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# Perceptions and values of Spanish women scientists towards digital science communication

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**Abstract**

The digitalisation of science communication has been widely promoted within the Open Science movement in Europe to foster the social impact of research, as well as a more participatory culture of science. Using semi-structured interviews, we explore Spanish women scientists' values and perceptions regarding digital science communication. Results highlight the social value of science communication as well as intrinsic motivation as factors to actively engage in disseminating, educating and promoting science digitally. Adopting Open Science principles, participants craft open access multimodal materials (e.g., educational short videos, podcasts), use supporting multimodal resources and digital tools, and engage in social media to reach broad audiences. Finally, we propose some policy recommendations and pedagogical guidelines in terms of digital literacy, digital genres, and science accommodation strategies to promote digital science communication.

**Keywords**

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

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# 1 ▪ Context

## 1.1 ▪ *Science communication as part of the Open Science movement*

Scientists' communicative practices are often regarded as in-reach communication that occurs within academic and specialised contexts. However, scientists are also expected to participate in outreach science communication activities addressed to broad audiences [Cerrato et al., 2018; Llorente & Revuelta, 2023]. As part of these outreach practices, it is frequent to find scientists in lay settings such as science fairs and media broadcasting, but also on digital spheres writing science popularisation publications and addressing the general public on social media [Burns et al., 2003; Tuttle et al., 2023]. These initiatives are currently promoted by national agencies and institutions that encourage researchers to inform of science-related topics to different stakeholders as diverse as policymakers, scientists from other disciplines, science enthusiasts, or citizens [Dai et al., 2018].

Scientists who participate in science communication initiatives generally rely on three main types of communicative practices: unidirectional, bidirectional, and multidirectional [Bucchi & Trench, 2021; Houtman et al., 2021]. First, there is unidirectional communication in which scientists lead communication and inform the audience about a specific topic (deficit model). Then, there is bidirectional communication, where scientists and citizens engage in dialogic practices (dialogue model), and multidirectional communication where citizens adopt an active role in the different stages of research projects (participatory model or citizen science). While the deficit model might be regarded as less favoured by recent policy development in comparison to dialogue or participatory models [Houtman et al., 2021], the choice of science communication practices may depend on the purpose, intended audience, or format of the activities [Burns et al., 2003; Davies et al., 2021; Loroño-Leturiondo & Davies, 2018; Nerghes et al., 2022]. Therefore, all approaches bring a rich variety of outputs that contribute to the free circulation of knowledge and democratisation of science.

In the European context, these communicative practices are framed within Open Science (OS). This movement aims at making scientific outputs available to broad audiences since the early 2000s [Dai et al., 2018; Fecher & Friesike, 2014]. The OECD [2015] describes OS as a strategy employed by institutions to make "publicly funded research more widely accessible in digital format to the scientific community, the business sector, or society more generally" [Dai et al., 2018]. OS is conceptualised by UNESCO [2021] as any transparent, accessible, and collaborative practices that:

> make multilingual scientific knowledge openly available, accessible and reusable for everyone, to increase scientific collaborations and sharing of information for the benefits of science and society, and to open the processes of scientific knowledge creation, evaluation and communication to societal actors beyond the traditional scientific community [p. 7].

Many of the OS principles included in the *Horizon Europe research and innovation program (2021–2027)* introduce specific requirements regarding open access to scientific knowledge production, data collection, curation, management, analysis, and science communication [European Commission, 2020]. Hence, institutions such as governments, funding agencies, universities, and research institutes emphasise the value of those scientists who share their scientific knowledge production on digital formats (e.g., accessible online repositories, open access publications, open research data platforms), and those who actively engage with stakeholders outside the scientific community [Revuelta et al., 2020; Sanz Merino & Tarhuni Navarro, 2019].

## 1.2 ▪ *The digitalisation of science communication*

OS advocates for the digitalisation of science as part of supra-national policies [Dai et al., 2018; OECD, 2015; UNESCO, 2021]. The principles of accessibility, collaboration and reusability are strongly related to large investments in powerful digital infrastructures to create, evaluate and maintain scientific knowledge openly. Likewise, digitalisation influences how science is communicated, with scientists taking advantage of technology to expand their science communication practices to the digital medium. Traditionally, scientists have reached broad publics through media channels like the press, TV, or the radio [Claessens, 2008]. Currently, scientists also rely on digital tools and exploit Web 2.0 affordances — hypertextuality, interactivity, and multimodality — to create their own digital communication channels and interact with diversified audiences [Bucchi & Trench, 2021; Davies et al., 2021].

A myriad of digital science communication formats and texts — or digital genres — have remediated face-to-face science communication practices into hybrid [e.g., videos in on-site science talks, cf. Brennan, 2021] and digital ones (e.g., the radio interview into the podcast, the press article into the digital newspaper article, the science presentation into the webinar). Additional digital communication practices have emerged such as science blogging [Dai et al., 2018; Luzón, 2018; Zou & Hyland, 2020], forum and social media posting [Darling et al., 2013; Davies et al., 2021; Hara et al., 2019; Huber & Baena, 2023; Mehlenbacher, 2019; Pavelle & Wilkinson, 2020], TED talks [Scotto di Carlo, 2014], science videos [Beautemps & Bresges, 2021; Luzón Marco, 2019], and citizen science projects [Gascoigne et al., 2022; Giardullo et al., 2023], just to mention a few. For instance, science blogging allows scientists to disseminate scientific information and facilitate conversations about science [Dai et al., 2018; Puschmann, 2014]. Social media posting has grown significantly due to its potential to reach wide diversified audiences, but also special interest groups. Moreover, social media allows the easy and fast creation and access to content, and prompts interaction between multiple users [Davies et al., 2021; Huber & Baena, 2023; McCarthy & Bogers, 2023; Pavelle & Wilkinson, 2020]. Audiovisual genres such as TED talks, podcasts, or science videos have also received exponential attention because their multimodal features make scientific content more accessible, appealing and engaging to the general public [Beautemps & Bresges, 2021; Luzón Marco, 2019; Picardi & Regina, 2008; Scotto di Carlo, 2014].

As a result of this digital transformation, the remediation of science communication to the digital environment brings to the fore the challenge of science accommodation [Wickman & Fitzgerald, 2019]. Scientists must accommodate scientific knowledge to unknown audiences, as digital communication blurs the distinction between specialised and non-specialised audiences. This brings discursive adaptations that comprise communication-related skills to reframe scientific content in an engaging way that appeals to broad digital audiences. It also requires learning how to recontextualise scientific concepts with language strategies such as defining, exemplifying, using explicitations, and avoiding technicisms to make science understandable [Altman et al., 2020; Reid & Anson, 2019]. However, transforming scientific knowledge into accessible content is often regarded as challenging or as an underdeveloped skill that scientists need to address and train [Altman et al., 2020; Calice et al., 2022; Nicholas et al., 2018]. Another challenge refers to the development of digital and technical skills for science communication. Having the digital skills necessary to identify reliable electronic sources of information and reuse digital content, along with mastery of software to create digital texts (e.g., video, image, audio, editing tools, web administration), can help scientists maximise the impact of science communication [Llorente & Revuelta, 2023]. A third challenge targets the mastering of multimodal skills, which entails crafting appealing and engaging texts exploiting multimodal resources, hypertextual and interactive affordances of Web 2.0 [Pérez-Llantada, Carciu & Villares, 2025]. Therefore, communication, digital, and multimodal skills can maximise the impact of science communication.

### 1.3 ▪ *Mismatches between policies and practices*

Despite clear efforts to promote the OS agenda, European science communication still witnesses a series of mismatches between OS policies and the scientists' actual practices. These mismatches may explain the low levels of engagement found in Claessens [2008], with only 20% of European researchers disseminating science actively, although this trend is slowly changing. For instance, a study that surveyed more than 300 French researchers indicated that over 50% of the surveyed researchers considered a priority the dissemination of scientific findings to broad audiences [Birch-Becaas et al., 2023]. Another recent study conducted with almost 900 Spanish scientists reported that 48% of the scientists were involved in science communication targeted at non-specialised audiences, and over 30% were planning on doing it in the future [Pérez-Llantada, Carciu & Villares, 2025]. These studies, alongside previous research [cf. Davies et al., 2021], confirm that science communication engagement is uneven and depends on national policies and disciplinary factors, among others.

Other factors influencing scientists' engagement in science communication shed light on various challenges. For example, the pressure on scientists to publish in impact factor publications for academic promotion and funding makes scientists spend more time preparing publications [Calice et al., 2022; Ferrández-Berrueco et al., 2023; Rose et al., 2020]. Other obstacles involve the lack of professional recognition for engaging in outreach activities and subsequent low institutional reward systems [Sanz Merino & Tarhuni Navarro, 2019], the lack of mastering effective communication skills [Altman et al., 2020; Nicholas et al., 2018] and reduced science communication training options [Davies et al., 2021; Hu et al., 2018; Rodrigues et al., 2025; Saladie et al., 2023]. It has also been found that gender disparities can affect the level of engagement in both face-to-face and digital science communication [Huber & Baena, 2023; Pérez-Llantada, Carciu & Villares, 2025; Ramos-Vielba & D'Este, 2023].

In contrast, individual factors such as motivation and personal instinct and experiences [Besley et al., 2018; Hu et al., 2018; Riley et al., 2022; Rodrigues et al., 2025], as well as perceiving science communication as a responsibility towards society [Cerrato et al., 2018; Houtman et al., 2021; Loroño-Leturiondo & Davies, 2018], have a positive impact and enormously influence scientists' involvement and attitude towards science communication.

## 2 ▪ Objective

As part of a broader project, we have previously carried out a cross-disciplinary survey with women scientists regarding their disciplinary practices and use of digital technologies to produce, share, and communicate in-reach and outreach scientific communication [Pérez-Llantada, Carciu & Villares, 2025; Pérez-Llantada, Villares & Carciu, 2025]. As a follow-up study, the current research adopts a qualitative approach to further explore this issue as "the views of women scientists alone are not typically represented in studies of scientific research" [Pérez-Llantada, Carciu & Villares, 2025, p. 5]. Therefore, this study aims to understand how Spanish women scientists perceive and value science communication to the general public, with a special interest in the digital format of such practices. Specifically, we address the following research questions:

**RQ1.** How do women scientists understand science communication in the context of digital transformation?

**RQ2.** What are the women scientists' motivations for communicating science beyond expert publics in digital forms?

**RQ3.** What digital practices do women scientists engage in to align with OS science communication initiatives?

We focused on the Spanish context because policy changes have been implemented to strengthen the Spanish OS research system since 2021. More recently, the Spanish *national Open Science strategy 2023–2027* [FECYT, 2023] has been designed with the objective to improve the "quality, transparency, and reproducibility of scientific activity in Spain, improving dissemination among the scientific community and knowledge transfer to society" [p. 7]. For example, by including OS requirements within research project grant calls, changes in the assessment process of scientists that reduce the weight of traditional bibliometric indicators and combine qualitative indicators such as dissemination, training in transversal skills, the social impact of research, and digital bibliometric indicators such as altmetrics, which track the online presence of research and SC output across social media, online news media, or academic websites [Aksnes et al., 2019]. All of this is expected to influence scientists' views towards OS and science communication.

## 3 ▪ Methods

### 3.1 ▪ *Data instrument*

Following Creswell [2014], we chose a semi-structured interview protocol because it gives the interviewer enough flexibility to adapt it to the participants' comments as they talk freely. Previous research on science communication [Altman et al., 2020; Davies et al., 2021; Loroño-Leturiondo & Davies, 2018; Nerghes et al., 2022; Saladie et al., 2023] has relied on this type of interview to enquire in detail about scientists' insights towards different science communication dimensions.

The interview included 5 open-ended questions to investigate: the conceptualisation of science communication, interviewees' experience with science communication, perceived values and challenges, previous experience in digital science communication, and any identified training needs in digital science communication (Appendix 1. Interview protocol).

Each question of the interview aimed to address the specific themes discussed in the literature (e.g., science communication practices, motivations, or challenges).

### 3.2 ▪ *Data set*

Drawing on previous studies [Pérez-Llantada, Carciu & Villares, 2025; Pérez-Llantada, Villares & Carciu, 2025], we identified a Spanish association of female and male researchers (AMIT, Spanish Association of Women Researchers and Scientists) working mainly in — but not restricted to — the fields of science and technology as a convenient sample population for this study. AMIT was created in the early 2000s as a national platform that supports women scientists and promotes gender equality within the scientific, academic, and technological sectors. It aims to raise awareness about the situation of women in science, promote collaboration within its members, and give visibility to its members' work. As a result, the association provides an online open-access database with all its members (https://cientificas.amit-es.org). The database includes members' information such as professional experience, areas of expertise, participation in science communication, contact details, languages, and digital profiles. We established the following criteria to select our pool of interviewees:

1. Using the database's filter of "science communication frequency", we focused on those researchers who frequently communicate science to general publics. Although this could bias our results, we established this initial criterion to ensure that participants would be familiar with the concept of science communication and could offer more informed insights regarding (digital) science communication. We also expected to report their personal experiences as good practices.
2. We targeted scientists with at least 5 or 10 years of experience in academia, as early career researchers tend to devote their time to produce journal article publications for career stabilisation and are less likely to engage in science communication [Nicholas et al., 2018; Riley et al., 2022; Rose et al., 2020].
3. Another criterion referred to the online presence of participants. This was tracked on the database where members shared links to personal websites, blogs, and social media accounts (e.g., X,/Twitter Instagram, LinkedIn). It was hypothesised that scientists with different online profiles would be prone to participate in digitally mediated science communication.
4. Additionally, as previous research has reported linguistic diversity in digital communication [Luzón, 2018] and OS advocates for multilingual scientific knowledge circulation [UNESCO, 2021], we considered it important to select scientists who could engage in science communication in at least two different languages.

The data set consisted of 20 women scientists from STEMM (Science, Technology, Engineering, Mathematics, Medicine) and social sciences (political sciences) (Table 1). With this selection criteria, we aimed at ensuring a pool of interviewees representing varied disciplinary fields, and who engaged in digital science communication. Nonetheless, future research should conduct follow-up studies with a larger and diverse pool of participants regarding disciplines, genders, or nationalities. Therefore, the results presented in this study do not allow for generalisations. They would rather provide an exploratory analysis that can

**Table 1.** Data set description (N = 20).

| *ID* | *Experience as a scientist* | *Discipline* | *Online presence* | *Languages** |
|---|---|---|---|---|
| P01 | 10–20 years | Engineering | X**, LinkedIn | Sp, Eng, Fr, Ge |
| P02 | 5–10 years | Medicine | X, Facebook, Instagram, personal website | Sp, Cat, Eng |
| P03 | 10–20 years | Marine sciences | X, Instagram | Sp, Eng, Fr |
| P04 | 10–20 years | Earth sciences | X, Facebook, LinkedIn, ResearchGate, personal website | Sp, Eng, Fr |
| P05 | 10–20 years | Biomedicine | X, Facebook, Instagram, institutional website | Sp, Eng, Ge |
| P06 | 10–20 years | Technology | X, Facebook, Instagram | Sp, Eus, Eng |
| P07 | 10–20 years | Engineering | X, LinkedIn, institutional website | Sp, Cat, Eng |
| P08 | 10–20 years | Earth sciences | X, Facebook, Instagram, institutional website | Sp, Esp, Ge, It |
| P09 | 10–20 years | Physics | X, Facebook, Instagram, institutional website | Sp, Eng, Fr, Sw |
| P10 | +20 years | Marine sciences | X, Facebook, Instagram, blog | Sp, Eng, Cat |
| P11 | 10–20 years | Engineering | X, ResearchGate, personal website | Sp, Eng |
| P12 | 10–20 years | Political sciences | X, Facebook, Instagram, personal website | Sp, Eng |
| P13 | 5–10 years | Medicine | X, Facebook, ResearchGate, institutional website | Sp, Eng, Fr, It, Pt |
| P14 | 10–20 years | Engineering | X, Instagram, institutional website | Sp, Fr, Gal, It |
| P15 | +20 years | Engineering | X, Facebook, Youtube | Sp, Eng, Fr |
| P16 | 10–20 years | Life sciences | X | Sp, Eng, It |
| P17 | 10–20 years | Chemistry | X | Sp, Eng, Fr |
| P18 | 10–20 years | Earth sciences | X, Facebook, Instagram, ResearchGate | Sp, Eng, Fr, It, Pt |
| P19 | 10–20 years | Engineering | X, institutional website | Sp, Eng, Eus |
| P20 | 10–20 years | Medicine | X, institutional website | Sp, Eng, Fr |

* Languages: Cat = Catalan, Eng = English, Eus = Basque, Fr = French, Gal = Galician, Ge = German, It = Italian, Pt = Portuguese, Sp = Spanish, Sw = Swedish. ** Previously known as Twitter.

contribute to ongoing research on science communication and the digitalisation of science in the Spanish context.

## 3.3 ▪ *Data collection*

Before contacting any participant, approval from our home university's Ethics committee was obtained in February 2024.[1] Following this, we contacted 50 scientists on their professional email addresses, inviting them to participate in the study and to read the participation consent form. If we received no answer in a week, we emailed the scientists again. Finally, we received 20 positive answers, 4 negative answers, and 26 invitations remained unanswered.

1. Ethical approval by the University of Zaragoza (Spain) was obtained and all participants were provided with a description of the project and asked for their consent to be recorded and to use the data for the publication of this study. Protocol number: C.I. PI23/597.

Semi-structured interviews with the scientists who agreed to participate in the study were conducted online and recorded on the videoconference software Zoom between February and March 2024. The interviews were conducted in Spanish to facilitate comprehension, fluency of expression and collaboration. On average, each interview lasted 34 minutes. The full interviews were transcribed with the AI-based Transkriptor website, accounting for 11:36 hours of recorded material (about 86,819 words).

### 3.4 ▪ *Analytical procedure*

The transcriptions were uploaded and analysed with the computer-assisted qualitative data analysis (CAQDAS) software Atlas.ti v.8.4.2. The software allows researchers to qualitatively analyse large amounts of textual and (audio)visual data and structure raw data according to codes and emerging themes. It also provides researchers with tools such as memos, code descriptions, statistical measurements and Krippendorff's c-$\alpha$-coefficient inter-coder reliability test that ensure accuracy and reliability of the coding scheme throughout the whole analytical procedure [Friese, 2021].

We analysed the interviews in two stages following a thematic analysis approach to identify, describe and interpret the overarching themes emerging from the interviews [Braun & Clarke, 2006]. In the first stage, 10 interviews were annotated by the first author following an inductive approach to organise the emerging themes into semantic domains (e.g., "definitions of science communication", "features of science communication", "digital activities"). Depending on the interview questions and subsequent semantic domains, the unit of analysis for establishing the initial codes corresponded with individual words (e.g., "Twitter" for digital tool), short phrases ("video creation" for digital science communication activities) or sentences (e.g., "science sharing activity with non-experts" for definitions of science communication). Multi-valued coding was applied in some cases, as the same unit of analysis could receive several codes (e.g., a unit could be annotated with codes such as "local audience" and "positive value of multilingualism").

To ensure validity and reliability throughout the data analysis, we ran an inter-coder agreement (ICA) test. The list of codes predefined by the first author was shared with the second author so that she could annotate deductively two randomised interviews (i.e., 20% of the already annotated 10 interviews). We compared both analyses with the Atlas.ti's ICA tool that applies Krippendorff's c-$\alpha$-binary coefficient test to validate the coding scheme [Friese, 2021]. Krippendorff [2019] suggests disregarding any rate below $\alpha = 0.667$ and accepting as a reliable rate $\alpha \geq 0.800$. Our test scored 0.784. Therefore, the whole coding scheme was reviewed and discussed by both the first and second authors to avoid overlapping and misinterpretations of the data.

In the second stage, the first author annotated all the interviews with the refined coding scheme. Following Hennink et al. [2017], new codes were added to the coding scheme until a saturation point was reached, and no new codes emerged from the data. New codes were discussed among the three authors in relation to the semantic domains and interview questions to maintain the study's reliability. Additionally, we cross-referenced the final coding scheme with the literature to identify recurrent patterns and themes within the data.

Emerging from the data, and based on grounding (i.e., how many times a code has been annotated) and distribution principles (i.e., in how many interviews it appeared), we identified the following themes: perceptions of science communication, values attached to science communication, digital science communication, and skills for digital science communication (see Appendix 2. Themes, semantic domains and codes).

## 4 ▪ Results

This section is organised according to the main emerging themes and subthemes, which are empirically grounded and provide a rich thick description of the most salient findings: perceptions of science communication, values attached to science communication, digital science communication, and skills for digital science communication. The semantic domains and codes reported in this section correspond with high scores of grounding and distribution that can be found in Appendix 2. Themes, semantic domains and codes.

### 4.1 ▪ *Perceptions of science communication*

There was considerable agreement regarding science communication (SC) as the scientist's responsibility to transform and positively impact society. In support of this definition, we encounter references made to research accountability and scientists' responsibility for solving society's problems, and to justify the public funding received. SC was systematically associated with activities aiming at disseminating, educating, and promoting science literacy among the general public. This conceptualisation of SC was strongly connected by the interviewees to the deficit model through frequent mentions of participation in activities such as school talks, science talks to non-experts, radio and TV interviews, and writing science popularisation genres (e.g., books, magazines, and comics). Nonetheless, interviewees also made brief mentions of the dialogue model, i.e., exchanges between scientists and the general public. Textual references to scientists' face-to-face participation included science fairs, mentoring projects, and workshops with children and families, while participation in digital discussions revolved around podcasts, live video streaming, or social media dissemination.

The intended audience of science communication activities was consistently defined as local, heterogeneous and lay. Specific reference was made in the interviews to the general public either in the form of diverse local audiences (e.g., children, teenagers and adults) or interested audiences (e.g., families, groups of interest, and funding agencies). Perhaps as a side effect of the participants' affiliation to AMIT, a particular audience segment was overrepresented, i.e., girls, who was explicitly targeted by the participants with the purpose of reducing gender gap in scientific and technical disciplines.

Textual evidence also points to various sources that our interviewees drew on in their SC activities: own research outputs (e.g., papers), and open access and shareable digital materials made available by national and international associations to disseminate science widely. In all cases, interviewees agreed on the need of adapting the content and language of SC activities to the general public. For example, there were abundant references in the interviews to content simplification and plain language to help audiences understand the message, as the extract illustrates:

> I adapt the content and the discourse, especially to the audience, because otherwise, it would be unfeasible. Nobody would understand anything if I started talking about isotopes, iridium, and so on. People would ask "What are you talking about?", so I don't go into details. I speak in a way that people can understand me, but without losing rigour. (P04)[2]

This suggests that scientists who engaged in SC developed audience awareness and were perceptive of the need to accommodate science, recalling Wickman and Fitzgerald [2019]. Evidence of discursive strategies was found in the interviews, including paraphrasing and exemplification, and the use of references to daily activities and popular culture to make abstract concepts tangible to audiences.

Alongside language adaptation and content accommodation strategies, there were specific mentions to SC as a type of communication that involves the support of multimodal resources, namely images or videos:

> In face-to-face events, for example, I try to bring tangible objects so I can show what I am talking about. And then, in online activities, I include images, videos, and other visual elements. (P09)

As the extract illustrates, textual evidence was found of linking visuals with the purpose of making the SC contents appealing and engaging to the audience. Others highlighted the role of digital (audio)visual support in making the content accessible to audiences with potential hearing or visual impairments.

### 4.2 ▪ *Values attached to science communication*

Intrinsic motivation rather than external factors was frequently mentioned in the interviews in relation to the value attached to SC. For example, interviewees signalled reasons such as enjoyment of sharing and talking about science, personal satisfaction, the appreciation scientists receive from their audiences, and the opportunity to establish close relationships with the audience:

> [I do SC] because I really enjoy it. I work in a research institute so I don't have the contact that professors have with students on a daily basis. So, on the one hand, [with SC] I can interact with younger people who have different interests, and it also forces me to revise my language and find new ways to explain the scientific topics. It is challenging, but I have a great time telling stories that I find fascinating (P18).

The positive impact of SC on citizens' lives emerged as a common subtheme among interviewees, hence scientists' motivation to communicate science to society and engage with varied formats and practices. This was echoed by other subthemes such democratising science by increasing society's scientific literacy and encouraging learning and curiosity, especially in social spheres with low access to education.

2. Interview excerpts were translated from Spanish into English by the authors.

Another common view that interviewees shared was SC as a social responsibility, which was closely related to the respondents' status as civil servants. For example, this view is conveyed by textual references of perceiving SC as a means of paying back society because of public funding of science. Importantly, these diverse motivations are often intertwined, as exemplified in the following quote, where vocation is connected to the social impact of research on real-life problems:

> I think the main reason is motivation. I get really hooked on doing things with the patients because it gives a sense [to my research]. I don't know, you connect with a reason to do the work you carry out. When you get to know [the patients], it stresses why and for what you are researching breast cancer. It is for them. (P20)

We further found mentions of challenges such as research duties, lack of resources, and colleagues' negative beliefs that impeded engagement in SC. Interviewees appeared to share a common assumption that SC and dissemination forms of communication (e.g., science blogging, podcasts, popularisation articles) are not highly valued by national research assessment systems. This was backed up by remarks regarding the pressure to publish in high-impact factor journals to meet institutional productivity requirements and raise funds for research, the need of spending spare time in SC activities so as not to jeopardise research and publication, and the need for career stabilisation before committing to SC more seriously. Interviewees also discussed the role that available technological resources (e.g., software, tools) and institutional-based science communication training courses have in sustaining engagement in SC. Lastly, some interviewees raised the issue of the belief that science communicators were likely to be perceived as unsuccessful scientists by some of their colleagues.

### 4.3 ▪ *Digital science communication*

When asked about their digital SC practices, interviewees discussed several activities which involved video creation. For example, among the video-mediated outreach activities that they commonly mentioned are video adaptations (e.g., translations of videos), participation in longer video formats (e.g., podcast interviews, documentaries), or interaction with the audience via streaming on social media. Interviewees shared the view that videos can be effective tools to share scientific information with diversified audiences as they can be appealing, interactive, and easy to consume, especially by younger generations and students.

Digital SC on social media platforms — primarily X, Instagram, and LinkedIn — was a second significant theme emerging from the interviews. Interviewees reported their use for dissemination purposes and giving visibility to events and work-related activities. Some interviewees underscored the role of social media communication activities in complementing face-to-face SC activities and amplifying their reach to broader audiences.

It is noteworthy that there were mentions in the interviews of emerging forms of sharing and disseminating science online, such as specialised science websites and scientific project websites. Science popularisation articles on specialised websites, science blogs, digital newspapers or e-newsletters were the digital genres recurrently cited by interviewees.

Furthermore, digitally mediated practices were regarded as a fundamental support for SC, as deduced from references to online talks, interviews in podcasts, and the creation and storage of materials on repositories.

When comparing digital and face-to-face SC activities, there was no clear preference for either format as illustrated in the variety of SC activities reported in section 4.1 (see also Appendix 2). Both formats presented advantages and disadvantages depending on the context, audience, and purpose of the SC activity. In the case of digital SC, participants often reported advantages such as long-distance reach, accessibility and reusability. Textual evidence included references to how online talks could reach people from different cities or countries, how videos and resources could be stored on YouTube and repositories to grant more visibility and future accessibility, and how digital SC could better cater to diversified audiences' needs (e.g., creating transcriptions of online talks, including visual representations of abstract concepts, adding subtitles to videos).

### 4.4 ▪ *Skills for digital science communication*

The challenges of digital composing and communication skills was an important theme for our interviewees. Digital skills related to handling technical aspects of image and video editing were perceived as essential skills for effective digital SC. However, mentions were found regarding lack of time to invest in training courses for developing technical skills. Or, sometimes, even lack of institutional training opportunities. Therefore, participants chiefly described themselves as self-trained learners and employed user-friendly and open access software.

Another digital skills-related subtheme concerns the functional consequences of mastering multimodality — i.e., combining language with other semiotic resources such as images, video, audio. Textual evidence was found about the importance of carefully composing short multimodal texts (e.g., infographics, videos) so as to attract broad, diversified audiences:

> I tried to make it as much visual as possible, without too much text, so [the activity] has a bigger impact and is less boring. (P17)

This finding reinforces the shared view of our interviewees that effective digital SC is both educational and entertaining. Additionally, the subtheme of the adaptation of SC according to the audience and medium was recurrent in the interviews. In other words, although several SC activities might share the same content, their format was adapted to match the activity context. For instance, mentions were found of content adaptation to different platforms (e.g., transforming an e-newsletter into an Instagram post and X thread), audience's interests (e.g., adaptation of slides for children or teenager audiences), and audience's needs (e.g., fonts, size, colour combinations, and captions).

Another example of content adaptation skills that was provided by interviewees involved linguistic accommodation of scientific content to diversified audiences. Similar to its face-to-face counterpart, mentions were found of the need to master skills for digital SC such as the use of plain language, metaphors, daily life examples, and storytelling techniques to arrange ideas in a clear and appealing manner. In this way, it was expected to achieve a higher level of engagement with the audience that could prompt interaction and the active participation of citizens.

Finally, a digital skill that was frequently named by interviewees was that of the use of artificial intelligence in an ethical manner. Although participants were wary of artificial intelligence use, they agreed on its potential for image generation and content revision of the SC activities. Nonetheless, there was a common consensus that artificial intelligence required pedagogical training for scientists, as well as critical thinking skills for citizenship.

## 5 ▪ Discussion

This paper explored Spanish women scientists' perceptions and values of science communication within the digital transformation of science fostered by the Open Science movement and European scientific policies. We identified that these scientists perceive science communication as part of their responsibility towards society and value its social impact for disseminating, educating, and promoting science related activities. While they showed no clear preference for face-to-face over digital science communication practices or vice versa, our interviewees explicitly advocate unanimously for the positive values of digital science communication. Moreover, there was ample evidence of engagement in a variety of digital practices such as video-mediated activities, video creation, specialised science websites, science blogs and social media. Regarding how they experienced engagement in digital science communication, we identified a number of training needs that mainly centred on technical, composing, and content adaptation-related skills to effectively engage with diversified audiences online. In the following sub-sections, we discuss the main implications of the findings in relation to the study's research questions and the literature.

### 5.1 ▪ *Perceptions of science communication in the context of digital transformation*

Even if the Open Science agenda aims at participatory science models, this study shows that, so far, Spanish views on SC appear to fall within deficit and dialogue models [Bucchi & Trench, 2021]. This finding echoes the lowest rungs of disseminating, educating and promoting science according to Gascoigne et al.'s [2022] science communication ladder. The data show that our interviewees acted as scientific experts, combining face-to-face and digital formats to share scientific knowledge with non-specialist audiences and reduce a perceived gap in citizens' scientific literacy. For doing so, interviewees engaged in scientist-led communicative practices like webinars, science talks to non-expert audiences, or video creation. Moreover, some popular dialogic activities included participating in science fairs, workshops, podcasts or video streaming where participants could discuss and exchange ideas in a more interactive format.

Lack of evidence on participatory SC, where citizens play an active role, seems to point to the scientists' perception that SC activities are not sufficiently recognised for professional development purposes [Sanz Merino & Tarhuni Navarro, 2019]. Although our data are limited considering the small sample population, this finding suggests that policy intervention might still be necessary to strengthen SC in general, and dialogic and participatory SC in particular, as also previously claimed by the literature [Ferrández-Berrueco et al., 2023; Houtman et al., 2021; Loroño-Leturiondo & Davies, 2018; Nerghes et al., 2022].

### 5.2 ▪ *Motivations to communicate science communication in digital forms*

Supporting earlier studies, our findings have confirmed that the main motivations to participate in SC revolve around personal satisfaction and the social impact of science [Calice et al., 2022; Cerrato et al., 2018; Loroño-Leturiondo & Davies, 2018]. Among the main motivations for engaging in SC, the most common ones included sharing excitement and curiosity about science, personal satisfaction, and impacting society. As further noted by Loroño-Leturiondo and Davies [2018], our findings seem to suggest that outreach is viewed as a main duty of scientists' work and helps seek solutions to public concerns and educate society for better-informed decision-making. Thus, the main function of digital science communication seems to be that of maximising impact by reaching broader audiences, as also shown by Pavelle and Wilkinson [2020], Beautemps and Bresges [2021], or Zou and Hyland [2020].

However, our data have shown that SC engagement is hindered by national scientific policies advocating SC initiatives, while pressuring scientists to publish as the main indicator for promotion and stabilisation requirements [Aksnes et al., 2019; Riley et al., 2022; Sanz Merino & Tarhuni Navarro, 2019]. In line with Calice et al. [2022], we found that lack of time and resources were perceived as the main constrains for SC engagement. These self-reported challenges explain the tendency to favour deficit-model over participatory activities, as the latter require more resources, planning, and spontaneity [Burns et al., 2003]. Indeed, the lack of references in our study to citizen science, debates and discussions, or crowdfunding projects could imply that participatory SC and active engagement with societal actors still need to be integrated into the existing Spanish context. Raising scientists' awareness of participatory SC also emerges as an impending challenge to be addressed at supranational, national and institutional policy levels [Ferrández-Berrueco et al., 2023]. Future research should determine how policies can best promote and recognise varied SC activities aimed at engaging the general public in dialogic and participatory science, mirroring European research grant calls.

### 5.3 ▪ *Digital science communication to open science up*

A notable finding from this study is that the main forms of SC addressing the general public rely on digital formats. On the one hand, the use of digital resources and tools for crafting face-to-face activities served the function of tailoring content to the audience's interest and needs. For example, the interviewees reported the reuse of open access resources, and (audio)visual materials. On the other hand, some interviewees reported to rely on digital SC principally for their perceived value of reaching wider international and national audiences.

Digital SC also supports the OS principles of accessibility and sustainability as materials and resources can be stored online for reusability [UNESCO, 2021]. The digital genres mentioned in our study, such as specialised website articles, science blog posts, webinars, podcasts or social media publications, serve the purpose of opening science up. Engagement with these digital genres has the potential to increase the level of interaction, collaboration and transparency during the whole scientific process with diversified audiences, as corroborated by a large body of research on digital genres [Hara et al., 2019; Luzón Marco, 2019; Mehlenbacher, 2019; Picardi & Regina, 2008; Scotto di Carlo, 2014; Zou & Hyland, 2020].

Concerning the use of social media, which has been identified by the literature as a tool with significant relevance to communicate science [Davies et al., 2021; Nerghes et al., 2022;

Pavelle & Wilkinson, 2020], the interview data show that social media usage was rather limited to sharing information and raising awareness rather than creating content. This finding suggests that, even though our interviewees engaged in digital SC, they profited very little from the Web 2.0 affordances of interactivity to foster engagement with their audience. As Nicholas et al. [2018] contend, social media activity should rely on different strategies to engage broad audiences in co-creation, discussion, or collaboration processes [cf. Darling et al., 2013; Mehlenbacher, 2019; Pavelle & Wilkinson, 2020]. Leveraging on this interactive approach, digital SC would lean towards more participatory and citizen-led science [Gascoigne et al., 2022]. For instance, first-hand opinions could be obtained from citizens through social media's affordances; therefore, research projects and research objectives would be better tailored to the citizens' real concerns and needs, which would increase the social impact and value of science [Darling et al., 2013; Loroño-Leturiondo & Davies, 2018; Pavelle & Wilkinson, 2020].

Digital tools and resources are essential to transform scientific knowledge into accessible and appealing content to diversified audiences [Scotto di Carlo, 2014]. However, our data showed very occasional references to advanced and refined audiovisual tools. Scientists were aware of the importance of using attractive videos and visuals to communicate effectively, yet there were references to easy-to-use and free software to create their supporting digital multimodal materials. These tools were preferred as scientists lacked time to develop the necessary technical skills on their own or by enrolling in training courses. This finding could reinforce the existing mismatch between scientists' motivation to engage in SC and institutional policies that value research and teaching over SC, as previously reported by the literature [Calice et al., 2022; Ferrández-Berrueco et al., 2023; Riley et al., 2022; Sanz Merino & Tarhuni Navarro, 2019].

Of the three main digital affordances of Web 2.0, multimodality was perceived in our study as an inherent feature of SC. An important pedagogical implication of this finding is that hypertextuality and interactivity could be further exploited to support both communication and engagement with the general public digitally. Digital genres studies have shown that hypertextuality is key for knowledge construction and expansion since multiple resources can be interconnected to build up a topic or illustrate a scientific concept [Puschmann, 2014; Zou & Hyland, 2020]. Interactivity, on the other hand, is likely to be an essential feature of digital participatory SC activities happening on social media platforms, citizen science, crowdsourcing and crowdfunding projects [Giardullo et al., 2023; Hara et al., 2019; McCarthy & Bogers, 2023; Mehlenbacher, 2019; Reid & Anson, 2019]. Learning how to catch the audience's attention, foster discussion and exchange of opinions, and create a call to action are SC dimensions that should be addressed in practical training courses of science communication [cf. Llorente & Revuelta, 2023].

## 6 ▪ Conclusions

The findings of this study should be interpreted in view of several limitations. Regarding the sample, this study should be complemented with a broader sample pool in terms of size, gender, and disciplinarity to be able to draw generalisations from the data. Similarly, the fact that all interviews took place in the Spanish context, and participants were frequent woman science communicators, might result in the findings being overrepresented and biased. Follow-up studies should include a pool that offers a wider variety of views and practices regarding science communication in different national contexts to offer a more accurate picture of digital science communication in the European landscape.

Despite these constraints, this study has contributed to the field of science communication with an empirically grounded exploration of perceptions, values and needs towards science communication that benefits from the in-depth analysis. These findings can contribute to policy considerations alongside pedagogical implications regarding digital science communication training. Aligning with Ferrández-Berrueco et al. [2023], we suggest that addressing policy mismatches and a lack of resources is essential to increase and maintain scientists' SC practices. Institutions should create policies explicitly valuing and incentivising SC while minimising the pressure to publish in high-impact journals. This means that, in addition to traditional bibliometric indicators such as citation or journal indexes, digital indicators such as altmetrics that measure the societal impact of research and the level of online engagement could be included in the assessment of scientists' professional careers [cf. Aksnes et al., 2019; Pérez-Llantada, Villares & Carciu, 2025].

Finally, the development of appropriate skills and reliance on digital genres to foster digital dialogic and participatory SC with the public is another key area for digital science communication. Professional training on science communication practical models [cf. Llorente & Revuelta, 2023] should include, on the one hand, opportunities to develop digital, technical, language, composing, and communication skills. On the other hand, exposure to a wide range of digital genres that rely on different multimodal (i.e., textual, visual, aural) combinations and digital affordances can show how scientific contents can be adapted to different forms, styles, and language usage for greater appeal, impact and audience engagement.

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**Data availability statement**
Structured data will be available upon request. The interview protocol and coding scheme can be found in the appendices.

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### Supplementary material

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Appendix 1. Interview protocol
Appendix 2. Themes, semantic domains and codes


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