Traditional, dialogical and complex scholarly communication: towards a renewed trust in science

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In loving memory of Grazia Messina Foderaro

Abstract

Purpose – The credibility crisis of science is a growing topic of investigation. This study approaches the problem from the sustainability of the scholarly communication system by merging argumentation with information science.

Design/methodology/approach – Coding and content analysis drawing from a well-established textual argumentative tradition; a novel non-textual approach to complex communication and, an overlooked definition of sustainable information, were applied to 34 research works. The retrieval was carried out using Inciteful, a tool exploring literature networks. Additional information, such as keywords, mapping to Sustainable Development Goals (SDGs) and citations were acquired through the OpenAlex API. Operationalisation of concepts from the theoretical framework underpinned the selection and analysis of documents.

Findings – Scholars virtually involve peers, funding agencies, research councils, policymakers, experts, practitioners and representatives of the public in their formal written production. The described coalitions are occasional, while the needed ones are deep. Three forms of scholarly communication were found: traditional, dialogical and complex depending on the involved audiences. The sample tells us about the sustainability of the scientific communication system and the impact it may have on the public construction of imaginaries of science.

Originality/value – This investigation frames scholars, their products and societies as intertwined dialogical entities constantly communicating and impacting each other. Direct and indirect forms of scholarly communications are addressed too, showing how poor sustainability in these processes may entail a failure to reach different layers of societies.

Keywords: sustainable information, sustainable communication system, sustainable impact, sustainable design, epistemic justice, epistemic activism, scholarly argumentation, Maria Lugones

1. Introduction

The centrality of science in contributing to national growth in terms of innovation and commerce is widely recognised. Science has also unquestionably a pervasive impact on individuals' and societies' development (e.g. Russell, 1952). However, the public accepts this impact differently depending on how and by whom it is framed.

Biased use of science, polarized communication practices and scientific illiteracy hinder public benefits and trust in scientific findings. Moreover, online platforms allow for a new and different public participation in scientific debate, in which people are not passive receivers of truth but critical reviewers (Marres, 2023). All these aspects add to the current facts-resistance epidemic and contribute to the contemporary crisis of the scientific system. This problem is relevant not only because it involves the scientific community but also because it exposes entire societies to campaigns of disinformation and ideological manipulation by means sometimes difficult to detect (Haider and Rödl, 2023). So far, the problem has been approached from either the perspective of production or dissemination (for an overview see Kappel and Holmen, 2019), with some exceptions with a focus on evaluation (Walter *et al.*, 2007).

This investigation looks at the scientific communication system considering evaluation too as a way through which the academy mediates its value, supporting and justifying decision-making (Ràfols and Stirling, 2021, p. 165). Failing to consider the perspective of different audiences in all these processes, the scholarly communication system could be a contributing factor to the growing distrust and mistrust in science. To address these issues, this investigation looks at how researchers communicate in written *scientific production*, whom they address and involve, and what kind of relationship they describe and intend to build with their interlocutors. Then, we evaluate their argumentation practices in terms of sustainability according to the audience and the process addressed. We investigate how these adopted and sometimes described or discussed practices may affect public imaginaries and trust in science. Finally, we present what the authors consider an obstacle to sustainability. We accomplish this with the support of 1) a well-established argumentative textual approach tradition (Lepori and Greco, 2019; Rigotti and Rocci 2006), a novel, powerful contribution to non-textual argumentation (Lugones, 2006), and an overlooked definition of sustainable information (Nolin, 2010).This study introduces these approaches as intertwined in the theoretical framework (section 2) and discusses future steps towards sustainability and renewed trust in science (section 6). In doing this, it draws from a rich pre-existing literature, the selection of which is meant not to be systematic (see Research material). The literature was acquired using

the free-to-use software Inciteful (Weishuhn, 2023) which works on citation networks and facilitates interdisciplinary research. Since the scope of this study is to investigate the sustainability of the scholarly communication system through its formal products, two outputs from the theoretical framework dealing respectively with sustainable information (Nolin, 2010) and science communication/argumentation (Lepori and Greco, 2019) were selected as seed papers. The retrieved documents' relevance was assessed based on their titles. Concepts such as *sustainability*, *scholarly communication*, *(public) impact(s)*, *diversity*, and processes such as *(co-)production*, *dissemination*, and *evaluation/assessment* were considered to fit the purpose of this study. Among these documents, those fulfilling a set of criteria designed to obtain relevant information were studied (section 4.1). Through the analysis of the communication practices in a sample of 34 documents, we aim to find strategies to strengthen the sustainability of the scholarly communication system and trust in science. By highlighting the obstacles to sustainability reported by the author(s), we intend to show how a change toward a more sustainable system is already in line with scholars' needs and aspirations.

To this relevant collection of literature, coding and content analysis were applied (section 4). The rest of the paper presents the related works (section 3), describes its findings (section 5), discusses their significance for science and society (section 6), and finally acknowledges its limitations suggesting paths for further research (section 7).

2. Theoretical framework

2.1 Sustainable impact

The scholarly communication system involves multiple stakeholders, and the main one is the scholar producing and using information. Other stakeholders are the learned societies, the publisher, the product, the librarian and the influence of the new communication technologies (Fleming-May, 2023, in Background, citing Hills, 1989, p. 100).

In this investigation, we introduce societies as stakeholders, and we look at the relationship between them and the scholars through the analysis of their written products. We consider all three as dialogical entities (e.g. Borgman, 1989), constantly communicating and impacting each other. Scholars adopt different communication strategies that we define according to the audience addressed, the interaction field (Rigotti and Rocci, 2006, p. 155) to which they belong, and the means used to communicate. Societies are demanding participation in the solution of complex problems and critically evaluating the proposals of scientists (Marres, 2023). Moreover, societies model the production of knowledge in terms of geographical problems and political interests and values (Mahony, 2013; Perry, 2022; Felt *et al.*, 2016; Kearne

and Wienroth, 2011). The products are dialogical entities too, not only as results of the dialogue conducted by scholars, but because they are communicating something by themselves: scientific advancement. However, they also talk about the researchers and their interests, the scientific community, the society to which they belong, the addressee and their values. The product is also what tells the scientific system about the "value" of the scholar. It is on top of such value of research products that scholars contribute to the advancement of science and are evaluated. Their scientific impact is valuable to industries, societies, etc. It is ultimately the product that is used by the publisher and by different academic-related agencies not only to reach the broader public, but to preserve knowledge (e.g., Liu, 2003). Finally, the product mirrors in content, methodologies, format, etc., the influence of the new communication technologies. For all these reasons, scientific impact is usually quantitatively measured, and products focused.

According to Reale *et al.* (2018, p. 299), "Scientific impact is commonly defined as a change in research, which breaks the dominant paradigm and influences future research investigations." Impact is also understood and measured outside the academic realm, in terms of "external socioeconomic impact" (Penfield *et al.*, 2014, p. 21). In this study, we focus on the latter. We consider the actual crisis of public trust in the scientific system as a symptom of its lack of sustainability, and we argue that societal impact should be measured and understood not exclusively in terms of the usefulness of science to solve complex social problems, but also in terms of its capability to display and communicate its value to different audiences.

In research evaluation, the difficulty in defining social impact is created by a divergence of opinions on what should be intended by and included in the concept of *social* (Reale *et al.*, 2018). However, when we think in terms of audiences, this problem loses in part its relevance, because the concept's meaning may change depending on the culture to which it belongs. These audiences are composed of people with different cultures, interests and backgrounds, education and expertise, health, gender, colour and age, located around the globe and by institutions, public or private (e.g., should the latter be excluded just because they aren't public even if they are a relevant part of societies?), with different functions and interests who follow the laws according to which their society is more or less justly organised. Therefore, society should be understood as societies, in which different stakeholders in different countries are included. This would make a univocal definition of "social" and what should be included in it unattainable and somehow unfair for people belonging to other cultures. To this kind of audiences -

"(…) resources that either facilitates integration and participation according to the three constitutive parts of sustainable development (social, economic and environmental protection) and/or contributes to the

strengthening of the process in which society is transformed according to the ideals of sustainable development."
(Nolin, 2010)

- should be offered.

According to this definition, not only scholarly information, communication and dissemination practices, but also their evaluation process should consider people and the societies to which they belong, not as passive objects to be filled with findings and rankings, but as participatory subjects/agents. As such, these audiences should have the right to be integrated as they are impacted. Shortly, sustainable information deeply involves the entire scientific communication system.

Science, however, as mentioned, is products focused. When it comes to sustainability though, what matters more are the scholars and the products that come right after, because scholars do not only represent societies, but bridge science and societies showing the care it has for them. People and the communities in it dialogue seldom directly with the products by which they are impacted. This is due to different reasons, some of which can be simultaneously present: a) because they are not accessible, b) because they are unintelligible c) because they are in an unknown language; d) because they are not of immediate interest e) because they are poorly disseminated, etc. but they do dialogue with the scientists and the institutions they trust. Additionally, the more they are involved in terms of co-creation and co-production, the more they become interested, trust them (Walter *et al.*, 2007), and are more willing to accept their products.

This entails that *societal impact* should also be considered in terms of the capability of science to communicate its value to different audiences. In this communication process, the focus should be put on the scholars as trusted mediators in their communities. The *usefulness of the products* should improve not exclusively the society to which one belongs but consider the consequences to other societies. This implies that the political and commercial "arena" (Nowotny *et al.*, 2006) expands into a global *sustainable arena*. When assessing the *societal impact* of different institutions, the *usefulness* criterion fails to represent a thick slice of curiosity-driven and basic science. Therefore, *indicators* should focus on the contribution to the advance of societies in terms of education, and the capability of these institutions to display plurality of people, epistemic and societal problems.

Sustainability includes all the political, economic, societal, scientific and environmental complexities that need to be addressed to *care for human well-being*. It implies a joint effort to find solutions that do not destroy plurality. It requires multiple perspectives because it reflects

the complexity of reality and reality includes things that are meaningful without being useful, but also that are useful without being meaningful.

However, when reflecting critically on how to reach sustainability, the academia is mainly focused on the product and its accessibility, mirroring the market's priorities of productivity and usefulness. These values are framed as a tension towards more democratic ideas, such as participation, integration, and legitimacy (Felt et al., 2016, p. 2). In this investigation, we look at how these values are addressed by researchers in their ordinary formal written production.

2.2 Traditional, dialogical & complex communicationIntegration and *participation* are relevant notions suggested by Nolin (2010), however, these notions are more complex than they seem and generate debate on what they entail (e.g., Nogueira *et al.*, 2021, p. 5; Fisher *et al.*, 2015). We assume that to integrate and enable participation, every individual needs to be considered in its complex unicity, as a rational, emotional/spiritual and social being (Foderaro, 2023). Scientists, even if they are usually thought in terms of a community, are individuals driven by different research interests and adopting different methods. They are rational, emotional beings and active members of societies. As such they are in a bridging position to enable communication and integration processes between different communities, stakeholders, layers of the public and domains of science, by using not only different communication channels but also different communication forms. In this investigation, integration and participation are considered and studied from the angle of researchers' ability to take different agents and agencies into consideration as "virtual" interlocutors even when their needs and interests may be divergent and dissonant, i.e. they belong to different interaction fields. This is done by analysing formal written products by scholars.

To this end, Lepori and Greco (2019) study on grant proposal, clearly proves how scholars' communication strategy can further be strengthened by considering scientific writing as a dialogic process. This contribution takes into consideration social and communicative interactions over time being the latter an essential dimension for the building of trust. Their findings are extensible to scientific writing because, even though the goal may be different from grant proposal, they share the same architecture, which is dialogical. This dialogue is *traditionally* between peers, but it can be broadened by including other virtual participants. Particularly significant are the concepts that the authors borrowed from Rigotti and Rocci (2006, p. 155) such as *interaction field*, intended as the "social reality characterized by shared goals and mutual commitments", and *interaction schemes*, i.e., the "culturally shared 'recipes' for interaction" predefining the dialogue games, e.g. deliberation, negotiation, mediation, teaching, etc. (Rigotti and Rocci 2006, p. 173). As Lepori and Greco (2019) point out "Grant proposal writing per se, in fact, is a scheme that can be applied to different interaction fields

(…)" where it occurs "the presence of different segments of readers in the public", "or the expectation of a high standard argumentative text (…)." (p. 379)

Grant writing is therefore versatile, adaptable to different interaction fields and arguably to formal and informal scholarly communication. It is both "task-oriented" and "relationship-oriented" (Rigotti and Rocci, 2006, p. 175). *Relational goals* are what, over the long term, give rise to common ground influencing the institutional dimension (ibidem).

The scientific system has all the necessary conceptual and argumentative tools to interact with multiple audiences and to include members of the public as part of its communicative context. However, the public cannot be thought of either as an object (Nolin, 2010; Marres, 2023) or as an abstraction, but need to be considered in its intrinsic multiplicity (Lugones, 2003; 2006). This should enable not to regain the "old trust", purely based on *authority*, but a renewed one, made of constructive and critical participation, understanding and recognition (Marres, 2023). Moreover, to communicate with the public entails to acknowledge that the traditional form of argumentation might be unfair for some and that other forms of communication can be more sustainable (Medina, 2019, p. 24). However, non-verbal communication can be considered complex communication (Lugones, 2006), only when its aim is not to convince but rather to address people's uniqueness (Foderaro, 2023) and enable mutual understanding and acceptance (Lugones, 2006).

For scientists, it entails not only contextualised targeted approaches but integrating information needs previously overlooked. It is also a way to fight against discriminatory biased campaigns, including "distorted visual communication" (Medina, 2018). Sustainable scientific communication does not mean reducing science to an argument of persuasion in times of crisis, a tool easily manipulated by the powerful, or an act of intellectual hubris where only a perspective is taken into consideration, pretending that one's authority is enough to be understood and trusted (Nogueira *et al.*, 2021; Foderaro and Lorentzen, 2022). It means to restore science as a *liminal* space, "an interstice from where one can most clearly stand critically toward different structures" (Lugones, 2003, p. 59).

The *limen* as intended by Lugones, is a space where multiplicities meet (Casalini, 2022, pp. 77-78). It enables but does not guarantee change because the latter depends on the reciprocal willingness to cross different epistemic worlds and to start genuine, deep coalitions (Lugones, 2006). It involves both an inner personal dimension and a collective one. However, without the latter, the first does not have the strength to enable change, because change needs the creation of meanings that can only be produced collectively (Casalini, 2022, p. 87).

To seriously address the contemporary crisis of science as a trustworthy system, the system needs to put itself in that space where "one can most clearly stand critically toward different structures" (Lugones, 2003, p. 59). There, it can see itself critically from different perspectives, and change and generate change.

3. Related works

Although the interest in credibility and trust in (online) resources is a tradition in some research fields, such as information literacy studies (e.g., Francke and Sundin, 2012), the investigation on scientific credibility is still largely unexplored. Works about the building of trust in academic social networking sites have recently grown, addressing the issue from an existential (Francke, 2022) and an evaluation point of view (Francke and Hammarfelt, 2022). The impact on trust in science by some scholarly communication practices, mainly co-creation in knowledge production (Nogueira *et al.*, 2021) and public dissemination (Davies, 2021) also on social media, such for instance, the construction of "scientific argument" (Foderaro and Lorentzen, 2022), the linking of outputs only with self-promotion intents (Nelhans and Lorentzen, 2016; Thelwall *et al.*, 2013) or the share of publications to sustain and reinforce one's ideological views (e.g., Vainio and Holmberg, 2017) increasing polarisation around scientific topics, have been investigated and discussed. However, a more comprehensive approach addressing trust in science in relation to the sustainability of its communication system is lacking. Studies about the environmental and economic impact of science and information have increased lately (e.g., Haider *et al.*, 2022), still, sustainability is mostly framed within the open access (OA) discourse and the environmental communication, leaving the social pillar at the margins. Evans and Reimer (2009) findings suggest that OA has a positive impact on world participation in science, widening the audience reading and making use of it. Taking into consideration the information and communication needs of multiple audiences in scholars' written production, would therefore further expand science usability. Moreover, it would allow science to flow from different disciplines, changing the actual public imaginary - boosted also by social media dissemination - that science consists of a small core of medical and natural ones (e.g., Nelhans and Lorentzen, 2016; Lorentzen and Nelhans, 2024).

Godemann (2011, pp. 39-40) highlights the complexity of such an 'in-between' approach moving among three dimensions: science, public and practice and overcoming both disciplinary and scientific boundaries. The relevance of language for a deeper and mutual understanding of all the involved stakeholders can, according to the author, transform this already demanding work into a challenge. For effective communication, a deeper reception of different perspectives is indispensable, therefore, interdisciplinary and transdisciplinary need

to be understood as a "form of interculturality" (pp. 48-49). Scientific information within and between groups is arguably what enables knowledge processes and therefore needs to be considered as the spark allowing or preventing their efficacy (Godemann, 2011, p. 45).

The relevance of the dialogical dimension has lately become increasingly central in different disciplines and application areas. In journalistic studies, Ettinger and Painter (2023) highlight the significance of conversations as scientific and democratic vehicles of climate change communication. In social media studies, several findings on how scholars interact when different actors are involved in debating climate change (Foderaro and Lorentzen, 2023) and other topics of political and public health interest (Lorentzen, 2014, 2016, 2021) have been enabled by the collection and analysis of conversations. The political importance of these discussions has been further deepened by Greco (2023), who argues that they are not to be interpreted as a social media isolated phenomenon, but rather as part of a poly-logical argumentation taking place in different venues. Dialogue and co-creation are also tested strategies with short- and medium-term benefits (e.g. Zamani *et al.*, 2024) used by practitioners and scientists to address the communication gap between specialists, experts and different communities when responding to health information needs.

As earlier research shows, science is deeply interested in sustainability and largely investigates on how interdisciplinary and transdisciplinary approaches may enable it through integration and participation. Dialogues and conversations are also presented as privileged vehicles of information and co-creation/production as a valuable strategy for knowledge exchange and dissemination. All these aspects are relevant to science on sustainability therefore, we assume they should be helpful too to reach sustainability in science to renew public trust in its system.

4. Methods and research questions

Lugones' (2003, p. 59) vision of liminality as an "interstice from where one can most clearly stand critically toward different structures"; and of complex non-textual form of communications as "occurring among intercultural polyglots who are disposed to understand the peculiarities of each other's resistant ways of living" (Lugones, 2006, p. 84); Lepori and Greco's (2019) approach to scientific writing as dialogical dimension, and Nolin's (2010) definition of sustainable information, are all valuable approaches to sustainability and trust in science. Therefore, this investigation uses them as a theoretical frame to seek answers to the following questions:

RQ1. What kind of communicative approach do researchers use and what audience do they involve in their formal written products?

RQ2. What do these products tell us about the sustainability of the scientific communication system?

RQ3. What can be learned from these practices and products to improve public trust and sustainability in science?

4.1 Dataset

To find relevant literature to answer these questions, this investigation adopted Inciteful (Weishuhn, 2023). This tool is free and displays graphs of scientific publications mainly using bibliographic coupling, co-citations and algorithms. Showing important and similar papers starting from one or more seed paper(s), it enables optimisation of retrieval through scholarly networks (Inciteful, Paper Discovery explained, 2023). It visualises also journals with the most papers, frequent authors, most cited authors and prominent institutions in the graph. All this was considered relevant to generate an interdisciplinary bibliography but also to see if some significant quantitative pattern would surface.

The literature was collected in May 2023. It took off by inserting two seed papers, Nolin (2010) and Lepori and Greco (2019). This choice is motivated by the theoretical framework developed by merging information science and argumentation and by the focus on sustainability and written formal scientific communication. The graph generated by the system was small, presenting only 7 papers, two of which were defined as important by the tool for the number of citations, respectively from 1993 and 1995. Because of its small size, the graph was extended so that citation paths from one step to five steps from an article were considered, resulting in 132 documents (papers, doctoral dissertations, book chapters, reports, editorials) including the abovementioned seven and the seed papers, published between 1987 and 2023.

All the documents retrieved were considered relevant to the aim of this investigation based on their title. This is because it has been proven that title words alone provide a classifier performance regarding precision comparable to the entire abstract (Eklund et al., 2019). Of the 132 papers on the graph, 47 (35%) were considered relevant and downloaded for further reading. Post retrieval adopted criteria for the selection of documents were at least one of the following: relevance to sustainability in terms of criticism of current practices and/or introducing innovative ideas; focus on communication and information strategies towards different audiences; applicability of the findings to one or more of the scientific communication processes production, evaluation, and dissemination.

Of the 47 publications downloaded, 32 (68%) met one or more selected criteria. These, together with the seed papers, provided a sample of 34 documents consisting of 28 articles,

three book chapters, one report, one dissertation, and one editorial. A coding scheme was developed based on the theoretical framework, considering the sustainable impact of resources, the sustainability of communication strategies, and the scholarly communication approach (Supplementary material tables: S4, S5: Sustainability of communication strategies).

The articles were analysed in two ways, through coding and content analysis. We set up a coding scheme a priori to analysis based on theory outlined above. This scheme covered aspects such as the three pillars of sustainability, communication approaches, type and levels of coalitions, and argumentation strategies. We then made use of qualitative content analysis based on White and Marsh (2006), in which the answers were derived from the accessed outputs in an inductive approach. We looked up all the documents in the Open Alex API (Priem *et al.*, 2022) for additional data, such as keywords, when the author chosen keywords were unavailable, mapping to Sustainable Development Goal (SDGs), and citations. Three documents could not be found in Open Alex. We used researchers' names, pictures and pronouns in their presentations to find gender identification. However, this practice may have generated some false attribution, because it is unclear if the information was compiled by the author(s) or the institution(s) and because the author(s) may have chosen to not share publicly their gender identity. Even if the size of the sample is small, it gives some interesting insights into the representativeness of gender and geographical distribution. The consistency of this pattern on a large scale may affect public imaginaries of science.

The coding scheme and the tables with the analysed data can be found in the Supplementary material.

4.2 Data analysis

Scientific outputs are a domain-specific communication form that changes according to the typology and function of the texts (Lepori and Greco, 2019). Since this work analyses five distinct types of scholarly outputs, the majority of which are interdisciplinary, the approach to text analysis needs to respect this diversity. Therefore, it took off concepts from the theoretical framework operationalised in a set of questions to empower such diversity.

The questions are divided into three blocks: production, dissemination, and evaluation (Supplementary material: Sustainability of communication strategies). They try to capture the sustainability of the argumentative and communicative strategies adopted and how they affect the process. The goal is to let the texts answer questions considered relevant to sustainability in science, as in a virtual dialogue. The questions were refined multiple times to keep them within the paper's scope. Even though we didn't explicitly mention feminist theories in the

formulation of the theoretical framework, Lugones' philosophy is entirely permeated by the effort to approach feminism in a more plural and inclusive way (Rodrigues, 2022). The philosopher's work "The coloniality of gender" (Lugones, 2016) was read during this study and may have influenced the design and the approach to text analysis.

5. Findings

5.1 Scholarly communication approaches

The most common argumentative approaches adopted in the analysed documents were: *Dialogical*, 14 instances; *Traditional*, 11 instances; *Dialogical & Complex*, 8 instances, and *Traditional & Complex*, 1 (Table I).

Dialogical	Fisher *et al.*, 2015; Guston *et al.*, 2014; Herman *et al.*, 2015; Horta *et al.*, 2008; Laudel, 2006; Maruster, 2008; Nolin, 2010; Nogueira *et al.*, 2021; Palmer, 1999; Pohl *et al.*, 2021; Roberts, 2009; Rodríguez *et al.*, 2013; Schot and Steinmueller, 2018; Sjöö and Kaltenbrunner, 2023
Traditional	Felt *et al.,* 2013; Hallonsten, 2014; Huutoniemi, 2016; Klerkx and Leeuwis, 2008; Lepori and Greco, 2020; Mahony, 2013; Polk, 2014; Rosenlund *et al.*, 2017; Sherren *et al.*, 2009; Smart *et al.*, 2019; Walter *et al.*, 2007
Dialogical & Complex	Beck and Krueger, 2016; Davies, 2021; Felt *et al.*, 2016; Ferrannini *et al.*, 2021; Jacucci *et al.,* 2016; Mobjörk and Linnér, 2006; Perry, 2022; Ràfols and Stirling, 2021
Traditional & Complex	Kearnes and Wienroth, 2011

Table I Scholarly communication approaches, Table by the author(s)

Scholars are constantly addressing peers, however, when they include other stakeholders as virtual interlocutors, such as funding agencies, research councils, policymakers, members of the public, etc., their communication strategy changes accordingly. The products show communication asymmetries due to different expertise, lack of a common ground of shared values, continuity of interaction over time and not seldom deeply dissonant interests. The more the involved parties belong to different interaction fields, the more scholars are likely to

highlight issues, power imbalances and to criticise distorted communication with the intent of restoring balance.

The means adopted in the studied sample were mainly written argumentation (dialogical and traditional), however, some scholars discussed and displayed non-textual argumentation, such as images, installations, and performances of different kinds (Davies, 2021), criticised the distorted use of such means by influent agencies (Felt *et al.*, 2016; Kearnes and Wienroth, 2011), denounced power imbalances inside and outside the scholarly communication system (Mobjörk and Linnér, 2006; Perry, 2022; Ràfols and Stirling, 2021) affecting, for instance, information systems (Jacucci *et al.*, 2006) and policies (Ferrannini *et al.*, 2021; Beck and Krueger, 2016).

5.2 Sustainability of communication strategies

In the sample, arguments were backed by evidence and earlier studies; however, the robustness of these arguments and evidence to multiple audiences' evaluation, relies on their accessibility. While the OA status allows the access to the document, it doesn't make evidence provided by early studies accessible too, unless they are OA. Openness and transparency in science, within the limits imposed by law (e.g. General Data Protection Regulation - GDPR), are therefore the first necessary steps towards public trust.

Reasonable and constructive arguments from involved and impacted audiences were seldom directly addressed in the sample and public involvement and participation not anticipated and rarely practiced. Even if some of these issues could be overcome by the mediation of science communicators, it would be interesting to know how many of the analysed studies have benefited from it. If the answer is "some" or "any", then even if these outputs are virtually including and impacting a broader audience, they may have failed to reach it practically.

The level of coalition between scholars and the stakeholders was occasional, due to contingencies such as projects, however, the desired or needed ones were deep. These occasional relationships seemed to impact scholars' research and students negatively (e.g., Felt *et al.*, 2013; Laudel, 2006; Sherren *et al.*, 2009).

The sample shows how scholars' findings always have consequences either on all three pillars of sustainability (22 instances out of 34), on the social and economic (8 instances), or on the social (4 instances), showing deep awareness of the relevance of the social pillar, neglected by funding agencies (Mobjörk and Linnér, 2006). However, when we looked at the Sustainable Development Goals (SDGs) mapped to the documents, the goals related to social justice such as SDG 4 (quality education), 5 (gender equality), and 10 (reduced inequalities), weren't as

common as SDG 17 (partnerships for the goals). This could be partially due to the capability of the language model used in tracking these instances.

The scientific fields covered by the sample were: science policy (5), science communication inclusive evaluation (6), science and technology studies (4), higher education (2), economics (1), sociology of science (4), philosophy of science (1), information science inclusive information systems (4), environmental science and related disciplines (7). This variety of disciplines and audiences is reflected in the choice of journals. Some of them are recurrent as the research areas: Science and Public Policy (4), Journal of responsible innovation (3), Social Epistemology (2), Research Policy (2), Environmental Science & Policy (2). The geographical distribution obtained from scholars' affiliation, shows a void of the presence of researchers and institutions from the south and east of the globe (Supplementary material tables: S1). This could be partially related to poor dissemination of the documents in the graph, to their novelty, or to funding-project requirements excluding for instance not-European countries from collaboration.

The gender distribution offers some quantitative and qualitative patterns that help to understand how scientists are not used to questioning gender unequal representation in the production of outputs. This is relevant not only per se but also because scholars represent communities in societies and may give insights into overlooked societal problems narrowing the communication gap between science and the public. In terms of quantitative patterns, we counted a presence of 35 females (she/her), 60 males (he/him), and 0 non-binary (they/them, she/they, he/they) identifiable authors on a sample of 34 outputs mainly produced in Europe. The authors with available pictures were prevalently white. This also indicates unequal geographic distribution and poor representation of discriminated scholarly communities. While female authors appeared with single and mixed contributions, there was a pattern of multi-authors with only male contributions, which is significant considering the research fields covered by the sample. USA, UK and The Netherland were the countries with more male multi-authored products in the sample. In terms of qualitative patterns, we noticed that both female and male scholars made use of dialogical and complex communication, while more males than females made use of traditional. However, this latter pattern is less significant being the number of male scholars nearly double that of female. The complex communication was adopted by scholars belonging to the fields of science policy (2), science communication (2), science and technology studies (1), environmental science (2), economics (1), information science (1). The related countries were UK (3), Austria (2), Sweden, The Netherland, Canada, Germany, Italy, Norway, and Spain. This proves how distorted visual communication and power imbalances are recurrent problems everywhere.

Scholars' findings in the sample were mainly applicable to the processes of production and evaluation (12); production, dissemination and evaluation (9). Findings applicable only to production (4), evaluation (8) and production and dissemination (1) were also present, showing how production is deeply associated with evaluation and only occasionally put in relation to dissemination (Roberts, 2009) except for the instances where all three processes were addressed. However, when it comes to communication strategies, dialogical and complex communication are robust and sustainable in all the processes, while traditional communication stays anchored to production and evaluation. Twenty out of thirty-four outputs were open access with a high number of citations. However, citations are not a sustainable measure of impact outside the scientific community and arguably within it. The language adopted in these instances was oriented to a specialised audience, even when virtually involving different stakeholders. This practice suggests that the commitment to dissemination which starts in the production process is considered more as a responsibility towards governments and funding agencies rather than towards impacted audiences and the public. These OA products would not arguably reach outside of a specialised audience even if shared in social media channels (e.g., Foderaro and Lorentzen, 2023).

5.3 Obstacles to sustainability and imaginaries of science

Although limited to the studied sample, the products tell us something about the sustainability of the scientific communication system, the scholars and their societies. The communication approaches change with the broadening of the audience and the authors are generally committed to sustainability. However, when it comes to gender equity, geographical representativeness, awareness towards impacted communities, and robustness of arguments from a multiple audience perspective, there is a wide space for improvements. These limitations show that the scientific system could benefit in terms of public trust and sustainability by transitioning to OA, by actively and consistently ensuring participation and visibility of underrepresented scholars' communities and by anticipating the involvement and participation of the public in its communication processes.

Researchers highlight different kinds of issues emerging from the production, evaluation and dissemination of science; about the modelling, formulation and application of policies and the actions/choices of funding agencies. They present these issues as related to the country of affiliation. However, the qualitative analysis shows that they are recurrent in all the countries in the sample. We introduce them in order of recurrence, but they need to be understood as deeply related and intertwined: 1) political and market influence through research programs and councils, policymakers and funding agencies 2) systemic pressure on productivity and

usefulness over quality and meaningfulness 3) fragmentation or strategic abstraction in addressing the complexity of sustainability.

Scholars agree that research councils, programs, policymakers, and funding agencies are framing how science is evaluated (Rosenlund, *et al.,* 2017) and what goals need to be prioritised with impact in scientific production and consequentially into societies (e.g., Beck and Krueger, 2016; Felt *et al.*, 2016; Laudel, 2006; Mobjörk and Linnér, 2006; Roberts, 2009; Schot and Steinmueller, 2018; Sjöö and Kaltenbrunner, 2023). Political and market interests and agendas play a significant role through funding agencies and the appointment of government representatives inside strategic institutions. For instance, when addressing sustainability, the more neglected pillar by these agencies and agents is the social, which is not by chance, the one which considers inequalities and imbalances of powers (Mobjörk and Linnér, 2006) within people globally and within and between institutions. These agencies and agents, by awarding proposals and introducing policies, not only decide what are the priorities that need to be addressed but also what typology of science can address them, and which are the more impactful branches in terms of return on investments (Kearnes and Wienroth, 2011). This influences negatively knowledge production in terms of quality and diversity (Laudel, 2006), it impoverishes the public's view of science as only certain typologies of science get funding (Mobjörk and Linnér, 2006), increases epistemological and ethical uncertain in addressing sustainability and climate change (Beck and Krueger, 2016), and turns scientists into producers of outputs in view of grant awards and career advancements (Laudel, 2006).

This leads to the second problem, systemic pressure on productivity and usefulness, causing a) fragmentation (Rodríguez *et al.*, 2013; Sherren *et al.*, 2009; Sjöö and Kaltenbrunner, 2023) without any follow-up in terms of real accomplishments (Felt *et al.*, 2013; Sjöö and Kaltenbrunner, 2023) and b) strategic abstraction such in defining and addressing the complexity of sustainability in order to justify questionable decision making (Mobjörk and Linnér, 2006).

All these issues are affecting the scientific system, scholars and societies. However, researchers are not only denouncing problems (criticism), but also proposing solutions. Alternative funding is introduced against political and market influences as an option (Herman *et al.*, 2015). Different policy framings (Beck and Krueger, 2016; Ferrannini *et al.*, 2021) and quality control are needed through interdisciplinary scholars (Huutoniemi, 2016). Alternative responsible metrics, indicators and evaluation criteria are suggested (Herman *et al.*, 2015; Ràfols and Stirling, 2021; Walter *et al.*, 2007) to preserve scientific integrity over systemic pressures and exogenous change (Hallonsten, 2014) and promote diversity in higher education and in science (Horta, *et al.*, 2008; Laudel, 2006). To address fragmentation and ease the time-consuming

work of interdisciplinary research groups, co-production as praxis (Perry, 2022) and the role of librarians mediating exchange between different scientific domains is also proposed (Palmer, 1999). Inequalities, injustices and distorted visual communication are denounced, and a strong commitment to the public and the mission of science over political, market and individual interests are overall expressed by the products in the sample.

How science is framed and communicated by different agencies and agents impacts people's understanding and its credibility (Davies, 2021; Felt *et al.*, 2016; Kearnes and Wienroth, 2011; Mahony, 2013; Nogueira *et al.*, 2021; Smart *et al.*, 2019). This is proved extensively through different examples. Some of these examples are strictly related to sustainability as they denounce distorted visual communication on the topic, displayed by different agencies in collaboration with different stakeholders (Felt *et al.*, 2016). Others are more focused on general dissemination interventions, also conveying imaginaries of science (Davies, 2021) and political interests (Kearnes and Wienroth, 2011).

In these examples, scholars but also the agencies involved, make use of non-verbal forms of communication. While funding agencies use them as rhetorical instruments to reach and convince different audiences, scholars on the other hand, present and discuss these forms denouncing distorted visual representations of science and imbalance of powers (complex communication). These distorted communications are used to reinforce public imaginaries of a high national approach and performance (Felt *et al.,* 2016), to highlight the achievements of an individual, group or institution (Davies, 2021) or to strengthen the political position of the funder(s)/organiser(s) (Kearnes and Wienroth, 2011).

To counter these distorted narratives, scholars discuss them to show their structural weaknesses, and the political and market interests behind them, trying to restore balance and facts to the audiences they address.

6. Discussion

Science is *always* useful to societies even when it may appear theoretical or without immediate gain/applicability and purely curiosity driven. Instead, it should be highlighted how its significance to societies is mediated and by whom. Research councils, funding agencies and policymakers are, according to the research material, the most powerful agents influencing the discourse about science value, and what this value should be. Often the vision mediated reduces science to its utility or to 'value for money' (Kearnes and Wienroth, 2011). This narrative is politically steered in terms of democratic oversight and accountability for the investment of public money.

To reduce this imbalance, in the evaluation process of societal sustainable impact, the most meaningful indicator should not be the product's usefulness but the communication endeavour preceding, accompanying, and following it. This is done by the scientific system in different ways, some of them are explicit and some are implicit. Explicit communication forms are relatively easy to recognise as is proved by the literature and by the findings presented in section 5. They consist mainly of written formal and informal products, with or without the participation of different stakeholders. However, there is a large constellation of verbal and non-verbal, formal and informal outputs that contribute to the creation of these written outputs and add to the sustainability of the scientific communication system: meetings, e-mails, distance teaching, audio records, presentations, visuals, digital tools, etc. Non-verbal forms of communication are defined as complex (Lugones, 2006) because they recognise that people, inclusive scientists, are complex beings too and may have multiple interests and ways to access and communicate knowledge.

Implicit communication is more difficult to spot because it is embedded in the system and becomes explicit through evaluation which enables decision-making such as awarded grants, career advancements, admission of PhDs students, acceptance or rejection of manuscripts, dissemination of outputs, etc.

As the literature shows, there is a dissonance between scholars' expectations and what they actually can do, because systemic power and political and social forces, influence the communication process from the very beginning (Beck and Krueger, 2016), hindering the advancement of science in the directions needed and desired by scholars (Laudel, 2006; Mobjörk and Linnér, 2006).

We consider the actual crisis of science and academic-related institutions to be also a symptom of this dissonance. As the findings show, scholars are accountable mediators between societies and science. They are mediator both on an institutional and interpersonal dimension (Rigotti and Rocci, 2006; Davies, 2021). They dialogue constantly, not only with peers and are at the same time, attentive listeners. Such focus is shown in different epistemological problems, in the variety of disciplinary, interdisciplinary, transdisciplinary approaches and in the diversity of argumentation and communication strategies, aimed to solve, but also to highlight issues. In complex communication, for instance, scholars disrupt power imbalances, pointing to distorted visual communications and legitimising multiple ways of knowing (Perry, 2022, p. 347).

None of these practices have diminished the rigor or the quality of the scholars' investigation. However, the more the discussion is open considering and involving a wide range of possible

virtual interlocutors (Godemann, 2011; Rigotti and Rocci, 2006), the more the accessibility of the product will impact the addressed audiences. As scientific and social mediators, scholars need to dialogue with multiplicities to be understood by them, but more importantly, they need to represent these multiplicities (Jacucci *et al*., 2006; Mahony, 2013; Zamani *et al*., 2024). Therefore, we assume that if a scientific field, topic, methodology, communication strategy, perspective, gender, ethnicity, colour, language, geography, community etc. is underrepresented in science, also the related societies, cultures, way of knowing and communicating their relevant problems are neglected too, and this means that for that portion of the audience, science fails to communicate its value. A value which consists of scientific advancement in the direction of social, environmental and economic sustainability.

To impact societies, science needs dissemination activities by agents and agencies that the users/public trust (Francke, 2022; Francke and Hammarfelt, 2022; Roberts, 2009, pp. 214-215). Therefore, a sustainable path to credibility is consequentially the displaying of pluralities. It can be argued that not all scientists engage with societal problems, however, this attitude is also true for many people in societies. The more variety and typologies of scholars science displays and finances (Herman, *et al*., 2015), the more open and transparent their communication approaches and strategies become, the more it talks to a plurality of people, offering them the perspective they need not only to make informed choices (Walter *et al*., 2007), but to actively contribute to the available options (Felt *et al*., 2016). Different agencies should come into play in different dissemination contexts. Needless to say, here academic journals, science communicators, universities, libraries, but also journalists with expertise in the same area or scientists with a passion for blogging, should play their relevant role in addressing different layers of their societies, utilising all the possible channels, inclusive social media (Ettinger and Painter, 2023; Foderaro and Lorentzen, 2023; Greco, 2023). The findings show that the most adequate form of communication for dissemination purposes with multiple audiences is not the traditional one, but the dialogical and complex one. This is also confirmed by the related works (Ettinger and Painter, 2023; Foderaro and Lorentzen, 2023; 2022; Zamani *et al*., 2024)

As Floridi (2008, section 7) points out, all information agents and agencies should think of themselves as *collaborative informers* having the *epistemic obligation* to share information even when the audience does not ask for it. These collaborative informers however, should design scientific information in a sustainable way (Nolin, 2010), meaning not only accessible, but also locally sustainable (Jacucci *et al.,* 2006) and contextualised, with a high argumentation quality adapted to the targeted audiences (Foderaro and Lorentzen, 2023; 2022; Lepori and Greco, 2020; Lugones, 2006), not neglecting the sustainability of the adopted technologies and

systems (Maruster *et al.*, 2008; Nolin, 2010). This entails that the communication strategy changes according to what people need (Medina, 2019), and not only according to the "performance" of scientists (Davies, 2021). If we think the digital environment is polluted with disinformation and racist campaigns (Matamoros-Fernández and Farkas, 2021), skewed towards a self-referential form of scientific dissemination (Hammarfelt, 2023; Nelhans and Lorentzen, 2016) and populist communication behaviours (Mede *et al.*, 2023; Smart *et al.*, 2019) we should agree that it is needing mitigation targeted initiatives too (Holford *et al.*, 2023).

As the findings point out, the weakest point of the sustainability of the scholarly communication system is that it is a system (Ferrannini *et al.*, 2021, p. 9) and, we add, that it is a system evaluated either by itself or by heavily politicised institutions. As such it mediates systemic interests and values instead of collective interest (ibidem), and it has a structural limit to change. From the analysed sample of literature, some solutions emerge. Collective interest should integrate their values in the systemic reaching of a collectively balanced shared vision (Ferrannini *et al.*, 2021, p. 9). Moreover, what is more problematic in reaching sustainability is that the concept is abstract, heavily rhetorically and politically loaded. Because it transcends sector and disciplinary boundaries (Godemann, 2011) affects a wide variety of interest groups, values and priorities, in different places and cultures, it is hard to operationalise (Pohl *et al.*, 2021; Polk, 2014). In science, however, this complexity is less fragmented because of its general goal of *care for human well-being* shared by all the scientific areas and disciplines (Reale *et al.*, 2018). Even if it is not an economically independent system, it still has a strong power due to its contribution in terms of education, innovation, technologies and tension to environmental, social and economic sustainability. Therefore, if collective sustainable values grow inside the scientific communication system, it will substantially impact also societies, and this process has already started. As the findings and the literature show, it started in the production context, but now it needs to grow further and involve the dissemination and evaluation contexts. With the active engagement of all the different stakeholders involved in production, dissemination and evaluation, sustainability can have something appealing for anyone and be a concept not only meaningful, useful but also resourceful, i.e. allowing the system not to poorly survive the change, but to flourish in it. If we consider science as a *limen* (Lugones, 2003) where pluralities meet without necessarily change themselves, but looking for different perspectives about themselves, it is possible to learn something new, find solutions meaningful and useful to everyone, without losing unicity and at the same time respecting others' unicity (Foderaro, 2023). Sustainability could hardly be something more than that, seeing the preciousness of other beings, even when they are not perceived as useful, and doing something to preserve it.

Summing up, the societal impact of science cannot be evaluated sustainably only focusing on the product and in terms of its general usefulness. It needs to consider both explicit and implicit forms of communication. This investigation has introduced some of them. It has also proposed to look at the product, the producer and the societies as dialogical entities explicitly and implicitly communicating and impacting each other. Finally, it presented implications for practices and research, examples of how these communication forms talk to different people and reach different layers of societies, influence public trust and contribute to the creation of imaginaries of science.

7. Limitations

This contribution acknowledges several limitations. The first is a consequence of the method. The analysed sample, although extremely relevant, is skewed toward interdisciplinary and transdisciplinary approaches, therefore more studies are needed for robust results applicable to different disciplines. The second is the focus on some types of written communication over others informal written and formal/informal verbal contributions (e.g., e-mails, material for students, talks, workshops, online meetings, media, etc.) used daily by scientists. All these instances could be relevant objects for future studies. A third limitation is the difficulty of scaling up a similar study to thousands of texts. However, it will not be impossible for a Large Language Model (LLM) to extract involved and impacted audiences through SDGs and find communication types by processing images and relevant, recurrent words in texts. Finally, the fourth limitation is in the design of the paper: despite the effort to adopt a *sustainable design*, this contribution is not itself an example of complex communication, except for the general purpose of equity and justice implicit in the very concept of sustainability. Even though the same scrutiny was not applied to the analysed sample, our list of references tries to display the richness and diversity of the scholarly communication endeavour and the tension toward epistemic justice. Still, imbalances in geographical and gender representation may be present, mirroring that same lack of sustainability found in the system through our analysis.

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Supplementary material: Tables

Art.	Geographic Distribution	N. of Authors & Gender
1	Canada, Germany	1F+1M 1st author F
2	Austria	F
3	Austria	3F+1M 1st author F
4	Austria	3F+1M 1st author F
5	Italy	3M+1F
6	USA, UK	6M
7	USA, Germany, UK, Netherlands	5M+1F
8	Sweden	M
9	England, Spain, Italy	3F+3M 1st author F
10	Portugal, USA, UK	3M
11	Finland	F
12	Norway, South Africa	3M
13	UK	2M
14	Netherlands	2M
15	Australia	F
16	Switzerland	1M+1F
17	UK	M
18	Netherlands	1F+2M 1st author F
19	Sweden	1F+1M 1st author F
20	Norway	2F+1M 1st author F
21	Sweden	M
22	USA	F

23	UK	F
24	Switzerland, USA, Australia	4F+1M
25	Sweden	F
26	Netherland, UK, Spain	2M
27	USA	F
28	USA, Spain, Netherlands	3M
29	Sweden	3M
30	UK	2M
31	Australia	3F+2M 1st author F
32	Sweden, Netherlands	1F+1M 1st author F
33	UK	3F+4M 1st author F
34	Switzerland	4M

Table S1. Geographic & gender distribution, Table by the author(s)

Article	Publication Type	Keywords	SDGs	Cit.
1	ja, OA	Assessment modeling, uncertainty, political dimensions	SDG13	43
2	bc, OA	Science communication, scientific identity, public	SDG11	1
3	ja	Transdisciplinarity, sustainability technopolitical cultures engagement	SDG12,9,15,17	90
4	ja	Transdisciplinarity, doctoral education, research socialisation	SDG10,4	68
5	ja, OA	Covid19 pandemic, industrial policy, government intervention	SDG1,17,12	73
6	ja, OA	Socio-technical integration, collaboration, transdisciplinarity	SDG9,17	92
7	editorial, OA	Responsible innovation, journal, motivation	SDG9,8	72
8	ja	Individual scientists, organizing, resource dependence theory	SDG12,17,8,9,15	10
9	report, OA	Funding mechanisms, open science, reputation	SDG17,12	1
10	ja	Competitive research funding, diversity, higher education	SDG17,4,9	50

11	ja, OA	Interdisciplinarity, accountability, research evaluation	SDG17,16,4	22
12	ja	Standardization, district health information system, sustainability	SDG9,17	61
13	ja	Boundary work, science policy, United Kingdom	SDG17,9	62
14	ja	Research funding, authority, delegation	SDG2,17	55
15	ja	Funding, scientists	SDG9,17,8	204
16	bc	Grant proposal, writing	SDG4,10	1
17	dissertation, OA,*			
18	ja	Sustainability, knowledge management, adaptation	SDG12,15,9	21
19	ja	Research policy, research funding, sustainable development	SDG17,9	11
20	ja, OA	Co-production of knowledge, post-normal science, experience-based knowledge	SDG17,16,10	6
21	ja, OA, *			
22	ja	Science, structures, strategies	SDG8,9	75
23	ja, OA	Co-producing critique, boundary work, epistemic choreography	SDG16,11,10	2
24	ja	Integration, transdisciplinary research learning, co-production of knowledge	SDG10,17	78
25	ja, OA	Transdisciplinary research, sustainability, symmetrical participation	SDG10,17	140
26	bc, OA	Evaluation, assessment, indicators	SDG16,10	2
27	ja, OA	Broader impacts, societal benefit of science, public dissemination	SDG17,16	42
28	ja, OA	Socio-technical integration, EU Framework Programmes, Research solicitations ELSA	SDG9,8,12,17	65
29	ja, OA	Mode 2, relevance of research, choice of research	SDG17,12,15,9	7
30	ja, OA	Transformation, sustainable development goals, R&D National systems of innovation	SDG9,17,12	744
31	ja, OA, *			
32	ja, OA	Research governance, gender mainstreaming, policy instruments	SDG10,5	
33	ja, OA	Open innovation, knowledge production, societal impact	SDG9,17,12	31
34	ja	Societal impact, societal effects, impact evaluation, evaluation model	SDG16,17	235

Table S2. Publication type, keywords, SDGs & citations, Table by the author(s)

ja=journal article; bc=book chapter; * =Not found in Open Alex Api

The 17 SDGs are: No poverty (SDG 1), Zero hunger (SDG 2), Good health and well-being (SDG 3), Quality education (SDG 4), Gender equality (SDG 5), Clean water and sanitation (SDG 6), Affordable and clean energy (SDG 7), Decent work and economic growth (SDG 8), Industry, innovation and infrastructure (SDG 9), Reduced inequalities (SDG 10), Sustainable cities and communities (SDG 11), Responsible consumption and production (SDG 12), Climate action (SDG 13), Life below water (SDG 14), Life on land (SDG 15), Peace, justice, and strong institutions (SDG 16), and Partnerships for the goals (SDG 17).

Source: Wikipedia (2023), Sustainable development goals, available at: https://en.wikipedia.org/wiki/Sustainable_Development_Goals#:~:text=The%20short%20titles%20of%20the,) retrieved 14 November 2023

Article	Sustainable Impact of Resources	Schol. Comm. Approach
1	1, 2b, 3a, 4, 5, 6 science policy, 7*, 8s+underdev., 9pe	Dialogical & complex
2	2s, 3a, 4, 6 science communication, 7so, 8b, 9pe	Dialogical & complex
3	1, 2b, 3a, 4, 5, 6 STS, 7*, 8b, 9pe	Dialogical & complex
4	1, 2s, 3a, 4, 6 higher education, 7so/ec, 8s, 9pe	Traditional
5	1, 2b, 3b, 4, 5, 6 economics, 7*, 8b+underdev./underrep./discrimineted, 9pe	Dialogical & complex
6	2b, 3a, 4, 6 STS, 7*, 8b, 9p	Dialogical
7	1, 2s, 3b, 4, 6 STS, 7*, 8b, 9pd	Dialogical
8	1, none, none, 4, 6 sociology of science, 7so/ec, 8s, 9pde	Traditional
9	1, 2b, 3b, 4, 6 research evaluation, 7so/ec, 8b, 9e	Dialogical
10	2b, 3b, 4, 6 higher education, 7so/ec, 8b, 9e	Dialogical
11	2s, 3a, 4, 6 philosophy of science, 7so, 8s, 9e	Traditional
12	1, 2b, 3a, 4, 6 information system, 7*, 8b+underdev., 9pe	Dialogical & complex
13	none, none, 5, 6 science policy, 7*, 8b, 9pde	Traditional & Complex
14	1, none, none, 4, 6 science policy, 7so, 8s, 9pe	Traditional
15	1, 2b, 3a, 5, 6 sociology of science, 7*, 8b, 9pe	Dialogical

16	1, 2b, 3b, 4, 6 scientific argumentation/communication, 7so/ec, 8s, 9p	Traditional
17	1, 2s, 3b, 4, 6 environmental science, 7*, 8s+underdev., 9p	Traditional
18	1, 2b, 3a, 4, 6 information science, 7*, 8b, 9pde	Dialogical
19	1, 2b, 3a, 4, 5, 6 environmental science, 7*, 8b+underdev., 9pe	Dialogical & complex
20	1, 2b, 3a, 4, 6 science communication, 7*, 8b, 9pde	Dialogical
21	1, 2b, 3b, 4, 6 information science, 7*, 8b, 9pde	Dialogical
22	1, 2b, 3b, 4, 6 information science, 7so/ec, 8b, 9pe	Dialogical
23	1, 2b, 3a, 4, 6 environmental science, 7*, 8b+underrep./discriminated, 9p	Dialogical & complex
24	2b, 3a, 4, 6 environmental science, 7*, 8b, 9pde	Dialogical
25	2s, 3a, 5, 6 human ecology, 7*, 8b, 9e	Traditional
26	1, 2b, 3b, 5, 6 science evaluation, 7*, 8b+underrep./underdev., 9e	Dialogical & Complex (disrupting structures of powers)
27	1, 2b, 3a, 5, 6 sociology of science, 7*, 8b, 9e	Dialogical
28	1, 2b, 3b, 5, 6 science policy, 7*, 8b, 9pe	Dialogical
29	none, none, 5, 6 environmental science, 7so/ec, 8s, 9e	Traditional
30	1, 2b, 3b, 4, 6 science policy, 7*, 8b+underrep./discriminated, 9pde	Dialogical
31	1, 2s, 3a, 5, 6 sustainability, 7so/ec, 8s, 9pe	Traditional
32	1, 2b, 3a, 5, 6 STS, 7so, 8b+underrep., 9pe	Dialogical
33	none, 3b, 5, 6 sociology of science, 7*, 8s, 9pde	Traditional

34	1, 2s, 3a, 4, 6 science evaluation, 7*, 8s, 9e	Traditional

Table S3. Sustainable impact of resources, Table by the author(s)

Supplementary material: Coding scheme

Sustainable impact of resources

Code	Description	Note
1	proposed action	
2s	types of the coalition, involved agents and agencies: scholars	
2b	types of the coalition, involved agents and agencies: broad multiple audiences	
3a	levels of the coalition, occasional, i.e. expression of short-term interests	
3b	levels of the coalition, deep, i.e., constant, expression of shared values	
4	novelty	
5	criticism	
6	scientific field	
7e	impacted sectors, environment	
7so	impacted sectors, social	
7ec	impacted sectors, economic	
7*	impacted sectors, all the previous instances	
8s	impacted audiences: scholars	
8b	impacted audiences and communities: broader multiple audiences	communities: minorities, discriminated/underrepresented, underdeveloped
9p	applicability of findings in research, production	Sustainability of communication strategies: Production
9e	applicability of findings in research, evaluation	Sustainability of communication strategies: Evaluation
9d	applicability of findings in research, dissemination	Sustainability of communication strategies: Dissemination

Table S4. Sustainable impact of resources, Table by the author(s)

Scholarly communication approach

Code	Description
Traditional	written; interaction field: involving/addressing peers in different academic departments/disciplines, i.e., dialoging inside the same interaction field.
Dialogical	written; interaction field: involving/addressing scholars + different stakeholders not necessarily sharing the same goals and mutual commitments, i.e., moving also outside one's interaction field.

Complex	written but also including non-textual argumentation/communication, i.e., visual, installations, different performances; interaction field: involving/addressing different stakeholders and layers of the public not necessarily sharing the same goals and mutual commitments. In particular but not exclusively, involving and addressing marginalized/discriminated individuals/communities, disrupting structures of powers and/or distorted communication practices, i.e., addressing multiple interaction fields.

Table S5. Scholarly communication approach, Table by the author(s)

Sustainability of communication strategies

Production: Is the design of the output sustainable in terms of gender balance in authorship and geographical representation? Did the author(s) consider all the three pillars of sustainability? Did the author(s) involve virtually or otherwise different stakeholders, impacted audiences, underrepresented communities, in the creation of the output? Is the output open access? Is the aim of the output to dialog and convince peers of the validity of its claims or to present evidence also to the involved and impacted audiences? Are the means of communication verbal or complex? Does the involvement of different stakeholders require occasional participation in the achievement of the goals and of the proposed solutions or a long-term commitment?

Dissemination: Is the language used understandable to the audiences involved? Is the open access status sufficient on itself to reach outside of the scientific domain? Could the social media dissemination of the output as it is, be sufficient to reach a non-scientific/specialized audience? Is the dissemination process considered as a part of the overall communication endeavor?

Evaluation: Does the output consider the consequences and the impact of its findings on other societies, underrepresented communities and the public? Are reasonable and constructive arguments from involved and impacted audiences being considered and addressed? Are arguments and evidence accessible to a non-specialized/scientific audience?