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Roles, incentives, training and audiences for science communication: perspectives from female science communicators

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Abstract

Both research and anecdote in science communication suggests that it is a field where women feel 'at home', with high numbers of women science communicators and students on training programmes, but why might this be the case? Using data gathered from a survey of 459 science communicators based in Italy, the Netherlands, Poland, Portugal, Serbia, Sweden and the U.K., we examine the perspectives of female science communicators, in terms of working practices, motivations and barriers to communicate.

Keywords

Professionalism, professional development and training in science communication; Public engagement with science and technology; Women in science

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Context

Anecdotally in science communication and in surveys [Lewenstein, 2019] there can be significant sex and gender based disparities in regards to who is involved in science communication. One study of 325 US scientists, found that twice as many female (83%) as male (43%) graduate students had been involved in 'outreach' as undergraduates, and that this was a pattern which continued throughout scientific careers [Andrews et al., 2005]. Although we would distinguish science communication and engagement from outreach [Davies, 2021], which can imply promoting public awareness and education alone, this raises significant questions for the science communication sector. If under 30% of those working in STEM (science, technology, engineering and mathematics) globally are recorded as female [UNESCO Institute for Statistics, 2019], it may be perceived as a positive step that women appear to be so heavily engaged in science communication. But the disparity between male and female scientists participation in outreach raises questions for the field of science communication.

Language around sex and gender is not without its complexities [Talbot, 2019]. Whilst sex is assigned to someone on the basis of their biological and physiological

characteristics, often 'sex' and 'gender' are used interchangeably to mean 'male' or 'female' [Stonewall, 2022]. Language around sex and gender has a tendency to impose binaries, despite circumstances whereby both can be considered continuums [Talbot, 2019]. In some languages gender does not exist as a concept at all [Council of Europe, 2022], whilst in other settings blurring distinctions between sex and gender takes place for political reasons [Talbot, 2019]. Gender however, is culturally and socially determined, can have performative aspects, and whilst it might relate to the sex someone has been assigned at birth, people can also express a sense of their own gender, whether 'male', 'female' or described in other ways, which may or may not conform with societal expectations of gender [Stonewall, 2022; Talbot, 2019]. As such gender is firmly rooted in 'social attributes and opportunities' which are socially constructed and learned through context and time-specific socialization processes [European Insitute for Gender Equality, 2022].

In this context the communication of science to the public has been described as having a 'duelling' relationship with gender:

> The androcentric ideal of the production of expert knowledge that must be shared with an unsophisticated public competes with the feminized labor of those who create the pedagogical practices to communicate with various publics [Pérez-Bustos, 2014, p. 857].

Some authors describe the communication of science as a caring practice, in the ways in which it seeks to share and create bonds collectively [Johnson, Ecklund and Lincoln, 2014; Pérez-Bustos, 2014; Pérez-Bustos, 2019]. Yet, concurrently science communication has been critiqued for its reproduction of certain tropes as to who a scientist might be and what can be considered as legitimate knowledge [Pérez-Bustos, 2014; Pérez-Bustos, 2019]. This concern sits against a backdrop of wider feminist critiques regarding the androcentric and masculinist biases of science more generally [Fox Keller, 1982; Fox Keller, 2001; Bartsch and Lederman, 2001], as well as accounts which have highlighted the ways women's 'greatness', where science is concerned, is often 'qualified' by their gender or association with a man, parental and/or marital status [Harding, 2001; Rasekoala, 2019; Steinhardt, 2019, p. 3]. 'Gendered processes are a pervasive feature of science', therefore we may expect this to also impinge on differences in how female and male scientists communicate and engage [Johnson, Ecklund and Lincoln, 2014, p. 87].

Megan Halpern [2019, p. 3–4] has argued that science communicators can therefore 'sit at an intersection between dominant and marginalized perspectives', she continues that if 'western science communication is still grounded in the idea of detached, objective science' the make-up of science communication practitioners and researchers as predominantly women can offer benefits in identifying with other marginalized groups, standpoints and perspectives. This type of 'standpoint theory' [Harding, 2001] may offer multiple opportunities for science communication as it grapples with questions of equity and inclusion working from the perspective of the marginalized. But standpoint theory is also critiqued for an emphasis on biological traits where gender is concerned (for example, assumptions around women also being mothers) and the complexity of sifting this kind of biological determinism out from other social and political contexts [Kerr, 2001].

Whilst the participation of women, and increased gender diversity in science communication may then suggest some benefits for science communication in regards to equity, diversity, inclusion, and representation, as well as the perspectives that women may bring, more recently authors have suggested it could point to a more worrying trend, whereby the comparably low status, pay and instability of careers in science communication has created a 'ghetto' for women [Rasekoala, 2019; Lewenstein, 2019]. As we imply in our abstract, women may feel at 'home' in science communication with which comes an extensive list of tasks which are collective, trustworthy and empathetic. This may subtly and implicitly come to be perceived or performed as 'women's work', whilst others pursue more privileged professional and academic pursuits [Johnson, Ecklund and Lincoln, 2014; Bartsch and Lederman, 2001; MacFarlane, 2018].

An alternative explanation of the visibility of women in science communication may however come from positively intended aspirations and efforts to increase and diversify role models in science. Such 'role modelling' often aims to increase the numbers of girls and young women entering and remaining in science, reduce stereotypes, and alter perceptions of both science and scientists [Bayram and Ironside, 2021; Fogg-Rogers and Hobbs, 2019; Fogg-Rogers, Sardo and Boushel, 2017; Johnson, Ecklund and Lincoln, 2014]. Early role-modelling efforts, however, were critiqued for their lack of theoretical underpinning, understanding as to the end results and abilities to retain women in scientific careers [Bartsch and Lederman, 2001; Steinke, 1998]. Whilst interventions to increase the visibility of females in science are much needed, they also come with their own burdens in terms of time [Hubner and Bond, 2021]. For example, women take on the majority of the workload associated with initiatives to increase women's participation in science [Wilkinson, 2019]. Some interventions are also critiqued for focusing too greatly on individual agency as opposed to organizational and structural issues that prevent gender equality [Bleijenbergh and Engen, 2015]. However, these types of intervention-based programmes and activities frequently offer women scientists an opportunity to communicate directly with people, and with this can come the ability to not only control one's message but also how they are represented. This may explain why some studies have found a difference between the involvement of women in community-based, local engagement activities, versus the mass media (where men tend to do more). But it also points to the need to avoid 'one-dimensional conceptualizations' of such science communication experiences [Anzivino, 2021, p. 836] recognizing the breadth of activities that are now available for communicators, including in a range of digital spaces.

The sense of control that a woman communicating may have over an engagement or role modelling intervention is often less possible where media representations of science communication are concerned. Numerous studies have explored the ways in which women scientists and communicators are depicted in the media [Chimba and Kitzinger, 2010]. In the news media, as well as television depictions, women and female scientists can be under-represented [González et al., 2017; Hetsroni and Lowenstein, 2014; Long et al., 2010] or depicted as exceptional [Chimba and Kitzinger, 2010]. Gender identity can 'undercut' a perception of 'expert opinion' [Pérez-Bustos, 2014], with a focus on femininity and/or sexuality associated with female scientists rather than simply focusing on their expertise [Chimba and Kitzinger, 2010]. Though some studies do suggest an improving picture where media representations of female scientists are concerned [Mitchell and McKinnon,

2018], others report featured scientists receiving gender-oriented and misogynistic threats after media coverage, which are often individual in nature, and for which there is a lack of underpinning support from those who have originally encouraged the communication (such as press officers, journalists, research institutes) in the first place [Samer, Lacombe and Calmy, 2021].

With regards to digital platforms, where we might expect anyone can be a content producer and therefore have more control of the message, we see similar trends emerging. A study of 391 science, engineering and mathematics–themed YouTube channels found that hosts of only 32 of those channels presented as female, and their channels, though having more comments per view, were also significantly more likely to have comments which were hostile, critical/negative, sexist/sexual commentary or associated with their appearance [Amarasekara and Grant, 2019]. Others have reported female science popularisers emphasizing their legitimacy online, considering clothing choices, and being wary of exploring certain topics, due to past experience with, or awareness of the potential for gender-based harassment [McDonald, Barriault and Merritt, 2020].

Whilst the opportunity to share online has resulted in many women and female scientists achieving high visibility and large social media followings [AbiGhannam, 2016; Brown Jarreau, 2015] there is still a perception that communications produced by male researchers are held in higher regard [Knobloch-Westerwick, Glynn and Huge, 2013]. A recent study of 'Ask Me Anything' sessions on Reddit found more male scientists participated in sessions and received comments but that female scientists received more positive comments from 'redditors' than male scientists, which may have been influenced by the written question and answer format excluding any influence of a researchers' appearance or voice [Hubner and Bond, 2021]. The authors suggest this may mean such types of online engagement can be effective mechanisms for female scientists to engage [Hubner and Bond, 2021], but one may perhaps question whether encouraging female communicators to use opportunities which allow them to distort or hide aspects of their identity, such as their visual appearance, really addresses the crux of the problem.

Despite the high numbers of women scientists and researchers involved in communication, female scientists and communicators continue to be underrepresented and misrepresented in the media, including in digital spaces, and very few surveys have empirically explored differences in motivations and deterrents to communication on the basis of sex or gender [AbiGhannam, 2016; Chimba and Kitzinger, 2010; Hetsroni and Lowenstein, 2014; Johnson, Ecklund and Lincoln, 2014; Kessler et al., 2022]. A study by Crettaz von Roten [2011] specifically explored attitudes to public outreach and engagement and found that attitudes were similar between women and men scientists, but activities were significantly more likely to be conducted by men. Despite finding this to be the case in the context of Switzerland, where their study was conducted, they highlight that there were inconsistencies 'in results regarding the relationship between gender and scientists' public outreach and engagement', and limited understanding of explanatory factors [Crettaz von Roten, 2011, p. 55]. This criticism that much work so far has been focused on descriptive studies of stereotyping, sex and gender appears to be reaching a crescendo, with increasing calls for work that goes beyond the descriptive where science communication is concerned [Lewenstein, 2019; Rasekoala, 2019]. This may also allow for further exploration of structural and

organizational barriers since studies of women science communicators' experiences have suggested that some participants reported having to convince supervisors and colleagues of the value of science communication and its merits as a career path [AbiGhannam, 2016].

Lack of research in this area has contributed to 'stigmatizing' science communication as a feminine or soft skill [Johnson, Ecklund and Lincoln, 2014], which can both alienate women, and inadvertently suggest they are unsuited to the technical aspects of science, whilst also deterring men from entering science communication careers [AbiGhannam, 2016]. Research has suggested that where women, men and scientific careers are concerned, there is more in common in terms of stereotypes about men and stereotypes about scientists than stereotypes about women and scientists [Carli et al., 2016]. Men are perceived to be highly agentic (leader-like, analytical, competitive, and independent), and women as highly communal (understanding, kinder and helpful), whilst scientific fields with higher proportions of women (such as psychology) tend to have more similar stereotypes around qualities that women are perceived to possess [Carli et al., 2016]. Thus, it may be the case that science communication not only aligns with stereotypical interests of women, but also that some of those qualities in terms of what is valued in science communication, have advanced as more women have entered the field. Whilst there is some evidence that scientific environments contribute to women's decisions to pursue communication careers, they prefer not to label that as an 'alternative career path' [AbiGhannam, 2016, p. 487]. There are also difficulties as research has not 'conclusively shown' if gender affects involvement in communication or public engagement activities and, if it does in what direction [Anzivino, 2021]. Tania Pérez-Bustos [2019] argues science communication has become 'feminized' as it has professionalized. Given that, much early science popularization was carried out by men this feminization was not a given:

> 'To say that science communication is a field for women is to say that it has become a field for women and this means that in the social imaginary it appears as subordinated to science (in the same way that education in general is subordinated to knowledge production and is also a feminized field).' [Pérez-Bustos, 2019, p. 1].

Objective

This article draws on findings from the RETHINK project which sought to 'rethink' science communication, both its theory and practice, to accommodate the major challenges to the individual and collective process of making sense about science [RETHINK, 2021]. The overall objective of RETHINK was to contribute to making the European science communication ecosystem more open, inclusive, reflexive and adaptive, and to create recommendations and training resources for nurturing open and reflexive science-society interfaces. As a part of the wider project, we were responsible for a series of activities which explored the networks, roles, repertoires and communicative actions of actors in the science communication ecosystems of seven European countries, including those activities taking place in the digital sphere. This included methods aimed to better understand the working practices of those engaged in the communication of science and their motivations, providing an insight into the nature of contemporary science communication and those who are involved with it [Milani et al., 2020].

In this article we firstly examine the numbers of females identifying as science communicators in our data. Next, we examine their professional roles, aims, motivations and deterrents for science communication. Finally, we explore the training female science communicators have received and the audiences with whom they aspire to communicate. The wider study also offered an opportunity to consider the changing dynamics of science communication in regards to digital communication. With some recent studies suggesting that 'old media' may be doing a better job of representing sex and gender than some newer, online and digital platforms [Mitchell and McKinnon, 2018], we were interested to explore this further and encompass a broad definition of science communication 'actors' to include a wide range of roles such as artists/illustrators, activists, bloggers, YouTubers and social media influencers. In doing so in both the RETHINK project and this article, we sought to expand understanding of who communicates science communication beyond a focus on researchers and scientists alone [Fähnrich et al., 2021].

Methods

We present data from a questionnaire survey which was distributed across seven RETHINK partner countries; Italy, the Netherlands, Poland, Portugal, Serbia, Sweden and the U.K., in 2019. The questionnaire was developed by Elena Milani, Clare Wilkinson and Emma Weitkamp and included several questions adapted from previous surveys and studies of scientists. This included survey work on science communication enablers, scientists and researchers, as well as surveys of press officers and science journalists [The Royal Society, 2006; TNS BMRB, 2015]. Questions were also informed by a scoping study conducted as part of the research [Milani et al., 2019].

The survey aimed to investigate the working practices, motivations and barriers of actors communicating science, technology and/or health. It also analysed the sources science communicators used, how they curate content, and consider the audiences they are working with [Milani et al., 2020; Milani et al., 2021]. In the survey we asked respondents a number of questions about their personal backgrounds and demographic features. This included questions on their age, sex, location and first-language, but did not include a question on race, due to the significantly differing contexts regarding the appropriateness of such a question in the countries in which the questionnaire was to be distributed. In relation to sex we asked respondents 'Are you?' with the option for them to select 'Male', 'Female', 'Non-Binary', 'Other (please self-identify here if you would prefer to)' or 'prefer not to say'. This question phrasing drew on advice from organizations, such as Stonewall [2019], regarding appropriate ways to ask individuals about their sex and gender at that time. We present our results here using the categories 'male' and 'female' as this is how we posed the question and the way our respondents categorized themselves within the questionnaire but we recognize that measuring both sex and gender is important to eradicate inequalities [Office for National Statistics, 2019; United Nations Division for Sustainable Development Goals, 2015]. With the benefit of hindsight, it may have been beneficial to ask two questions, one on sex and one on gender, though by including the option to self-identify, and also recognizing that sex can be changed [Council of Europe, 2022] we aspired to provide all respondents with an option with which they felt comfortable. We may also have asked this question in a different way, and asked respondents to categorize on the basis of gender alone rather than sex, though sex was implied by the options rather than as part of the question itself. Where we have referred to

other research and literature throughout this article, we have done so using the conception of gender or sex adopted by the original authors.

The questionnaire was developed in Qualtrics, and pilot-tested with 22 pilot respondents, before being translated to collate the responses across the seven countries included within the project. Although all of the countries included in the survey were in Europe, and there has been criticism that science communication has a tendency to focus on a narrow number of countries [Finlay et al., 2021; Gascoigne and Schiele, 2020], this did provide an opportunity to develop a picture of the science communication community beyond an individual country. The final questionnaire was distributed between September and November 2019 via official mailing lists, networks, associations, and societies of journalists, writers, press officers, communication officers, scientists, and public events organizers that communicate science. Individuals identified via a scoping study of science communication actors previously conducted as a part of RETHINK were also invited to participate [Milani et al., 2019], and we used snowball sampling to encourage respondents to pass the survey on to contacts also working in science communication. As we recruited through a combination of mechanisms, we are not able to estimate a response rate and all data presented in this article should be viewed with an awareness that it is drawn from a sample of science communicators in each respective country, all of which will have differing science communication histories, organizational contexts and reward structures [Johnson, Ecklund and Lincoln, 2014; Kessler et al., 2022]. Univariate and bivariate analysis was conducted using Qualtrics, Excel, and SPSS. Statistical analysis reported here was carried out using Pearson Chi-Square and Fishers Exact Test where cell size required. An alpha level of .05 was used for all statistical tests and these were only carried out to compare female and male responses, given the cell sizes associated with other categories were consistently low. The questionnaire received ethical approval from UWE Bristol, and complied with GDPR requirements.

Results

The results presented here relate to 459 respondents who completed the survey in full and who also answered a question regarding their sex. Over half reported that they were female (59%, n=272) and 40% (n=182) were male. One respondent selected non-binary, four respondents selected prefer not to say, and no respondents selected the category of other, and/or self-defined their sex or gender. As only one respondent identified as non-binary, we have not presented data where this could unintentionally identify them (for example, their age or country).

The higher response rate from females occurred for all countries, except Poland, where females accounted for 38% (n=11) of the respondents. Respondents were also more evenly spread in Sweden, where 48% (n=21) of respondents were male, compared to 52% (n=23) who were female (Figure 1).

The majority of both males (58%, n=105) and females (67%, n=181) were under 45 years old. 22% (n=40) of male communicators were aged 45–54, similar to females at 20% (n=54). Whilst in the older age categories there appeared to be more males communicating, with 19% (n=35) of male communicators aged 55 and older, compared with 12% of females (n=34) this was not statistically significant.

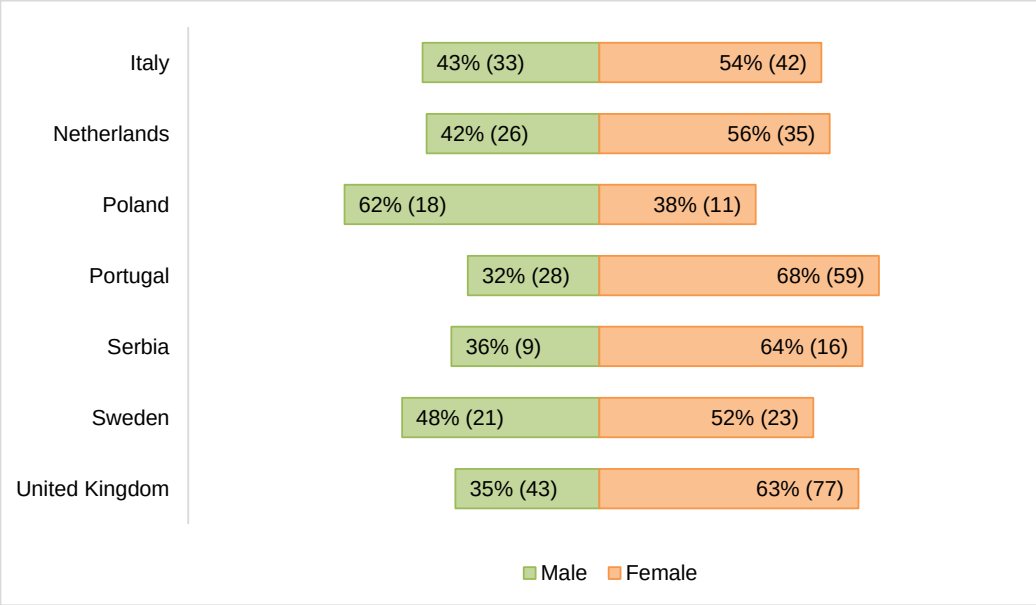

Figure 1. Respondents location.

When asked how they would describe themselves in terms of their professional role, the most common categories were press officers or communication officers (31%, n=143), freelance communicators or writers (26%, n=118), journalists (21%, n=97), and/or researchers (20%, n=92) with respondents able to select up to three choices. Considering any differences in the types of roles with which actors identified, there were some small variations for some roles (Table 1). Females less frequently reported being university lecturers or professors with 10%, n=28 of female respondents compared with 19%, n=35 of males (X^2 (1, N=454) =7.28 p=.007) reporting this role. Though more males reported being freelance communicators or writers (30%, n=54 males compared with 23%, n=62 of female respondents X^2 (1, N=454) =2.71 p=.100) and/or journalists or editors (24%, n=43 males compared with 18%, n=50 of female respondents X^2 (1, N=454) =1.84 p=.175) these results were not statistically significant. In relation to more contemporary roles, 8% (n=15) of male respondents reported being bloggers, YouTubers or social media influencers, compared with only 2% (n=5) of female respondents (X^2 (1, N=454) =10.61 p=.001). The category where we do see more female respondents was that of press officers or communication officers. 36% (n=97) of female respondents reported holding this role, compared with 25% (n=45) of male respondents (X^2 (1, N=454) =6.06 p=.014) which was also statistically significant. Despite variations in the types of roles performed across all respondents, 60% (n=276) both produced and curated content (57%, n=103 of males and 63%, n=170 of females) with no significant differences in response to this question.

Within the survey we asked two sets of questions in relation to the aims of communication and the communicators' broader motivations and deterrents in regards to their role in science communication. Turning first to the aims of their communication, we asked, 'when you communicate about science, technology and/or health, what are you trying to achieve?' with respondents able to select as many responses as they saw fit. The most popular responses to this question included to inform (91%, n=417), educate (69%, n=317) and to create conversations

Table 1. Respondents professional role(s).

	Male N (%)	**Female N (%)**
Researcher (including PhD student)	36 (20%)	53 (20%)
University lecturer/professor	35 (19%)*	28 (10%)*
Health professional (including allied health professional)	4 (2%)	4 (1%)
Journalist or editor	43 (24%)	50 (18%)
Documentary or movie maker	5 (3%)	7 (3%)
Freelance communicator or writer	54 (30%)	62 (23%)
Press officer or communication officer	45 (25%)*	97 (36%)*
Curator, explainer or museum employee	20 (11%)	23 (8%)
Policy maker or adviser	7 (4%)	13 (5%)
Artist or illustrator	5 (3%)	8 (3%)
Designer	10 (5%)*	4 (1%)*
Current undergraduate or postgraduate student	6 (3%)	7 (3%)
Teacher	10 (5%)	12 (4%)
Activist	9 (5%)	10 (4%)
Blogger, YouTuber, Social media influencer	15 (8%)*	5 (2%)*
Other. Please, specify	33 (18%)	58 (21%)

Note: * indicates statistically significant difference

between researchers and the public (66%, n=301) (Table 2). Exploring these results further, we can see that being female or male did not appear to significantly affect responses. However, more male respondents than female respondents indicated their aim was to counter misinformation (66%, n=120 males compared with 59%, n=161 females X^2 (1, N=454) =2.10 p=.147), entertain (46%, n=83 males compared with 40%, n=108 females X^2 (1, N=454) =1.55 p=.212) or that their aim was to influence their audiences' views on the topic (31%, n=56 of males compared with 17%, n=47 of females X^2 (1, N=454) =11.31 p=.001). The latter was the only response in this set of questions where there was a statistically significant difference in responses. Female respondents were moderately more likely than male respondents to indicate that they aimed to create conversations between researchers and the public (68%, n=184 females compared with 62%, n=113 of males X^2 (1, N=454) =1.49 p=.222) or that their aim was to reach underserved audiences (25%, n=67 females compared with 20%, n=36 of males X^2 (1, N=454) =1.46 p=.226) but both of these results were not statistically significant. A roughly equal number of female and male respondents were motivated to 'inspire young people to pursue a career in science, health, technology (54%, n=146 of females compared with 52%, n=95 of males X^2 (1, N=454) =0.96 p=.757).

With regard to broader motivations to communicate, we asked respondents to provide their three most important reasons to communicate science. There was very little variation with both males and females being motivated by their enthusiasm, desire to educate and as it was part of their job role (Table 3). Males, as indicated in the previous question, appeared slightly more likely to be motivated by an intention to counter misinformation (57%, n=104 of males indicating this motivation compared with 50%, n=135 of females, X^2 (1, N=453) =2.34 p=.126), and to raise their profile (9%, n=16 of males compared with 5%, n=13 of females, X^2 (1,

Table 2. Respondents and aims for communication.

	Male N (%)	Female N (%)	Non-Binary N (%)	Prefer not to say N (%)
Inform	169 (93%)	244 (90%)	1 (100%)	3 (75%)
Educate	129 (71%)	186 (68%)	1 (100%)	1 (25%)
Entertain	83 (46%)	108 (40%)	1 (100%)	2 (50%)
Inspire young people to pursue a career in science, health, technology	95 (52%)	146 (54%)	1 (100%)	1 (25%)
Create conversations between researchers and the public	113 (62%)	184 (68%)	1 (100%)	3 (75%)
Counter misinformation	120 (66%)	161 (59%)	1 (100%)	0 (0%)
Promote my work/project/myself	73 (40%)	99 (36%)	1 (100%)	1 (25%)
Encourage evidence-based attitudes and behaviour	103 (57%)	159 (58%)	1 (100%)	1 (25%)
Persuade them to adopt my point of view	9 (5%)	5 (2%)	0 (0%)	0 (0%)
Influence their views on the topic	56 (31%)*	47 (17%)*	0 (0%)	1 (25%)
Reach underserved audiences (e.g. ethnic minority groups, LGTBQ+ community)	36 (20%)	67 (25%)	1 (100%)	1 (25%)
Other	16 (9%)	32 (12%)	0 (0%)	0 (0%)

Note: * indicates statistically significant difference

N=453) =2.89 p=.089). Just under one in ten men also indicated financial benefits for them or their organization as a motivating factor. Whilst females appear to be moderately more motivated by the 'opportunity to work with other organizations (e.g. museums, science centres, schools)' (29%, n=78 of females compared with 19%, n=34 of males, X^2 (1, N=453) =5.96 p=.015). This was the only motivation which demonstrated statistical significance; all other differences were negligible.

When asked to provide the three most important reasons that prevented communication, the barriers to communicate were once again similar for females and males (Table 4). Males appeared to be slightly more likely to list a lack of reward and recognition (19%, n=34 of males indicating this reason compared with 13%, n=35 of females, X^2 (1, N=444) =2.87 p=.090) and financial rewards (18%, n=33 of males indicating this reason compared with 15%, n=40 of females, (X^2 (1, N=444) =9.52 p=.329) as reasons not to do more communication. They were also moderately more likely to indicate they were happy with the amount they do now (20%, n=37 of males indicating this reason compared with 14%, n=39 of females, X^2 (1, N=444) =3.21 p=.073) Females slightly more frequently (16%, n=44 X^2 (1, N=454) =1.47 p=.225) said insufficient support from their manager or organization was a reason not to do more. However, there were no statistically significant differences in relation to this question.

Turning to training, we asked respondents how they had developed their communication skills. 73% (n=336) indicated that they had developed their skills

Table 3. Respondents and motivations.

	Male N (%)	Female N (%)	Non-Binary N (%)	Prefer not to say N (%)
Because I am enthusiastic about science, technology and/or health topics	126 (69%)	180 (66%)	1 (100%)	4 (100%)
Because I am invited to communicate	28 (15%)	32 (12%)	0 (0%)	2 (50%)
Because I am keen to educate others about science, technology and/or health topics	120 (66%)	164 (60%)	1 (100%)	0 (0%)
Because I want to counter misinformation on science, technology and/or health topics	104 (57%)	135 (50%)	1 (100%)	0 (0%)
Because my communication work is recognised and valued	35 (19%)	40 (15%)	0 (0%)	1 (25%)
It counts towards my career (e.g. professional memberships/promotion)	16 (9%)	21 (7%)	0 (0%)	1 (25%)
It helps my own career	26 (14%)	28 (10%)	0 (0%)	1 (25%)
It is part of my job role	109 (60%)	177 (65%)	0 (0%)	4 (100%)
It raises my profile	16 (9%)	13 (5%)	0 (0%)	1 (25%)
My manager/organization supports it	18 (10%)	36 (13%)	0 (0%)	1 (25%)
None of the above	1 (0.5%)	0 (0%)	0 (0%)	0 (0%)
The opportunity to win prizes or awards for my communication work	5 (2%)	4 (2%)	0 (0%)	0 (0%)
The opportunity to work with other organizations (e.g. museums, science centres, schools)	34 (19%)*	78 (29%)*	0 (0%)	1 (25%)
There are financial benefits for me personally	16 (9%)	14 (5%)	0 (0%)	1 (25%)
There are financial benefits for my organization	14 (8%)	14 (5%)	0 (0%)	1 (25%)
Other	15 (8%)	18 (7%)	0 (0%)	0 (0%)

Note: * indicates statistically significant difference

through experience in public engagement or communication, 57% (n=260) through watching how other people (either professionals or amateurs) communicate with non-specialist audiences and 34% (n=156) of respondents said communicators and/or journalists had informally mentored them. 48% of respondents (n=221) had received training in public engagement or communication, 31% (n=143) had consulted resources such as books, handbooks, blogs, and YouTube videos and 28% (n=130) of respondents had or were completing a degree in journalism, media or science communication.

Table 4. Respondents and deterrents.

	Male N (%)	Female N (%)	Non-Binary N (%)	Prefer not to say N (%)
Could have a detrimental impact on my profile (e.g. drawn into controversy)	1 (1%)	8 (3%)	0 (0%)	0 (0%)
Difficult to attract audiences to my science communication work	13 (7%)	26 (9%)	0 (0%)	0 (0%)
Difficult to get others (e.g. researchers) involved in science communication work	38 (21%)	47 (17%)	0 (0%)	1 (25%)
Does not help my career progression	7 (4%)	17 (6%)	0 (0%)	0 (0%)
I don't have the right skills/training	9 (5%)	15 (5%)	0 (0%)	0 (0%)
Insufficient communication specialists at my organization	25 (14%)	34 (12%)	0 (0%)	0 (0%)
Insufficient encouragement from funders for science communication work	32 (17%)	40 (15%)	0 (0%)	2 (50%)
Insufficient support from my manager/organization	22 (12%)	44 (16%)	0 (0%)	0 (0%)
Insufficient support from other staff at my organization	16 (9%)	25 (9%)	0 (0%)	0 (0%)
Lack of confidence	7 (4%)	14 (5%)	0 (0%)	0 (0%)
Lack of opportunities	11 (6%)	25 (9%)	0 (0%)	0 (0%)
Lack of resources for science communication work	52 (28%)	80 (29%)	0 (0%)	2 (50%)
Lack of reward and recognition for science communication work	34 (19%)	35 (13%)	0 (0%)	2 (50%)
Lack of time	81 (45%)	127 (47%)	1 (100%)	2 (50%)
Negative perception towards the role of science communication from my peers	10 (5%)	17 (6%)	0 (0%)	0 (0%)
Not appropriate for my level/role	10 (5%)	20 (7%)	0 (0%)	0 (0%)
Not enough financial rewards from science communication work	33 (18%)	40 (15%)	1 (100%)	2 (50%)
I am happy with the amount I do now	37 (20%)	38 (14%)	0 (0%)	0 (0%)
I just don't want to	1 (1%)	2 (1%)	0 (0%)	0 (0%)
There are no barriers	21 (11%)	33 (12%)	0 (0%)	0 (0%)
Other	10 (5%)	12 (4%)	0 (0%)	0 (0%)

Note: * indicates statistically significant difference

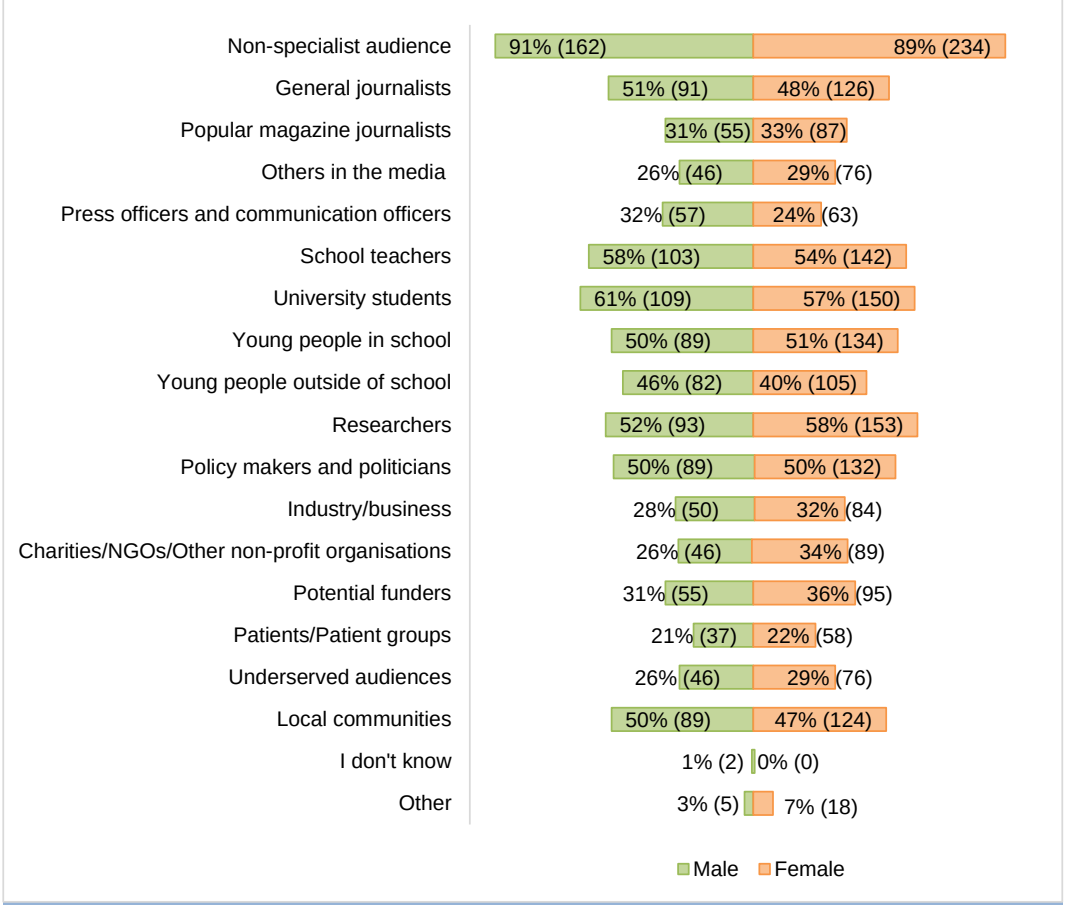

Figure 2. Respondents and audience they aimed to reach.

Being female appeared to play very little role in the likelihood of participating in training, with figures being very comparable for the development of skills via experience in public engagement or communication, watching and learning from others, through training in public engagement or communication, and via the consultation of resources. However significantly more females recorded that they had or were completing a degree in journalism, media or science communication (32%, n=86 of female respondents compared with 22%, n=40 of males, (X^2 (1, N=452) =5.01 p=.025) and females (35%, n=95) were also slightly more likely than males (32%, n=58, X^2 (1, N=452) =4.39 p=.507) to have received mentoring but this was not statistically significant.

Finally, with regard to the audiences with whom our respondents reported communicating, there was very little notable difference in approach at a general level, with 99% (n=180) of male respondents indicating that they communicated with audiences who were either already interested in topics, or that some of them were and some of them were not. 97% (n=263) of female respondents selected these same categories. Only a very small number of respondents indicated they were communicating with audiences that were not interested in the topics yet (1%, n=7), and these were moderately more likely to be female communicators (6 females vs. 1 male). Specifying this down further to specific groups, we asked 'which audiences do you aim to reach (Figure 2). Again, there were a number of strong similarities in responses to this question, though male respondents were slightly

more likely to say they were aiming to reach press and communication officers, as well as young people outside of school. Female respondents were more likely to say they were aiming to reach researchers, charities, NGOs and other non-profit organizations, as well as potential funders, which may reflect the higher numbers of females identifying with roles as press and communication officers. However, there were no statistically significant differences in responses to any of the options related to this question.

Discussion and Conclusions

There were more female (59%) respondents to our survey than male (40%) and this was the case in all countries apart from Poland, which could suggest science communication is indeed a female dominated field [Lewenstein, 2019]. But it could also be the case that more women took the time to respond to the survey. Previous work has suggested opportunities for engagement tend to come with increased expertise and higher academic ranks [Crettaz von Roten, 2011; Hetsroni and Lowenstein, 2014]. Our data found female and male communicators of all ages, and particularly aged under 45 (there were fewer female communicators aged 55 and older but this was not statistically significant). This may reflect the wide range of professional roles of survey respondents in our study but it could also suggest that science communication is perceived as being receptive to females at all career stages, albeit that age cannot be used as a proxy for length of time as a science communicator.

Though we see females and males across all role categories, it is of interest that males tended to be more likely to be university lecturers or professors, bloggers, YouTubers or social media influencers, while female respondents were more frequently than men working as press officers or communication officers, roles which could be perceived to align more with stereotypes of women as 'communal' [Carli et al., 2016], mediating and assisting others to communicate. This may have been influenced by our use of snowball sampling within the recruitment process, but could also suggest that women are more frequently working in 'supporting' roles in science communication and is an area worthy of further explorations, particularly as communication and engagement roles are often seen to hold less prestige, in universities for example, than those which are associated with research or other services [Watermeyer and Rowe, 2021]. It may also shed light as to why we can sometimes see discrepancies in research regarding women or female's willingness to participate in communication and engagement, with some research recording more engagement amongst men and vice versa [Anzivino, 2021; Hubner and Bond, 2021]. A closer understanding of differences in role within science communication would be helpful, as would further research on the science communication 'pipeline' and the influence of role modelling. We did not distinguish our participants on the basis of seniority, but as Elizabeth Rasekoala [2019, p. 3] highlights 'it is the men who have consistently occupied the senior and higher professional and status echelons of the science communication field, in spite of the growing over-representation of women.'

Whilst identifying in our survey as male or female appeared to play very little role in the likelihood of participating in training, more females recorded that they had or were completing a degree in journalism, media or science communication, suggesting a desire for a professional qualification. Similarly, the aims of communication did not greatly differ, though male respondents appeared more

preoccupied by influencing their audiences' views on their topic, as well as countering misinformation, entertaining and influencing, and females with creating conversations and reaching underserved audiences, though the differences in motivations were small. This may have ramifications for the time involved in communication amongst men and women, given that engagement and dialogue can take more time than unidirectional communication [Hubner and Bond, 2021], as can the complexities of understanding and aiming to work with underserved audiences. Both female and male respondents recorded interests in encouraging young people into STEM, suggesting that despite the high numbers of interventions focused on girls and young women, this is not something that female actors are focused on alone, at least in our data. These results combined, suggests there may be differences in how science communication is 'situated' and nuanced on the basis of the sex and/or gender of a communicator [Kessler et al., 2022; Pérez-Bustos, 2014] but this would require further investigation.

Similarly, the differences in barriers to engage in further communication activities were small with no statistically significant variations, though males were slightly more likely to report lack of recognition (including financial) as a disincentive and females reported on organizational issues such as insufficient support from a manager or organization, which may suggest some variation in agency. With regard to the audiences with whom our respondents reported communicating, there was very little notable difference with regard to their approach at a general level. This contributes to the limited empirical studies of sex or gender in science communication, but in a survey at this scale it was not possible to analyse the specifics of this context further, and additional research on cultural and social experiences is very much warranted [AbiGhannam, 2016]. Though not all of the actors we surveyed would have been directly communicating with audiences, we did not ask specifically about deterrents to communication associated to gender such as sexual harassment. Given the presence of this concern in recent literature [Amarasekara and Grant, 2019; McDonald, Barriault and Merritt, 2020; Samer, Lacombe and Calmy, 2021] it may have been useful to do so, however we did provide the option to report 'other' barriers and none of the comments in this section related to factors which could be seen as associated with sex or gender.

In relation to continuing work in this area, we recognize that the constitution of our sample was not able to shed light on the experiences of those with diverse gender identities and given this we have primarily focused on the experiences of females, but there is an increasing need to advance understanding of representation and science communication around LGBTIQA+ people [Bayram and Ironside, 2021; Bert, 2019; Motion, 2021; Roberson and Orthia, 2021]. This includes the experiences of trans women and men as science communicators where there can be burdens of responsibility to represent and perform not only ones science but also ones gender identity [Pérez-Bustos, 2014; Pérez-Bustos, 2019]. Similarly, sex and gender are only two personal characteristics which might be considered from an intersectional perspective [Evans and Lépinard, 2019] and science communication has a number of other important considerations to make around involvement and representation in a multiplicity of ways, including from the standpoint of race and ethnicity [Finlay et al., 2021; Rasekoala, 2019; Wilkinson, 2019], and social class. It is a limitation of our study that we did not include a question on gender as well as sex, or to have a question on gender alone, and though our response rates to the question, and the lack of engagement with self-defining 'other' options suggests

most respondents found an option which worked for them, we would recommend that future work in this area carefully consider such choices when designing research questions and methodologies.

To sum up, Evelyn Fox Keller [1982, p. 590] writing in the 1980's discussed liberal political criticism made against the sciences in relation to almost all scientists being men, she posed 'science itself would in no way be affected by the presence or absence of women'. This may lead us to ask how is science communication being affected by the presence or absence of females? If there is a gender ideology, a social construct, associated with the 'pervasive belief in the intrinsic masculinity of scientific thought' [Fox Keller, 2001, p. 60] what are the implications should science communication come to be seen as intrinsically feminine [Pérez-Bustos, 2014] and is that taking place? On the one hand it could be seen as positive that science communication appears highly appealing to women, and that we found few apparent variations in the experiences of females and males in the data we gathered suggesting science communication is not only a space for 'soft' or feminized skills. However, there also appears to be much more to explore around pay, perceptions of productivity, career progression and harassment and more nuanced survey work, over a greater range of countries, building on our initial work, would be welcome. In addition, we see opportunities to explore how the presence of women in science communication, already reported [Lewenstein, 2019] and which we found in six of the seven countries in our survey, affects science communication as a field [Rasekoala, 2019], the standpoints it takes [Harding, 2001], as well as the experience of men and a wider range of gender identities, in entering a field which may feel so at 'home' to women.

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