. When I received a grant, I was able to go abroad to write and then I had enough material to contact publishers. I got an editor that turned out to be crucial, because editors know what's needed for a book to sell. Working with that editor meant an iterative process; I added more science to the stories and some chapters were cut.

The process of writing described by R2D2 is collegial, and reflects an extensive experience over the years resulting in a set of specific lessons and strategies to engage the reader and build a story:

My colleagues around the world read what I write. One of them reads everything. Others have read bits and pieces; people want to help. I usually write a draft, then show it to others and they can tell me if something is wrong. It gets easier, the more you write: the writing is quicker and there are less mistakes. You learn that sometimes it is better to stop writing and check for facts, with the risk of losing your flow, because you don't want mistakes, in your texts. The main reason why it gets

easier to write is that you need to know a little about a lot. Teaching plays a role as well: you collect stories to use in your lectures to provide something that sparks an interest, and those stories can also be used in your writing. And you need to read a lot, to be able to write well.

When I write, I usually start from the very beginning. Maybe there is a synopsis in my mind, but I don't structure what I am going to write on paper, before I start. There must be a hook in the beginning, that you can return to later in the text, and it's all about finding the stories. Some stories I already know of, others I have to find. I have on occasion had a co-writer who has helped me with finding and formulating stories. My stories usually contain some current research but mainly they are aimed at educating the reader about science. One of my colleagues usually says that people are interested in other people, so that's what you find in my popular science texts. There also needs to be a good mix of people and places around the world and there can be stories of love and death.

Science communication for R2D2 involves also tapping into their linguistic repertoire (English vs. Swedish) in consideration of international geopolitics of publication:

If you can write in English, you should; it makes it easier to reach a larger audience. For strategic reasons, it is better to first write and get published in English, and then have your texts translated into other languages, including your own. Swedish publishers have less money and they're not as good at selling. But of course, it's easier to write in Swedish for me; it's faster, and the result is always better. When you're writing in a language which is not your mother tongue it's harder to get it right.

Regarding the university's support of faculty's engagement in science communication, and the question of who should be responsible for training future scientists, R2D2 makes some critical remarks:

For researchers to do science communication, there needs to be some incentive. Sadly, there is a total lack of incentives when it comes to researchers doing science communication, both when it comes to money and when it comes to what really counts on your curriculum vitae. There seems to be a very narrow perspective on utilization: science communication is often about selling 'cool' activities at the university. Everyone thinks that science communication is important, but at the same time it is not allowed to cost. There is no time for writing even though in principle it is part of the job. Everything else is prioritized. If there were more incentives, maybe more researchers who have never gotten around to doing science communication would be able to contribute, but I don't think that we should pressure people to get into science communication too early in their careers, because it's probably easier if they wait.

R2D3

Science communication is about giving back to society: doing research for and with someone.

R2D3 describes science communication as a vital facet of their academic work. Their account testifies to deep engagement and its intrinsic value to impact and contribute to a democratic society:

I've done a lot of science communication. I've worked with practitioners, and I like to return to places where I have done research with them, to see what's happened since then. When they tell me that they've changed the way they work because of my research, it's very rewarding! For me science communication is about giving back to society: doing research for and with someone. Making research accessible and reaching out is important. After all, most of my research is paid for by public authorities.

Research to me has always been about *who* you do research *for*, rather than doing research *about* a certain problem. I also want to do research *with*; co-creating is important to me. Research really does concern everyone in society! And I'm not afraid of a heated debate or controversial topics. I believe it's my duty to provide evidence-based opinions and try to influence politicians, a voice of knowledge. At times, however, I've felt like I've become a 'one topic' person.

Learning to communicate science outside academia happened primarily via mentoring and co-authoring with more experienced scientists, although a course helped:

I learnt about academic writing at the university where I did my doctoral thesis and I've also taken a university course in communicating science: writing opinion pieces and blogs, as well as doing oral presentations. I learnt a lot, like using concrete examples, working with recognition, and making what you write more attractive to the reader. Early in my career, I tried blogging together with a colleague who used to blog, but then I decided that social media was not for me. I prefer writing and being on the radio. One of my PhD supervisors was also an inspiration. He has been active in debate and has worked a lot with forming public opinion: I learnt a lot about writing from him.

R2D3 has a keen awareness of their approach to writing science communication, which includes focusing on the key message, asking for feedback, considering rhetorical elements typical of different genres, and tapping into their multilingual repertoire:

When I write, I always start by writing the first and the last paragraph. 'This is what I want to say', and then 'this is what I have said'. And I also like using bullets, which I later elaborate on, to find a sort of structure, or a storyline. Then I work on both ends of the text; I can start with the introduction, finish it, change something in the final paragraph, before writing something in the middle. What really works for me is when I 'find' the start and the ending, because they provide a common thread that I need, to find the flow.

Writing is fun! Sometimes I just write and write, and later revising is a major part of my process. When I feel done, I usually look for a second opinion, by asking a colleague, or my partner, to make sure that I've managed to tie it all together. Often, the writing process also has a natural ending because you have a deadline, or you have reached the word limit. Through writing science communication, I've learnt that keeping it short is difficult, and that it's alright to break the rules a little: your text will improve.

Opinion pieces can be tricky to write from a rhetorical point of view. They are to the point: this is what I want to say, here are my three reasons why, and the ending needs to affect the reader. There is a limited number of words. Writing opinion pieces together with others is good, for several reasons. When you write together from the start, you negotiate what to include, you must 'kill your darlings', write, and rewrite several times. It really is a good example of communicating before you communicate. And of course, when an opinion piece is signed by several scientists, it is considered more important.

Writing in Swedish is more straightforward; I don't have to think much about grammar, what words to choose. But there are more words to choose from in English and it is more appealing in a way. The choice of language is also connected to my field; a lot of my research takes place in a Swedish context and when it comes to opinion pieces, I often write in response to something I've read in a Swedish newspaper.

Regarding how to encourage science communication, R2D3 notes the challenges of engaging in these practices at different career points, and emphasizes the need for workplace structures and policies as well as training:

Doing science communication can be both good and bad for your career: it can help you build new networks but having a lot of science communication on your curriculum vitae can also be negative when you apply for a new job. It differs from university to university and from department to department. I think that we need to talk more about science communication, in our divisions and departments, about why it's important. You should also get training during your PhD studies: your writing is aimed at academia then, but you need practice in a variety of genres. I believe that there will be even more focus on this in the future. As a researcher, you need to be perceived as confident, when there is contradicting information everywhere. Researchers should receive training in writing science communication as skills development.

R2D4

I need to have a feeling for what I write, for it to be at all worth it.

R2D4 also underscores the value of science communication for democratic, educative, and intellectual purposes, and is quite critical of its use for marketization:

Unlike some others, I see science communication as something broader than just a tool to market my own research. In the beginning of my research career, I was quite satisfied working in the ivory tower, so to speak. But then I started to feel like certain societal issues, like climate change, were so important that I wanted to be a part of them in some way. I wanted to awaken the public's interest in such issues. My science communication is done with the belief that the issues I touch upon need to have more space devoted to them in the public sphere and we should be able to address them appropriately. I can see the potential meaning that my scientific work has on society, but I can't exactly point to what. I write because the questions are important, and I see a value in them getting more space in the general discourse. And personally, I like to write: writing contributes to a structuring of thoughts and formulation of new questions.

Interestingly, science communication is also perceived as an outlet to escape the constraints of scientific publication (in English) while connecting science to important issues in society. Scientific expertise is essential:

Learning to write science communication has been all about learning by doing for me. I now feel fairly at home as an author of both opinion pieces and popular science texts. When I started writing for a wider public many years ago, it felt rather liberating stepping away from the more traditional, 'dry' publication genres. I've published a number of books over the years relating to science and research, but the text type is a bit of a grey zone between being an academic text and a popular science one. The intention was to appeal to a more general public but still those interested in the issues at hand. I have communicated in many different forms – texts, videos, presentations, and I'm no stranger to being interviewed in the media. The emphasis is always on these very important societal issues. Even if the focus in this interview is writing, getting out and talking to the public is also fun and an important part of science communication for me: the work as a speaker and as a writer interconnect with each other.

My latest book has some connection to my scholarly publications though it's not always that strong. The book in fact spans many research areas, many of which I have not contributed to research-wise, although my field provides a good platform for contributing relevantly to many subjects. I don't allow myself to discuss things I don't understand, although of course that may not always be visible in my formal qualifications. I feel I can bring up many things in Swedish but might hesitate to do so in English depending on the topic and context. I have written in both English and Swedish, and I am comfortable in English, but it would feel a little arrogant to lift certain questions that pertain to an English or American society context. Writing in Swedish means that the potential readership is less, but still, as a representative of a non-global language, I think I have a particular responsibility for producing science communication in Swedish.

R2D4 also underscores the consequences of engaging in science communication, the awareness about potential conflicts and negative implications, and the importance of getting feedback from colleagues:

I'm often involved in topics which are rather controversial; I have made some enemies with people who see scientific evidence or its value differently from me. You don't need to be friends with everyone of course. I choose to face the conflicts I need to. I would of course feel better without these battles, but I end up in situations where I have to face them; I don't do it for fun. I don't want to wrap up what I say in many layers of diplomatic 'cotton wool' thus losing clarity. If I can't be allowed to express myself clearly, to get my message across, then I don't see much point in communicating at all. The opinion piece was written because my colleagues and I felt a discussion was missing: for us, this wasn't just a matter of science, but also one of the most important choices for Sweden for many years and, therefore, also a matter of democratic significance. We wanted to lift that. Our intention was also to create as calm and objective a debate as possible, which we feel we did, though editors set a headline that strongly suggested one side of the argument. The reactions we received were mixed, but some appreciated our objective tone and the debate it raised.

For feedback on content I sometimes turn to colleagues, but I haven't used the help of professional communicators: I have quite a large network, in Sweden and outside. I see a great value in consulting several people, within and outside of academia, as different readers may see different things, and I don't want to burden one and the same person with reading all my texts. With the editor on my latest book, I learned a lot of positive things, but there were also things they wanted to do with my text which I could not accept, and in the end that collaboration didn't work so well. I need to write as I write and can't change it into someone else's work.

Science communication seems to come with a cost, and R2D4 comments on the need for policy and structures that are sensitive to the differences among academics:

In order to work with science communication, I'm forced to steal from my research time. No regrets though, I do what I think is important. From what I've seen, there aren't structures within the academy that sufficiently consider the significance of science communication: the system is perhaps a bit too demanding, expecting everyone to be good at everything. Many researchers are perhaps not very good at this but are better at the other parts of research and teaching work. Myself, I choose what to write and who to write for; I need to have a feeling for what I write, for it to be at all worth it.

Discussion

Our objective was to explore how scientists experience writing science communication and what motivates them. Our participants were tenured academics at the senior level, with a long experience of science communication. Using ethnography-based interview techniques, we collected their stories to answer the questions of what science communication is to them, why they do it, and how they do it. Having provided the scientists' stories, we now turn to a discussion of the common themes which emerge from the analysis of these interviews, connecting these themes to the current literature on science communication and science communication training.

First, our participants' perspectives on science communication – what it is to them and why they do it – align with conceptualizations of *scholarship of engagement* (Boyer, 1990, 1996): science communication, to them, has democratic value rather than a strategic purpose (Davies, 2020; Priest, 2019). They conceptualized it as an opportunity to construct knowledge with relevant social actors and industry collaborators, educate and establish a dialogue with interested readers, disseminate, inform, and generally share knowledge and give back in a democratic society. This perspective, however, translated into different practices for our participants, reflecting the nature of their field: R2D1's collaborative training activities within the industry cut across *scholarship of application* and *scholarship of education* (Boyer, 1990). R2D3 mostly engaged in collaboration, co-creation of knowledge, and influencing policy makers – something that Davies (2020) indicates as the *pragmatic value* of science communication. On the other hand, R2D2 and R2D4, who wrote popular science books, emphasize the educational and the *cultural value* of science communication (Davies, 2020), as embodied in the non-fiction genre: 'the reader should have the opportunity to learn' (R2D2). These purposes are not exclusive but overlapping, depending on genre, target readers, and field.

Second, and in relation to the above, the diversity of activities and types of genres that fall under science communication stands out. Each scientist reported engaging in a range of communicative events across various modes and with various purposes, including levels of collaboration with non-academic colleagues and actors. This variety corroborates the findings of Renwick and colleagues (2020) illustrating that scholarship of engagement takes many forms. In terms of writing, applied linguistics studies on science communication genres have similarly shown a multifaceted picture, especially when considering the emergence of digital modes (Luzón & Pérez-Llantada, 2019). Importantly, our participants' underscore that science communication entails engaging in some form of public conversation and even debate (R2D1 being invited by journalists and R2D2 acknowledging that people will react), yet not everyone is comfortable with that: R2D3 and R2D4 responded

differently to controversy, as R2D3 pointed out 'I decided that social media was not for me'. This suggests that the potential consequences of engaging with science communication need to be lifted in training programs: not all genres need to be for everyone, and future scientists should be encouraged to find an approach to science communication which is comfortable to them. Training approaches should adopt a critical perspective on the consequences of engaging in science communication, underscoring how discursive and linguistic choices may influence the audience's perception of an author's credibility and the truthfulness of the information presented (Hendriks et al., 2016, 2018; Jensen, 2008).

Third, our study illustrates that while our participants have a genuine interest in science communication, they have limited space to do it in their work life and do it mostly in their spare time. They all lamented the lack of career incentives and recognition of the complexity of this work by university policies, confirming that science communication clashes with activities that are career meritorious in the current neoliberal university (Bohlin & Bergman, 2019; Merga & Mason, 2020; Schimanski & Alperin, 2018). Since our participants were all established academics, this either/or situation may be even more challenging for early-career researchers. In addition, it was clear that none of our expert scientists had received formal training in science communication as part of their education: only R2D3 mentioned taking a course, on their own initiative, and for R2D4 it was 'learning by doing'. This suggests that scientists still learn to communicate mostly in a self-taught fashion, with experienced colleagues, an editor, or a friend as mentors and informal guides along the way.

Finally, their writing strategies varied but one common theme was the importance of storytelling. The need to create a good story meant finding new ways to communicate, often deviating from typical academic discourse: 'I learned that it's ok to break the rules a little' (R2D3). These experiences imply that a focus on rhetorical and narrative skills is important for science communication training as also pointed out by science education research: 'more important to engage the audience's imagination perhaps through storytelling than the acquisition of media skills' (Bray et al., 2012, p. 37). Learning to tell stories and to manipulate language creatively should be a central peg of training programs.

Implications for research and education

Our study offers perspectives from four experienced tenured scholars, which is a constrained pool of participants. Another limitation is that their texts were not analyzed but only used for recall. Future research could improve on the study design using methodologies that combine text analysis with elements of ethnography, such as textographies (Paltridge, 2008) or text histories (Lillis & Curry, 2010). Another direction would be to tap the experiences of early-career researchers (ECRs) and examine how they learn to write and communicate their science within and beyond academia (Mason & Merga, 2021; Merga & Mason, 2020; Negretti, 2021). As ECRs face the pressure of mastering a variety of skills while building an academic career and a scientific ethos, their experiences and challenges may overlap in part with those of expert scientists – especially in terms of perceptions of value – but also likely accentuate time constraints, need of training, and/or a differential use of digital channels (cf. Cosentino & Souviron-Priego, 2021; Gavhi-Molefe et al., 2021; Nicholas et al., 2017). Despite the limitation posed by the number of our participants, their academic status and experiences offer valuable insights for future research and scientists' education, as many of the themes that we discussed above find resonance in the literature on science communication. We see two main implications.

One implication is that science communication research needs to acknowledge the diversity of experiences and genres that are comprised under this concept. Our participants' perceptions seemed to coalesce around a democratic value of science communication (Davies, 2020), yet they engaged in different communicative practices depending on their fields of work. This variety means that research should examine more closely the range of activities that fall under the concept

of science communication, possibly within the broader context of academic genre hierarchies (Swales, 2004): which genres are more relevant in certain scientific fields or topics? As pointed out by Pérez-Llantada (2021a), while certain genres such as the research article remain at the top of these hierarchies, hybridization and change is occurring thanks to the appearance of online genres and policy agendas that encourage public engagement in science. At the same time, disciplinary and local variations can be found in genres and modes of science communication: 'the use of online genres and emerging forms of communication is not always similar in all disciplinary fields' (p. 66). To complicate the picture, the role of language is mostly overlooked, yet language is not trivial in determining who communicates and why: most researchers publish in English but use the local language when engaging in science communication (Luzón & Pérez-Llantada, 2019), which may be problematic for international researchers who do not master these local languages. Applied linguistics research that examines the rhetorical purpose, discursive conventions, and linguistic form of new scientific genres (Pérez-Llantada, 2021b) can thus provide very useful insights for science communication training.

The second implication relates to science education. Considering the pressure to publish and obtain external funding that academics face (Defazio et al., 2022; Roumbanis, 2019), formal education must prepare scientists to engage both with scientific/academic writing and science communication. Our participants witnessed to a scientific literacy path that primarily occurs via mentoring and co-authoring (Yore et al., 2002). However, regarding who should take responsibility for science communication training and what practical forms it should take, their answers were less straightforward. Overall, they suggest the importance of incentives such as promotion criteria, staffing, and workplace policies that are sensitive to what is pertinent across fields, as well as training opportunities already at the doctoral level so that future scientists can feel confident in navigating the changing ways in which science is communicated. Perhaps what emerges more strongly from these scientists' accounts is that training programs should foster scientists' ability to write across rhetorical situations: engage the audience, tell stories, and calibrate linguistic choices towards one's audience and purpose. The rhetorical and discursive features of science communication are very different from those typical of academic publications, including use of narratives (stories) to convey knowledge, novelistic dramatization, dialogue, use of 'you' to address the reader (Kim, 2021), and even irony (Vitikka, 2021). For researchers – especially early career – it is quite an adventurous leap into a way of communicating science that they may not be familiar nor comfortable with (Mason & Merga, 2021). Training should incorporate pedagogies that have been shown to be effective in academic writing – known under the umbrella of *genre pedagogy*. These pedagogies scaffold writers' ability to analyze the language, discourse, and rhetorical features of a variety of genres, and then the ability to adapt this knowledge to different purposes and types of readers (Negretti, 2021; Swales, 2004; Tardy, 2016; Tardy et al., 2020). Genre pedagogy could complement conventional science communication training by adding writing expertise as a learning goal (Baram-Tsabari & Lewenstein, 2017), possibly in combination with storytelling and guided discourse (Bray et al., 2012; Yonai & Blonder, 2020).

Science communication is and will likely continue to be part of any future scientist's job. If university policies truly aim at promoting a scholarship of engagement (Boyer, 1996) rather than their own visibility, they should provide a framework to support and recognize this engagement (Entradas et al., 2020). Since becoming a scientist is primarily a process of acculturation (Yore et al., 2002), paying attention to scientists' own stories – at any level of career – is perhaps a good starting place to develop training opportunities that promote a scholarship of engagement that matches their experiences and motivations.

Notes

1. Our translation. Original: *Jag vill men hinner inte.*

2. This preliminary study mapped publications in the institutional repository, categories: 'newspaper articles', 'magazine articles' and 'chapters in popular science book', years 2015–2019. Because researchers themselves enter these publications in the database, the data only gives an approximate picture of actual productivity at the university.
3. The project data management plan and informed consent adhere to the university's GDPR guidelines and follow the Swedish Research Council's research ethics regulations: Ethics approval by an ethics committee was not required.

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Appendix

Interview Protocol (participants' version without potential follow-up questions).

Pre-interview preparation

Thank you for consenting to an interview. The interview should not take more than 1–1.5 h, and can be done either in English or Swedish depending on your preference. Please carefully read the informed consent document attached to this email and return it to us.

In this interview, we will ask you about your own experience with 'science communication' (forskningskommunikation) in written form. With this term, we mean all types of communication of research and scientific knowledge that is not addressed to other scientists for research-related purposes, such as publication or conferences. To give you a sense of what we mean, you can look at this diagram from Vetenskap och Allmänhet: https://v-a.se/forskningskommunikation/

For this reason, to ground the interview in your own experience, we ask you to bring to the interview 1–3 examples of science communication that you feel are representative of your writing 'beyond academia'. These can include anything from debate articles, blog posts, social media posts, non-fiction books for the general public, articles in professional magazines and/or newspapers. Note: we will not collect these examples, nor bibliographic information about them.

As background, we would like you also to answer a few questions below.

Thank you for your cooperation, we are looking forward to talking with you about your engagement in science communication.

Background questions (please email back)

(1) What is your field of research? (in broad terms)
(2) In what country/countries did you complete your higher education studies? (including post-doc experiences)
(3) Have you had non-academic jobs? Were these connected to your scientific expertise?
(4) Do you have funding that requires you to produce outreach and communication to the public?
(5) In the past 6 months to 1 year, have you (Circle or put an X next what applies):
- Authored or co-authored a paper for a popular science journal: Yes__ No__
- Authored or co-authored a paper for a professional journal or for a professional/organizational audience? Yes__ No__
- Written for newspapers? Yes__ No__
- Been invited to contribute to a text or participate to an interview on the basis of your scientific expertise? Yes__ No__
- Written debate articles, or responded to a debate article? Yes__ No__
  (If yes) Outlet:_____
- Written on a scientific topic on a website (e.g. blog, forum) Yes__ No__
- Posted on social media about a scientific topic you have expertise in? Yes__ No__
- Other: _____

Interview protocol (for your information)

Thank you for meeting with us today; we really appreciate your time. You have already given us some information via email as a background to the interview. We asked you to bring some examples of 'science communication' and today we will ask you about your experiences with this. We are really looking for *your own experience*, as an academic, with this kind of work.

Part 1 – your experience

- Could you tell us what the concept of 'Science Communication' means to you?
- Can you tell us what has been your experience with this over the years?
- (Artifacts) Can you describe the story of these (1–3) examples that you brought to the interview?

With regard to these examples that you brought today, we have a few more concrete questions about the writing process, perhaps comparing your experiences across your examples:

- How familiar are you with these genres/type of text?
- How did you prepare before writing these texts?
- Could you tell us concretely how you started the process of writing?
- As you were writing the text, can you describe the process of writing these texts? Did you have any specific strategy in mind, for instance?
- How did you know that you were done? How did you evaluate your final outcome?
- How does language (Swedish or English) play a role in your writing this type of texts?
- How has writing these texts given you an insight into yourself as a writer?

Part 2 – the bigger picture

A few questions about the overall role and space that science communication takes in your academic career.

- In your view, how does *your* scientific work influence society?
- What is the value *for you* in writing these kinds of texts?
- What is the space that this kind of work takes in your current work life and in your career overall?
- Have you ever got anything back from this writing this type of science communication?

Part 3 – your social context and story

We are now interested to hear a bit more about the social aspects behind this kind of writing:

- How would you describe the overall perspective on science communication at your department and/or division?
- Do you choose what to write and who to write for?

- Could you tell us about the kinds of experiences that helped you develop communication skills that are useful for this kind of writing?
- How do you share your knowledge about science communication writing to others, for example your colleagues, students, or doctoral students?
- Could you tell us about any co-authoring experiences of science communication? (if any)
- How do you get help or support with science communication? (if you do)
- Have you ever attended a writing workshop or course/similar focusing on this type of writing, i.e. science communication and writing beyond scientific publishing?
- In your view, how should Scientific communication skills be fostered among scientists? Who should take responsibility/the lead for this kind of training?

Conclusion

- Is there anything else that you would like to share or experiences you would like to tell us about?
- What was missing from the interview that could have given you the opportunity to express your point of view?