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ARTICLE

The effect of scientific impact on science communication through art from the lens of deviance theories

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Abstract

Exploring the multifaceted relationship between scientific impact and science communication through art, our study surveys 2,500 Spanish artistic researchers. Guided by deviance theories and double standards theories we reveal a nuanced pattern: the effect of scientific impact initially impedes science communication through art, turning positive after a given impact threshold. Striking a harmonious science-art balance emerges as a mitigating factor, fostering broader links between science communication through art and scientific impact. Our findings advocate for targeted incentives to encourage science communication through art without compromising scientific impact, contributing to a deeper understanding of their complex interplay.

Keywords

Public engagement with science and technology; Public understanding of science and technology; Science and technology, art and literature

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1 ▪ Introduction

The promotion of public engagement with science is increasingly important in societies where technological innovation and scientific advances shape our daily life. Science communication plays a crucial role in promoting this process as it can provide clear and accessible explanations of scientific concepts and discoveries to the public [Besley, Dudo & Yuan, 2018], allowing people, scientists and institutions to make informed decisions on issues related to science, such as public health and environmental policy [Bubela et al., 2009]. Most importantly, it also encourages engagement and collaboration between scientists and the public, which can in turn lead to a more socially robust form of innovation and science, and to an increased social impact of science [Sætra, 2024; Weingart, Joubert & Connoway, 2021].

Science communication, however, is not a single, monolithic practice. There are different aims and approaches in science communication [Kappel & Holmen, 2019]. Science communication has been traditionally divided in two main general approaches: public outreach and public engagement [Bao et al., 2023; Entradas, 2022; Anzivino, 2021]. Drawing from the long criticized deficit model, public outreach was supposed to involve one-way communication from scientists to the public, with the aim of disseminating information, raising awareness and increasing scientific literacy among non-experts [Irwin & Wynne, 2012]. The deficit model, however, was fiercely criticized for framing the general public as a passive observer that need to be educated in scientific matters in order to be able to appreciate science and technological advances [Simis, Madden, Cacciatore & Yeo, 2016; Maia Loureiro & Horta, 2024].

Informed by the "dialogue model", public engagement conceived science communication as a relational activity, establishing a two-way communication process, involving the public in the design of research agendas and the evaluation of scientific practices and policies [Azagra-Caro & Boni, 2023; Rossi, Rosli & Yip, 2017]. However, the term "public engagement" has gone through significant changes, losing accuracy and becoming an umbrella term, whose definition may vary depending on the objectives, motivations, audience involved, type of activities conducted or stage of the research process in which it is promoted [Weingart et al., 2021].[1]

However, as Metcalfe [2022] powerfully argued, these models could not really exist independently from each other but they all struggled to solve a specific problem, i.e. the relationship between scientists and the public, or blame someone for the difficulties in finding a solution. In contrast, she advocates to embrace the chaos and messiness of science communication, drawing elements from all theorized science communication models to actually increase the chances of success. As she puts it: "*Scientists and publics play multiple roles; they can seek out and receive scientific knowledge; they can discuss and debate scientific knowledge; and they can determine and shape the direction of scientific knowledge*".

Metcalfe, actually, was not alone in claiming that the boundaries between outreach and engagement have become essentially blurred. Indeed, drawing on cultural theory, Davies,

1. A third model, the "participatory model", in which science is understood as one of several sources of knowledge, focuses more on participation and knowledge co-creation and set scientists and lay public more or less on equal foot. This model reconfigured lay public and citizens in general as active and knowledgeable actors in a variety of co-creation process in knowledge production and technological innovation [Stier & Smit, 2021; Yang, 2024].

Halpern, Horst, Kirby and Lewenstein [2019] have argued that science communication is a process of meaning-making where the creation process occurs through: 1) the mobilization of ideas about experience; 2) the framing of science communication through identity work; 3) science fiction and 4) paying attention to emotion. In their view, science communication is always entangled within, and itself shaping, cultural stories and meanings. As a result, they suggest moving beyond debates concerning 'deficit or dialogue' as the key frame for public communication of science. More recently, it has been argued that science communication is also a way to expand citizen science, increase the diversity of publics who engage in science communication endeavours and helps citizens to address social justice issues [Lorenz, 2020].

Interestingly, some initiatives bringing together scientists and local people to co-produce scientific knowledge through art installation or collective story telling exercises proved *at the same time* a process of creative knowledge production, and a successful strategy of science communication and outreach [Rios & Negrete, 2013; Stevens & O'Connor, 2015]. Other initiatives based on the hybridization between art and science, otherwise known as SciArt initiatives, have not only helped reconsidering the complexity and potentiality of science communication, they have also raised a growing interest in art as a key element in science communication and engagement [Halpern & Rogers, 2021; Parks & White, 2021; Reinsborough, 2020; Zaelzer, 2020; Lesen, Rogan & Blum, 2016]. Science communication through art has, thus, proved a powerful and effective way of engaging audiences, making scientific concepts more accessible and understandable and leading to innovation [Fritzsche & Dürrbeck, 2020]. Art also evokes emotions, stimulates creativity and provides a visual representation of complex scientific ideas [Marozzo, Crupi, Abbate, Cesaroni & Corvello, 2024]. By using artistic mediums such as paintings, sculptures, installations, films and performances, scientists and science communicators can create a bridge between science and the public and affect public perception of science [Muscio, 2023; Kirby, 2016; van Dijck, 2003].

Yet, art is not only a successful medium to communicate scientific contents but actually a space where new and shared knowledge may be created through a successful engagement between scientists and local people [Tingay, 2018]. In fact, the role of art in science communication cannot be limited to the dissemination phase: art can play a key role in actually co-producing scientific questions, methods and results. As a result, an open and collaborative interaction between science and art in the early research stage can contribute to an increased understanding of science communication in both research *and* society [Jonsson & Grafström, 2021]. While the use of theatre in science communication, for instance, has opened up a fertile space for negotiation and co-creation of knowledge [Parry, 2020], the use of poetry as a research tool or as a public engagement method has facilitated dialogue between scientists and publics and often levelled existing hierarchies between scientists and publics [Illingworth, 2022].

The ability of science communication through art to increase the societal impact of science, thus, has been largely acknowledged and studied. Yet, what do we know about its relationship with scientific impact? Over the past two decades, researchers have been increasingly subjected to systematic pressure to redouble both their scientific and societal impacts [Smit & Hessels, 2021; Rushforth & de Rijcke, 2015; Hicks, Wouters, Waltman, De Rijcke & Rafols, 2015; Bornmann, 2013]. Even if, in principle, scientists can simultaneously increase their social impact and their scientific impact, the actual relationship between these two aspects of the scientific endeavour remains understudied. The effect of achieving an ever-higher scientific impact on the actual effort to engage in science communication is not always clear-cut and has been the subject of some debate [Sanz Merino & Tarhuni Navarro, 2019; Neresini & Bucchi, 2011]. Some studies have found a positive relationship between scientific impact and engagement in public communication, suggesting that researchers with a higher scientific impact are also more likely to engage with the public [Shema, Bar-Ilan & Thelwall, 2012; Jensen, Rouquier, Kreimer & Croissant, 2008]. Conversely, other studies have found a negative or no relationship between scientific impact and science communication [Besley et al., 2018; Bubela et al., 2009]. Despite the effectiveness of art in engaging audiences and making scientific concepts accessible [Rios & Negrete, 2013], the interplay between science communication through art and traditional scientific impact remains, thus largely, unexplored.

In this paper we will, thus, try to cast some light on the effect of scientific impact on science communication through art and explore whether it changes along the academic ladder. To do so, we will address specifically a community of researchers that we define "artistic researchers". Interestingly, a recent study addresses the motivations and visions of science artists, who, according to the working definition, are artists who use scientific contents, ideas and methods to generate artistic works. It comes to the conclusions that scientists, institutions, funders, and other organizations seeking to support science artists or incorporate SciArt into public communication efforts should ensure they offer opportunities for creators to fulfil both internal and external goals. Doing so could be an important step towards supporting more mutually rewarding collaborations and, ultimately, a more vibrant SciArt landscape [Fleerackers, Brown Jarreau & Krolik, 2022]. In our study, we have decided to focus on the ideal counterpart: i.e. scientists who also produce artistic works. In our working definition, artistic researchers are scholars who primarily identify themselves as academics, who also pursue artistic endeavours [Lam, 2020; Caerols Mateo, Verdú Ruiz & Viñarás Abad, 2017]. They employ various forms of art like creative writing, visual arts or performing arts, potentially in science communication [Matias, Dias, Gonçalves, Vicente & Mena, 2021; Zaelzer, 2020; Reinsborough, 2020]. Indeed, several eminent academics often develop artistic work [Root-Bernstein & Root-Bernstein, 2013], with over half of the research population showing artistic inclinations, frequently involved in science communication [Azagra-Caro, Benito-Amat & Planells-Aleixandre, 2022]. Indeed, scholars like Leonardo da Vinci, Santiago Ramón y Cajal, Umberto Eco, Alexander Borodin, and Thor Heyerdahl, exemplify the enduring presence of artistic researchers across time and borders.

This paper, thus, aims at contributing to a deeper understanding of the relationship between science communication through art and scientific impact in four key ways. Firstly, it adopts a theoretical lens grounded in deviance theories to explain the unique challenges faced by artistic researchers in science communication through art. Unlike non-artistic science communication practices, scientific communication through art needs an artistic personality [Feist, 1998] and a more intensive institutional support through communication units. This may intensify conflicts with scientific impact, potentially labelling artistic researchers as deviating from the norm.

Secondly, we explore how the relationship between achieving scientific impact and involvement in science communication through art changes according to different levels of scientific impact.

Thirdly, we introduce the concept of a "science-art balance" — the equilibrium between scientific and artistic work. Peer acceptance of the artistic facet is crucial, as it facilitates the reconciliation of the researcher's dual identity [Chen, Zhang & Jin, 2023; Tiffany, Hautea, Besley, Newman & Dudo, 2022]. Measures leading to peer acceptance of the artistic facet are expected to alleviate potential contradictions between the logic of scientific impact and science communication through art.

Though we are aware of the blurring conceptual boundaries between public outreach and public engagement [Bao et al., 2023; Entradas, 2022; Anzivino, 2021], we explore separately the effects of scientific impact on these distinct communication approaches.

In the rest of the paper, we will, first, outline and discuss the existing literature on scientific impact and communication, then we will discuss our hypotheses, our method, our samples and the variables, and then, we will finally present and discuss the results and the implication for policy making.

2 ▪ Literature review

2.1 ▪ *The conflictive context of scientific impact*

The main mission of researchers is to increase and refine scientific knowledge in their respective fields. Due to a variety of changes in the governance of science, evaluation and metrics that occurred in the final decade of the twentieth century, scientists' performance in relation to this objective has often been measured through citation impact, H-index or similar indicators. These bibliometric indicators have become the standard way to measure scientific impact, i.e., the recognition by peers of one's research work. A higher citation index leads to greater prestige and promotion, which in turn tend to drive researchers' motivations. Peers and evaluators judge researchers according to their scientific impact, while policy documents at every level (from supranational to organisational) encourage researchers to focus on increasing their scientific impact. In this context, scientific impact, and the citation indexes used to measure it, have become a norm of science [Abbott et al., 2010].

While this norm quickly became a distinctive dimension of research activity, the way of evaluating and measuring it has evolved across time and space, with the science citation indexes elaborated by Web of Science (WoS) or Scopus being the most accepted ones [Archambault, Campbell, Gingras & Larivière, 2009]. Nevertheless, these indexes have been criticised for being too narrow, encouraging perverse behaviours and pushing science into controversial directions, at the expense of more exhaustive, complex, open and socially responsible forms of conducting, supporting or evaluating science [American Society for Cell Biology, 2012: DORA declaration, CoARA declaration]. As part of these growing critiques, increasing emphasis has also been given to a different type of impact that science should pursue: societal impact.[2] Whilst there is still a raging controversy about what societal impact means and how it could be measured [Bornmann, 2013], there is consensus on the idea that the production of scientific knowledge should not only circulate among scholars but also among other societal actors, including civil society organisations, business companies, public institutions and the lay public [Sivertsen & Meijer, 2020], encouraging processes of co-creation [De Silva, Gokhberg, Meissner & Russo, 2021]. While the debate on how to identify and measure societal impact may go on for years from now, the emphasis on an increased societal impact has reached both national, international and European funding

2. https://coara.eu/agreement/the-agreement-full-text/.

Figure 1. Conceptual approach to artistic researchers' public outreach and engagement without science-art balance.

agencies [Reale et al., 2018; Milotay, 2017]. Hence, science communication, including SciArt, has acquired a renewed importance for scientists as a means of achieving increased societal impact. Notably, though, increasing societal impact requires continued efforts and dedicated strategies to implement communication plans [Daneke, Priscoli & Garcia, 2019], which may, in turn, withdraw resources from other activities specifically devoted to increase their scientific impact. The following subsections will, thus, explore the links between scientific impact and science communication through art in more detail. Figure 1 may help to visualise the relationship.

2.2 ▪ *Scientific communication through art and its emerging dilemmas: initial negative relationship with scientific impact*

Within this context, public communication through art has gained a prominent position, sparking attention towards artistic researchers [Azagra-Caro et al., 2022; Lam, 2020; Caerols Mateo et al., 2017; Root-Bernstein & Root-Bernstein, 2013]. In the context of our research, we consider artistic researchers to be scholars who produce both scientific and artistic works. Often, they use their artistic works in the context of science communication, getting involved in SciArt. However, due to the ever-present pressure to achieve a higher citation index, artistic researchers find it difficult to carve out time and resources to engage in SciArt as much as they would potentially like. If standard evaluation processes in academia continue to emphasise scientific over societal impact, artistic researchers — and scholars in general — face the choice between scientific and societal impact, often reducing the resources available for science communication. If we look at this process from the perspective of deviance theories, deploying too many resources for science communication could be considered a violation of the norm, not formally (like a crime against the law), but informally (by breaking unwritten rules). Fostering science communication through art would therefore be an informal deviance, which then acquires a negative connotation and may get easily sanctioned [Erikson, 1962].

When researchers use their own art for scientific communication, signalling their artistic skills, they may be labelled as 'artistic' researchers. Although, a priori, this does not have a positive or negative connotation, labelling theory suggests that the dominant group — scientific peers — has the power to decide what the sign of the connotation is, according to the behaviour of the labelled person [Becker, 1963]. If the artistic researchers score low in scientific impact and high in science communication, scientific peers operating according to current dominant evaluation paradigms will be likely to rebuke this behaviour and thus attribute a negative connotation to the 'artistic' label. We know from stigma theory that this judgement does not need to be always true: artistic researchers could, in principle, increase their scientific impact *and* sustain their involvement in science communication through art [Goffman, 1963]. However, we also know that people may internalise stigmatising norms and behave accordingly: some artistic researchers may internalise the negative connotation of the label, assuming they will not be able to improve their scientific impact and at the same time sustain their involvement in science communication. The pursuit of scientific impact requires focus, depth and awareness of what other researchers and research stakeholders consider interesting at a very precise moment and fast reactions in the event of shifting interests. These arguments would suggest a negative relationship between scientific impact and science communication.

This effect will be higher if artistic researchers communicate their science through public engagement rather than public outreach, given the higher complexity of the former (supported by the "dialogue model" and establishing a two-way communication process) compared to the latter (informed by the "deficit model" and involving one-way communication). Public engagement activities involve complex interactions with different types of lay public and thus require extra resources. In this respect, public engagement requires a *deeper* commitment to science communication [in the sense of Laursen & Salter, 2006], the same as creativity research considers public diffusion as a sign of commitment to art [Carson, Peterson & Higgins, 2005]. Even more recent approaches, which criticise the distinction between these engagement and outreach in favour of a more complex and sophisticated approach of co-creation between science and art, emphasise the high amount of time and resources that science communication activities require, especially when scientists and lay people are called into shared, co-creative activities. A predominant focus on scientific impact, conversely, requires time and efforts that may be detracted from the *depth* of commitment to science communication, especially in this co-creative and engagement modalities, which may be perceived as negatively stigmatising vis-à-vis quality peers [Azagra-Caro, Fernández-Mesa & Robinson-García, 2020; Becker, 1963]. Consequently, we may expect scientific impact to be negatively related to science communication, public outreach and public engagement through art.

Hypothesis 1. Scientific impact is negatively related to science communication, public outreach and public engagement through art.

2.3 ▪ *Science communication and scientific impact: positive relationship beyond a threshold*

While the previous subsection explains a possible negative effect of scientific impact on science communication, other theoretical reasons exist which suggest a positive effect [Jensen et al., 2008]. First, scientific impact tends to grant researchers social and academic prestige, which attracts society's attention. Second, elite researchers are more legitimised to speak for their organisations, especially to the public. Third, for researchers who have proved to their peers the importance of their findings, a later challenge may be how to also convince the public. Fourth, researchers who enjoy scientific impact may spend more time on social networking with stakeholders, for the mere reason that they attract more collaborators. Actually, empirical studies have shown that variables related to scientific impact, such as h-index, academic productivity, age and seniority, increase the probability of being involved in science communication [Thune, Reymert, Gulbrandsen & Aamodt, 2016; Bentley & Kyvik, 2011; Jensen, 2011; Jensen et al., 2008]. As a result, there is a legitimate reason, endorsed by published evidence, to expect a positive relationship between scientific impact and science communication.[3]

These two views are at odds with each other (a positive and negative effect of scientific impact on science communication) unless the effect of scientific impact on science communication changes over time, that is, along the distinct stages of a researcher's career, when scholars have achieved various levels of scientific impact. The deviance literature also suggests that there may be non-linearities in the relationship between scientific impact and science communication through art. In other words, the notion of double standards raises the expectation of a negative relationship up to a certain threshold, beyond which a higher scientific impact will involve more efforts in science communication, i.e., a curvilinear U-shaped relationship [Fleerackers et al., 2022; Collver & Weitkamp, 2018]. Society often employs double standards, and so do researchers. People may judge what is acceptable in some groups as not acceptable in others [Foschi, 2000]. Similarly, scientific peers may see science communication through art as non-acceptable in certain researchers but acceptable in others, especially if there is a shared belief in a minimum threshold of acceptable scientific impact, which may discriminate between groups.

Once that threshold is passed, scientific impact can even be beneficial for artistic creation. High-quality researchers may have more to say about science and can communicate science through art without much extra effort. Their proven facility for scientifically impactful ideas may allow them to be more creative artistically [Root-Bernstein & Root-Bernstein, 2013; Root-Bernstein et al., 2008]. It may also be the case that prestige attracts numerous research collaborators, which may free time and resources for the star scientist, who may, in turn, devote more efforts to science communication through art. This is another dimension of the Matthew effect in scientific credit and recognition [Merton, 1968], academic entrepreneurship [Van Looy, Ranga, Callaert, Debackere & Zimmermann, 2004], science funding [Ranga, Perälampi & Kansikas, 2016; Bol, de Vaan & van de Rijt, 2018] and funding of science-society interaction [Azagra-Caro, Carat & Pontikakis, 2010].

For these reasons, we expect that science communication through art will show a similar U-shaped relationship with scientific impact, that is, an initial negative relationship which becomes positive beyond a certain threshold. Given the previously mentioned difference in requirements between public outreach and public engagement, we may expect public outreach activities to benefit more than public engagement when the U-shaped curve becomes positive.

Hypothesis 2. Scientific impact is positively related to science communication through art (both as public outreach through art and as public engagement through art) beyond a minimum quality threshold.

3. The opposite line of causality, from science communication to scientific impact, also suggests a positive association between both [Fleerackers et al., 2022; Bevan, Mejias, Rosin & Wong, 2021; Alonso-Flores, De Filippo, Serrano-López & Moreno-Castro, 2020; Alonso-Flores & Moreno-Castro, 2018; Lamb, Gilbert & Ford, 2018].

2.4 ▪ *Science-art balance as a mediator between scientific impact and science communication*

It is important to mention that the tension between science communication and scientific impact does not proceed from an essential incompatibility between the two activities; rather, it derives from context specific and contingent individual, professional, organisational and institutional reasons [Chen et al., 2023]. There are also other possible reasons leading artistic researchers not to get involved in science communication through art, e.g., because their artistic work is unrelated to their research lines, does not open up professional opportunities through competence signalling or needs to be hidden from colleagues or because it simply does not count as a merit [Azagra-Caro et al., 2020].

These reasons lie in the continuum between individual and social behaviour in which a group shapes its members' selves, according to social identity theory [Tajfel & Turner, 1979]. Social identity is the portion of an individual's self-concept derived from membership of a social group [Tajfel & Turner, 1986]. In the case of scientific communication through art, this would be the self-concept of artistic researchers (outgroup) derived from the larger population of researchers in which they are embedded (ingroup). As soon as the group determines a preference for the self-concept of the ingroup (a positive distinctiveness), there is conflict with the outgroup, which may feel discriminated against [Tajfel & Turner, 1979]. However, a group can reduce the degree of conflict by accepting the value of different self-concepts [Hackel, Zaki & Van Bavel, 2017; Johnson, Massiah & Allan, 2013]. Yet, if different and previously irreconcilable self-identities become accepted, or even complementary, in the eyes the group, a balance is achieved. This importantly allows all members of the group to maintain, foster and combine their different selves. In the case of scientific communication, we may call this acceptance *science-art balance*.

This name of the construct is inspired by that of work-life balance, the equilibrium between personal life and career work [Collver & Weitkamp, 2018; Jones, Burke & Westman, 2013]. By analogy, science-art balance is the equilibrium between scientific work and artistic activities, which, drawing from social identity theory, we define as the extent to which other researchers accept and positively value the social self of artistic researchers. Researchers certainly need social support to feel motivated [Tur-Porcar, Salas-Vallina & Azagra-Caro, 2024]. Encouraging the positive evaluation of all aspects of the scientific endeavour, and not just the publication outputs, the CoAra agreement on the reform of research assessment, signed in 2022 by hundreds of academic institutions worldwide, is an example of a significant movement in the direction of a science-art balance.[4]

When science-art balance is present, there is no conflict between scientific impact and science communication, and our former prediction of a U-shaped relationship between scientific impact and science communication will no longer hold. While in the absence of science-art balance the U-shaped relationship prevails, when science-art balance is introduced, the latter mediates the relationship between scientific impact and scientific communication (through art).

Hypothesis 3. Science-art balance mediates the relationship between scientific impact and science communication, public engagement or public outreach.

Figure 2 proposes the final model to be tested after including this mediation effect.

4. https://coara.eu/.

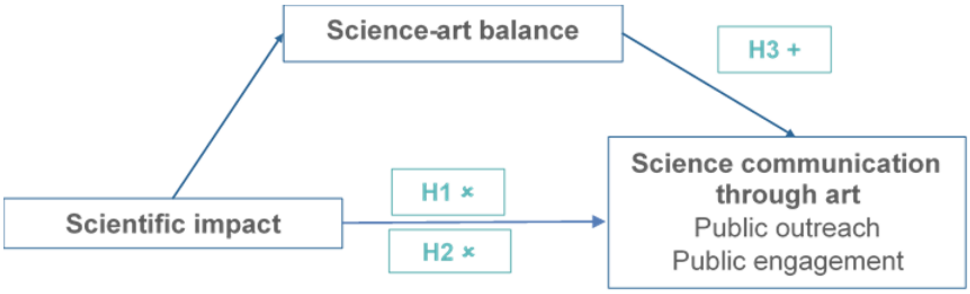

Figure 2. Conceptual approach to artistic researchers' public outreach and engagement with science-art balance.

3 ▪ Data and methods

The study population consists of Spanish researchers, defined as authors of scientific publications, affiliated to a Spanish organisation, and is taken from the corresponding authors on publications in the WoS from 2013 to 2016. The corresponding author is usually one of the lead authors and contributors to the content of the manuscript [Mattsson, Sundberg & Laget, 2011] or is perceived as such [Bhandari et al., 2014]. Editors appoint corresponding authors as reviewers [Weiss, 2012] and they are considered reliable sources of knowledge about the publication and the underlying research [Wren, Grissom & Conway, 2006]. Thus, corresponding authors match our concept of academic researcher, that is, academic regardless of organisation type, and the idea of researchers who identify as academic rather than artistic.

We gathered some 65,000 valid e-mails. To launch the survey, we obtained ethical certificates from our two mother organisations, CSIC and the Polytechnic University of Valencia. We ran a first pilot test in July 2017, a second pilot in April 2018, and the definitive survey was administered between July and November 2018. We received over 7,300 responses; that is, a response rate of 11% and a sample size with a 95% confidence level and a 1% margin of error, which is representative of the population.

The survey included a Short Creativity Achievement Questionnaire (SCAQ), adapted from Carson et al. [2005]. Respondents chose the art fields in which they had practised (see list and distribution of responses in Supplementary material Table A1). If they indicated a minimum of one, we considered them artistic researchers. A somewhat surprisingly 58% of the respondents developed artistic activities. Figure 3 illustrates their distribution by activity type, which clustered in three non-mutually exclusive groups: nearly half of artistic researchers engage in creative writing, one-third in visual arts, and a smaller portion in performing arts.

These artistic researchers had to voluntarily reply to two Science Through Art Questionnaires (STAQ I and II, see Supplementary material Table A2), based on the case study in Azagra-Caro et al. [2020]. A total of 2,543 respondents filled these in (59% of all artistic researchers), which conforms our sample.

The first questionnaire included four items on public outreach (the degree to which researchers incorporate scientific knowledge in their art), and the second included eight

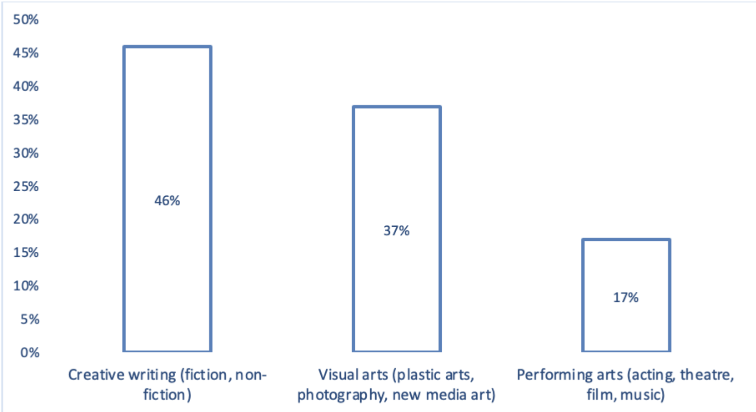

Figure 3. Types of artistic activities of academics (n = 7,352).

items on public engagement (the degree to which researchers diffuse scientific knowledge by word-of-mouth with art businesspeople, other artists and the public, or get ideas from them). All items were scored in a range between 1 and 5. Reliability was high with Cronbach's alphas of .89 and .85, respectively.

Our three dependent variables were *science communication through art* (mean of the 12 items of STAQ), *public outreach through art* (mean of the four items of STAQ I) and *public engagement through art* (mean of the eight items of STAQ II). The three dependent variables had continuous values but were constrained to the range of 1 to 5. To account for this censoring with lower and upper boundaries, we applied tobit regressions.

Our first independent variable was *scientific impact*, which addressed Hypothesis 1. We measured it as Field Normalised Citation Score (FNCS). In a first step, for each paper, we divided the number of forward citations (a two-year window: publication year and the following two years) by the average number of forward citations received by all Spanish papers in that thematic category and that year. For example, a paper published in 2016 received one citation in 2016, 2017 and 2018; this paper belongs to two categories: 'Mathematics, Applied' and 'Mathematics'; all Spanish papers published in 2016 in those two categories received an average of 1.25 and 0.97, respectively; the FNCS would be ((1/1.25) + (1/0.97))/2 = 0.91. In a second step, we grouped all the papers for every corresponding author and averaged the FNCS. Finally, because the distribution was unbalanced, we transformed it into quartiles, so the final variable ranged between 1 and 4.

Our second independent variable was *scientific impact squared* to account for non-linearities in the effects of scientific impact, which addressed Hypothesis 2.

The mediating variable was *science-art balance*, which ranged from 1 to 7, and addressed Hypothesis 3. The survey contained an eight-item questionnaire on the extent to which respondents had integrated art in their scientific profession (see Supplementary material Table A3), based on nominative statements from the qualitative research in Azagra-Caro et al. [2020], e.g. "I try to make colleagues aware of my artistic facet". Reliability was high and significantly improved with the elimination of three items (Cronbach's alpha $= .85$). The variable was the average of the five remaining components. The mean value of 2.89 (Table 1) indicated that the science-art balance was low in the sample, compared to the median of 4.

Table 1. Artistic researchers: descriptive statistics of variables.

Sample	*Role*	*Level*	*Variable name*	*Description/Explanation*	*Mean*	*Std. Dev.*	*Min.*	*Max.*
Full sample (n = 2,543)	Dependent variables	Individual	Science communication through art	Degree of involvement in either public outreach or engagement of artistic researchers	1.71	0.69	1.00	4.50
			Public outreach through art	Degree to which researchers incorporate scientific knowledge in their art	2.15	1.20	1.00	5.00
			Public engagement through art	Degree to which researchers diffuse scientific knowledge by word-of-mouth with art businesspeople, other artists and the public, or get ideas from them	1.49	0.59	1.00	4.62
	Independent variables		Scientific impact (H1)	Average Field Normalised Citation Score of the researcher's publications, grouped in 4 quartiles	2.42	1.12	1.00	4.00
			Scientific impact squared (H2)		7.11	5.61	1.00	16.00
	Mediating variable		Science-art balance (H3)	Degree to which researchers positively combine their research and artistic facets	2.89	1.40	1.00	7.00
	Control variables	Institutional	Multidisciplinarity	Number of science fields	1.31	0.46	1.00	2.00
			Science field	Medicine	0.20	0.38	0.00	1.00
				Life Sciences	0.14	0.33	0.00	1.00
				Other Natural Sciences	0.19	0.37	0.00	1.00
				Engineering	0.10	0.28	0.00	1.00
				Art and Literature (Social Sciences and Humanities is the benchmark)	0.04	0.18	0.00	1.00
			Region of residence	Madrid	0.24	0.43	0.00	1.00
				Barcelona	0.10	0.30	0.00	1.00
				Valencia ('other Spanish regions' is the benchmark)	0.08	0.27	0.00	1.00
			Foreign residence	Non-Spanish residence	0.08	0.28	0.00	1.00
		Sociodemographic	University researcher	At least one university affiliation	0.51	0.50	0.00	1.00
			Woman researcher	Sex of the researcher	0.41	0.49	0.00	1.00
			Age	Number of years	46.39	10.52	18.00	97.00
			Foreign nationality	'Spanish only' is the benchmark	0.09	0.29	0.00	1.00
			Non-Spanish first language	'Spanish only' is the benchmark	0.25	0.43	0.00	1.00
			Ph.D.	Ph.D. title	0.88	0.33	0.00	1.00
			Married or domestic partner	'Couple or single' is the benchmark	0.60	0.49	0.00	1.00
			Number of children underage	Father/motherhood	0.73	0.95	0.00	5.00
		Professional	Employed	Yes/no (unemployed)	0.95	0.21	0.00	1.00
Working for others or for others and self (n = 2,347)		Organisational	Number of organisations	Multiple affiliation	1.23	0.54	1.00	5.00
			Directive position	Yes/no	0.28	0.43	0.00	1.00
			Public organisation	Yes/no	0.82	0.36	0.00	1.00

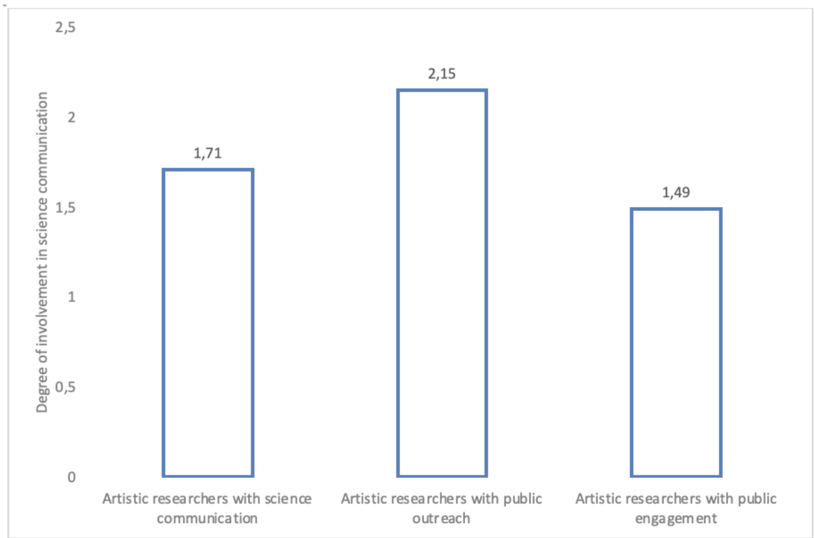

Figure 4. Degree of involvement of artistic researchers in science communications (n = 2,543).

For the full sample of researchers, we controlled for a wide range of institutional (science field, country and region of residence), sociodemographic (university affiliation, sex, age, nationality, language, education, civil status, number of children), occupational (employment situation and type) and organisational (number of organisations, ownership regime, directive positions) variables. Table 1 presents the descriptive statistics and Supplementary material Tables A4 and A5 the correlations. The final sample excluded outliers of some of these controls, e.g., abnormally high age or large number of children.

4 ▪ Results

4.1 ▪ *Descriptive results*

As Figure 4 indicates, the average value of science communication through art is 1.7. Given that it is below the median of 2.5, it suggests that science communication through art deviates from the academic norm and is not frequent. Within this low general level, the average value of public outreach is higher than of public engagement. This is consistent with the idea that public engagement deviates even further from the norm than public outreach.

Figure 5 shows that artistic researchers involved in either public outreach or engagement score lower in scientific impact, in agreement with Hypothesis 1.

4.2 ▪ *Main regression results*

Table 2 presents the results for estimating researchers' involvement in science communication through art. Columns 1–3 include regressions without the mediating variable, science-art balance. Scientific impact conflicts with science communication, public outreach and engagement. Hence, according to this finding, at least up to a certain threshold, scientific impact is detrimental to science communication, through either public outreach or engagement, which supports Hypothesis 1.

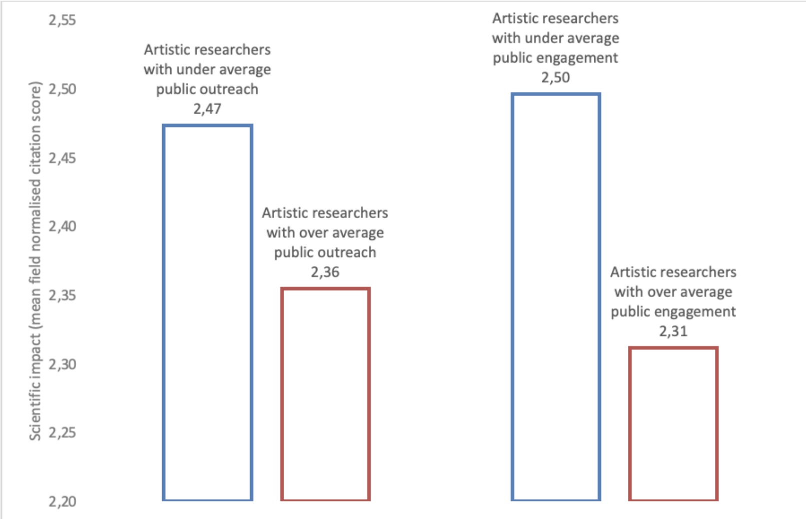

Figure 5. Scientific impact by type of science communication, under and over average (n = 2,543). Mean-comparison t tests indicate significant differences of scientific impact between groups.

There is a positive curvilinear effect of scientific impact on science communication and public outreach. Hence, both have a positive relationship with scientific impact beyond a certain threshold, which partially supports Hypothesis 2. The lack of a square effect of scientific impact on public outreach suggests that not even the mechanism of double standards can counterbalance the larger amount of resources required by public engagement compared with public outreach.

Testing the mediation of science-art balance requires two steps [Mihalache, Jansen, Van den Bosch & Volberda, 2014; Baron & Kenny, 1986]. First, we need to estimate science-art balance as a function of scientific impact. That the estimated effect is significant is a precondition for mediation. Column 4 shows that this is the case: scientific impact has a negative, significant effect on science-art balance.

Hence, we can proceed to add science-art-balance as an independent variable in columns 5–7, again with science communication, public outreach and engagement as dependent variables. Science-art-balance enters with a positive and significant coefficient, meaning than it fosters all types of science communication. Its inclusion also removes the significance of the linear and quadratic terms of scientific impact.

The only exception is that squared scientific impact has a significant effect on public outreach. However, it does not deserve much discussion because the effect is borderline significant and because after the robustness checks in the next sub-section, it is no longer significant. We can conclude that the evidence supports Hypothesis 3.

Among the control variables, age is beneficial, whereas being a woman is unfavourable for science communication, public outreach and engagement. Belonging to the field of Art and Literature, living abroad and holding a Ph.D. are all beneficial conditions for science communication, either public outreach or engagement. Multidisciplinarity, region, university affiliation, foreign nationality, not having Spanish as a first language, being married and having several children are not important before introducing the science-art balance variable. University affiliation and not having Spanish as a first language increase their positive

Table 2. Tobit regression of science communication through art (n = 2,543).

	1 *Science communication*	2 *Public outreach*	3 *Public en-gagement*	4 *Science-art balance*	5 *Science communication*	6 *Public outreach*	7 *Public en-gagement*
Scientific impact (H1)	-0.04^{***}	-0.08^{**}	-0.04^{**}	-0.10^{***}	-0.01	-0.01	-0.01
	(0.02)	(0.04)	(0.02)	(0.03)	(0.01)	(0.03)	(0.01)
Scientific impact squared (H2)	0.03^{*}	0.09^{**}	0.02	0.02	0.02	0.06^{*}	0.01
	(0.02)	(0.04)	(0.02)	(0.03)	(0.01)	(0.03)	(0.01)
Science-art balance (H3)					0.36^{***}	0.76^{***}	0.29^{***}
					(0.01)	(0.02)	(0.01)
Multidisciplinarity	0.04	0.07	0.06	0.11	0.01	0.02	0.03
	(0.04)	(0.09)	(0.04)	(0.08)	(0.03)	(0.07)	(0.03)
Medicine	-0.46^{***}	-0.78^{***}	-0.45^{***}	-0.60^{***}	-0.25^{***}	-0.33^{***}	-0.29^{***}
	(0.06)	(0.14)	(0.06)	(0.12)	(0.05)	(0.11)	(0.05)
Life Sciences	-0.23^{***}	-0.12	-0.33^{***}	-0.32^{**}	-0.13^{***}	0.10	-0.25^{***}
	(0.06)	(0.15)	(0.06)	(0.13)	(0.05)	(0.11)	(0.06)
Other Natural Sciences	-0.37^{***}	-0.64^{***}	-0.35^{***}	-0.44^{***}	-0.22^{***}	-0.28^{***}	-0.22^{***}
	(0.06)	(0.13)	(0.06)	(0.12)	(0.04)	(0.10)	(0.05)
Engineering	-0.53^{***}	-1.04^{***}	-0.46^{***}	-0.49^{***}	-0.35^{***}	-0.64^{***}	-0.32^{***}
	(0.07)	(0.17)	(0.08)	(0.14)	(0.05)	(0.13)	(0.06)
Art and Literature	0.29^{***}	0.27	0.36^{***}	0.45^{**}	0.13	-0.08	0.24^{**}
	(0.11)	(0.21)	(0.11)	(0.22)	(0.08)	(0.18)	(0.09)
Madrid	-0.02	0.01	-0.04	-0.06	0.01	0.07	-0.02
	(0.04)	(0.10)	(0.04)	(0.08)	(0.03)	(0.07)	(0.04)
Barcelona	-0.06	-0.25^{*}	-0.01	-0.04	-0.04	-0.17	0.01
	(0.06)	(0.14)	(0.05)	(0.11)	(0.04)	(0.11)	(0.05)
Valencia	0.07	0.09	0.06	0.04	0.06	0.07	0.06
	(0.06)	(0.14)	(0.07)	(0.12)	(0.05)	(0.11)	(0.06)
Foreign residence	0.11^{*}	0.11	0.15^{**}	0.05	0.10^{**}	0.09	0.15^{**}
	(0.06)	(0.15)	(0.07)	(0.12)	(0.05)	(0.12)	(0.06)
University researcher	0.02	0.09	-0.01	-0.09	0.04	0.13^{**}	0.01
	(0.04)	(0.08)	(0.04)	(0.07)	(0.03)	(0.07)	(0.03)
Woman researcher	-0.19^{***}	-0.34^{***}	-0.18^{***}	-0.18^{***}	-0.12^{***}	-0.19^{***}	-0.13^{***}
	(0.04)	(0.08)	(0.04)	(0.07)	(0.03)	(0.06)	(0.03)
Age	0.01^{***}	0.01^{***}	0.01^{***}	-0.01^{*}	0.01^{***}	0.02^{***}	0.01^{***}
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Foreign nationality	-0.01	-0.04	-0.00	-0.02	-0.00	-0.03	-0.00
	(0.06)	(0.14)	(0.06)	(0.12)	(0.05)	(0.11)	(0.05)
Non-Spanish first language	0.03	0.05	0.03	-0.08	0.06^{**}	0.12^{*}	0.06^{*}
	(0.04)	(0.09)	(0.04)	(0.08)	(0.03)	(0.07)	(0.03)
Ph.D.	0.12^{**}	0.27^{**}	0.07	-0.10	0.14^{***}	0.32^{***}	0.10^{**}
	(0.05)	(0.12)	(0.06)	(0.10)	(0.04)	(0.10)	(0.05)
Married or domestic partner	-0.05	-0.05	-0.06	-0.11	-0.01	0.02	-0.03
	(0.04)	(0.09)	(0.04)	(0.07)	(0.03)	(0.07)	(0.03)
Number of underage children	-0.02	0.02	-0.03	-0.03	-0.01	0.02	-0.03
	(0.02)	(0.04)	(0.02)	(0.04)	(0.01)	(0.03)	(0.02)
Employed	-0.05	-0.15	-0.02	-0.11	0.00	-0.04	0.01
	(0.08)	(0.18)	(0.08)	(0.16)	(0.06)	(0.14)	(0.07)
Constant	1.39^{***}	1.30^{***}	1.04^{***}	3.63^{***}	0.06	-1.43^{***}	0.01
	(0.14)	(0.31)	(0.14)	(0.27)	(0.11)	(0.26)	(0.12)
F	13	8	12	5	92	74	41
p	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pseudo R^2	0.05	0.02	0.05	0.01	0.26	0.16	0.17

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors in parenthesis. No multicollinearity according to VIF.

influence after introducing the science-art balance variable, but the fact that none of these variables have significant effects on science-art balance (column 4) implies that mediation is not taking place.

4.3 ▪ *Robustness tests*

The sample used so far includes all types of professional situations. The bulk consists of employed researchers working for others, but there are some unemployed or independent researchers. The survey asked some information exclusively to employed researchers working for others: number of organisations, occupation of a directive position and ownership regime of their organisations. This defined a subsample with more control variables. We performed a robustness check by applying the models in this subsample.

In Table 3, columns 1–4 contain the results (we show the results on public outreach and engagement for economy of space). The sign and significance of the independent and mediating variables remains the same, so the hypotheses hold.

Two new control variables exert a positive, significant influence on public engagement: working in several organisations and holding a directive position. Both are related to researchers' power, and their positive effect is consistent with the theory (underlying our hypotheses) that power facilitates deviance from the norm and thus allows for science communication.

In both the full sample and this subsample, many control variables are not significant. Including them in the regression may confound the significance of other parameters. To check the robustness of the results, Table 3, columns 5–8 show a stepwise estimation of the tobit models that removes insignificant variables progressively. The hypothesis testing is still unchanged.

We also tried alternative specifications of the model. We considered a sample selection model where, first, artistic researchers choose to either communicate science or not, and then their degree of involvement in science communication. The results indicate that the two decisions are independent; therefore, there is no sample selection bias.

We accounted for the possibility that public outreach and engagement decisions are correlated by running a multivariate regression. This is not a preferred estimation because it does not account for the censored nature of the variables and does not allow for the computation of robust standard errors. However, even if under these conditions the results hold, it constitutes a sort of robustness check. This is the case: the hypotheses are still verified. The results also suggest that both decisions (public outreach and engagement) are correlated.

5 ▪ Conclusions

In an increasingly complex research assessment context, where both scientific impact and societal impact are highly valued and being pursued, we may expect a tension between the two, given that time and resources are limited and scientists, thus, may be required to choose one over the other. Despite a growing literature on the rising importance of science communication through art (SciArt) to achieve higher societal impact, little is known about the relationship between SciArt and scientific impact. Drawing from deviance theories (notably labelling, stigma and double standards theories) and social identity theory, and supported by a large-scale quantitative survey evidence, our paper contributes to fill this gap by theoretically and empirically demonstrating a U-shaped curvilinear effect of scientific impact of researchers on science communication through art.

Specifically, as anticipated, we observe a negative relationship between scientific impact and scientific communication through art at lower scientific impact level, evolving into a positive relationship as researchers improve their scientific impact. Senior researchers, driven by

Table 3. Tobit regression of science communication through art: employed researchers and stepwise estimation (n = 2,347).

	1 *Public outreach*	2 *Public engagement*	3 *Public outreach*	4 *Public engagement*	5 *Public outreach*	6 *Public engagement*	7 *Public outreach*	8 *Public engagement*
Scientific impact (H1)	-0.07^{*}	-0.03^{**}	-0.00	-0.01	-0.08^{**}	-0.03^{*}		
	(0.04)	(0.02)	(0.03)	(0.01)	(0.04)	(0.02)		
Scientific impact squared (H2)	0.08^{**}	0.01	0.05	0.00	0.09^{**}			
	(0.04)	(0.02)	(0.03)	(0.01)	(0.04)			
Science-art balance (H3)			0.78^{***}	0.28^{***}			0.78^{***}	0.28^{***}
			(0.02)	(0.01)			(0.02)	(0.01)
Multidisciplinarity	0.07	0.05	0.01	0.03				
	(0.10)	(0.04)	(0.07)	(0.03)				
Medicine	-0.75^{***}	-0.42^{***}	-0.34^{***}	-0.28^{***}	-0.79^{***}	-0.48^{***}	-0.37^{***}	-0.31^{***}
	(0.15)	(0.06)	(0.12)	(0.05)	(0.12)	(0.06)	(0.09)	(0.05)
Life Sciences	-0.07	-0.28^{***}	0.08	-0.23^{***}		-0.32^{***}		-0.25^{***}
	(0.16)	(0.07)	(0.12)	(0.06)		(0.06)		(0.05)
Other Natural Sciences	-0.56^{***}	-0.28^{***}	-0.26^{**}	-0.18^{***}	-0.59^{***}	-0.32^{***}	-0.32^{***}	-0.21^{***}
	(0.14)	(0.06)	(0.11)	(0.05)	(0.11)	(0.05)	(0.09)	(0.05)
Engineering	-1.00^{***}	-0.41^{***}	-0.64^{***}	-0.29^{***}	-1.01^{***}	-0.43^{***}	-0.69^{***}	-0.31^{***}
	(0.18)	(0.08)	(0.13)	(0.07)	(0.16)	(0.07)	(0.12)	(0.06)
Art and Literature	0.25	0.37^{***}	-0.05	0.26^{***}		0.36^{***}		0.27^{***}
	(0.24)	(0.12)	(0.20)	(0.10)		(0.12)		(0.10)
Madrid	0.01	-0.06	0.07	-0.04		-0.07^{*}		
	(0.10)	(0.04)	(0.08)	(0.04)		(0.04)		
Barcelona	-0.31^{**}	-0.05	-0.22^{*}	-0.03	-0.30^{**}		-0.24^{**}	
	(0.15)	(0.06)	(0.12)	(0.05)	(0.13)		(0.11)	
Valencia	0.12	0.08	0.09	0.07				
	(0.15)	(0.07)	(0.12)	(0.06)				
Foreign residence	0.15	0.17^{**}	0.06	0.14^{**}		0.18^{***}		0.14^{**}
	(0.17)	(0.07)	(0.13)	(0.06)		(0.07)		(0.06)
University researcher	0.18^{**}	0.01	0.17^{**}	0.01	0.18^{**}		0.15^{**}	
	(0.09)	(0.04)	(0.07)	(0.03)	(0.09)		(0.07)	
Woman researcher	-0.31^{***}	-0.16^{***}	-0.18^{***}	-0.12^{***}	-0.30^{***}	-0.16^{***}	-0.19^{***}	-0.12^{***}
	(0.09)	(0.04)	(0.07)	(0.03)	(0.08)	(0.04)	(0.07)	(0.03)
Age	0.01^{***}	0.01^{***}	0.02^{***}	0.01^{***}	0.01^{***}	0.01^{***}	0.02^{***}	0.01^{***}
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Foreign nationality	-0.10	-0.02	-0.04	0.00				
	(0.16)	(0.06)	(0.12)	(0.06)				
Non-Spanish first language	0.05	0.03	0.13^{*}	0.06^{*}			0.13^{*}	0.07^{**}
	(0.10)	(0.04)	(0.08)	(0.04)			(0.07)	(0.03)
Ph.D.	0.25^{*}	0.06	0.31^{***}	0.09^{*}	0.26^{**}		0.31^{***}	0.09^{*}
	(0.13)	(0.06)	(0.10)	(0.05)	(0.13)		(0.10)	(0.05)
Married or domestic partner	-0.05	-0.07^{*}	0.02	-0.04		-0.09^{**}		
	(0.09)	(0.04)	(0.07)	(0.03)		(0.04)		
Number of underage children	0.01	-0.03	0.01	-0.02				-0.03^{**}
	(0.05)	(0.02)	(0.03)	(0.02)				(0.02)
Number of organisations	0.12	0.12^{***}	0.04	0.09^{***}	0.13^{*}	0.12^{***}		0.08^{***}
	(0.08)	(0.03)	(0.06)	(0.03)	(0.07)	(0.03)		(0.03)
Directive position	0.10	0.14^{***}	0.07	0.13^{***}		0.15^{***}		0.13^{***}
	(0.10)	(0.04)	(0.08)	(0.03)		(0.04)		(0.03)
Public organisation	-0.15	-0.01	-0.07	0.01				
	(0.12)	(0.05)	(0.09)	(0.04)				
Constant	0.95^{***}	0.89^{***}	-1.52^{***}	-0.02	0.99^{***}	0.98^{***}	-1.37^{***}	0.03
	(0.31)	(0.14)	(0.25)	(0.12)	(0.24)	(0.10)	(0.20)	(0.10)
F	7	10	63	35	15	18	150	59
p	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pseudo R^2	-0.07^{*}	-0.03^{**}	-0.00	-0.01	-0.08^{**}	-0.03^{*}		

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors in parenthesis. No multicollinearity according to VIF. Columns 5–8: Stepwise estimation.

factors such as prestige, power, and collaborative support, are more likely to find spaces where scientific impact and communication mutually reinforce each other. Notably, this pattern holds true for public outreach through art but it does not apply to the more demanding and sophisticated public engagement through art. We wonder, though, whether this may be different in some specific academic disciplines or controversial research topics which facilitate the adoption of public engagement activities, for example social science research or research topics connected to GMOs, AI or the biobased economy. We cannot, however, address this hypothesis here, which is certainly a limitation of this paper, but we consider that this specific issue requires further studies.

Introducing the concept of a “science-art balance” as a mediating factor, we found that this balance turns the relationship positive at every level of scientific impact, extending to public engagement through art. These outcomes, especially the existence of a U-shaped curvilinear effect of scientific impact on science communication through art, offer valuable insights and present several recommendations.

Meeting current policy targets for fostering science communication would be impossible unless we made the pursuit of scientific impact compatible with science communication at every stage of the academic career, not only during its last part. This initiative entails some controversial implications, such as the implementation of specific measures to diminish power differences based on scientific impact and to encourage a balanced integration of science and art. Peer recognition of science communication through art as a merit in researchers’ curricula, among a mix of incentives, can vigorously support science communication through art. A collateral finding is that even as science communication, and especially SciArt, evolves and becomes increasingly framed as an activity that goes beyond a mere dialogue between scientists and lay public into a more sophisticated approach aiming at establishing fertile co-creation dynamics generating new forms of knowledge, it still requires a very high amount of time and resources, which very few academics can afford to dedicate to communication activities.

One important implication of our findings, thus, is that policymakers and funding agencies should encourage researchers with lower scientific impact to engage in science communication through art by providing resources, training, and recognition for their efforts. This support can potentially increase the visibility and impact of their research, without diverting significant time and resources. Similarly, measures should be developed to inspire or support high-impact researchers to engage in science communication through art, and especially in both public engagement and co-creation activities.

Beyond these academic related initiatives, these findings suggest that it would important to design specific programmes to further bridge the gap between the scientific community and the public, by encouraging co-creation dynamics between researchers and different stakeholders, increasing public literacy in science *and* making science more responsible, open, effective and socially robust. The combined effect of a) providing resources and recognition to artistic researchers with lower impact to increase the impact of their research, b) providing support and incentive to high impact researchers to engage in science communication through art and c) generally supporting more interaction between researchers and the different social stakeholders could, in turn, lead not only to an increased effectiveness of public engagement with science, improving science literacy and evidence-based policy decisions, but also to more socially innovative, responsible and ambitious scientific research.

Since the data stems from Spanish artistic researchers, the generalizability of the findings in other contexts should be a line of future research. The culture of scientific impact is deeply embedded in the research system [Delgado-López-Cózar, Ràfols & Abadal, 2021; Cañibano, Vilardell, Corona & Benito-Amat, 2018]. The Spanish six-year research awards (sexenia) are based on journal impact factor and citation impact, and then sexenia-based indicators (e.g., ratio of actual versus potential sexenia) are used for promotion and funding. Publishing in first quartile journals has been a must for researchers now in their 40 or 50's (the average age of survey respondents), and a crucial threshold for feeling and being respected by peers. Concerns about societal impact are, thus, very recent in Spain. Hence, the results may be typical of countries like Spain, where scientific impact heavily influences promotion, and researchers experience more stress or pressure, especially if the evaluation process is highly quantitative, and may, thus, not be generalizable.

Last but not least, our study also opens avenues for exploring the impact of support from home organizations in facilitating researchers' outreach and engagement through art. Some institutions may employ communication specialists who assist in disseminating artistic findings to the public. While we controlled for organizational diversity by distinguishing between universities and other affiliations in our control variables, future research could employ more refined measurements and place greater emphasis on investigating this specific aspect.

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References

Abbott, A., Cyranoski, D., Jones, N., Maher, B., Schiermeier, Q. & Van Noorden, R. (2010). Do metrics matter? *Nature 465* (7300), 860–862. doi:10.1038/465860a

Alonso-Flores, F.-J., De Filippo, D., Serrano-López, A.-E. & Moreno-Castro, C. (2020). Contribución de la comunicación institucional de la investigación a su impacto y visibilidad. Caso de la Universidad Carlos III de Madrid. *Profesional de la Información 29* (6), e290633. doi:10.3145/epi.2020.nov.33

Alonso-Flores, J. & Moreno-Castro, C. (2018). Does science communication enhance researcher impact? A survey among scientists at Spanish universities. *Journal of Education & Social Policy 5* (2), 34–44. Retrieved from https://www.jespnet.com/journals/Vol_5_No_2_June_2018/5.pdf

American Society for Cell Biology (2012). *San Francisco declaration on research assessment (DORA): putting science into the assessment of research*. Retrieved from https://www.ascb.org/files/SFDeclarationFINAL.pdf

Anzivino, M. (2021). Is public engagement gendered? An analytical proposal using some evidence from Italy. *Public Understanding of Science 30* (7), 827–840. doi:10.1177/09636625211002060

Archambault, É., Campbell, D., Gingras, Y. & Larivière, V. (2009). Comparing bibliometric statistics obtained from the Web of Science and Scopus. *Journal of the American Society for Information Science and Technology 60* (7), 1320–1326. doi:10.1002/asi.21062

Azagra-Caro, J. M., Benito-Amat, C. & Planells-Aleixandre, E. (2022). Academic artists' engagement and commercialisation. *The Journal of Technology Transfer 47* (4), 1273–1296. doi:10.1007/s10961-022-09940-2

Azagra-Caro, J. M. & Boni, A. (2023). Enlarging the knowledge transfer realm through engagement with research stakeholders: a conversation attempt with action research. *Tapuya: Latin American Science, Technology and Society 6* (1). doi:10.1080/25729861.2023.2213596

Azagra-Caro, J. M., Carat, G. & Pontikakis, D. (2010). Inclining the columns to make the temple look straight: a first glance at monetary indicators on university-industry cooperation. *Research Evaluation 19* (2), 119–128. doi:10.3152/095820210X510115

Azagra-Caro, J. M., Fernández-Mesa, A. & Robinson-García, N. (2020). 'Getting out of the closet': scientific authorship of literary fiction and knowledge transfer. *The Journal of Technology Transfer 45* (1), 56–85. doi:10.1007/s10961-018-9672-6

Bao, L., Calice, M. N., Brossard, D., Beets, B., Scheufele, D. A. & Rose, K. M. (2023). How institutional factors at US land-grant universities impact scientists' public scholarship. *Public Understanding of Science 32* (2), 124–142. doi:10.1177/09636625221094413

Baron, R. M. & Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology 51* (6), 1173–1182. doi:10.1037//0022-3514.51.6.1173

Becker, H. S. (1963). *Outsiders: studies in the sociology of deviance*. New York, NY, U.S.A.: The Free Press.

Bentley, P. & Kyvik, S. (2011). Academic staff and public communication: a survey of popular science publishing across 13 countries. *Public Understanding of Science 20* (1), 48–63. doi:10.1177/0963662510384461

Besley, J. C., Dudo, A. & Yuan, S. (2018). Scientists' views about communication objectives. *Public Understanding of Science 27* (6), 708–730. doi:10.1177/0963662517728478

Bevan, B., Mejias, S., Rosin, M. & Wong, J. (2021). The main course was mealworms: The epistemics of art and science in public engagement. *Leonardo 54* (4), 456–461. doi:10.1162/leon_a_01835

Bhandari, M., Guyatt, G. H., Kulkarni, A. V., Devereaux, P. J., Leece, P., Bajammal, S., … Busse, J. W. (2014). Perceptions of authors' contributions are influenced by both byline order and designation of corresponding author. *Journal of Clinical Epidemiology 67* (9), 1049–1054. doi:10.1016/j.jclinepi.2014.04.006

Bol, T., de Vaan, M. & van de Rijt, A. (2018). The Matthew effect in science funding. *Proceedings of the National Academy of Sciences 115* (19), 4887–4890. doi:10.1073/pnas.1719557115

Bornmann, L. (2013). What is societal impact of research and how can it be assessed? A literature survey. *Journal of the American Society for Information Science and Technology 64* (2), 217–233. doi:10.1002/asi.22803

Bubela, T., Nisbet, M. C., Borchelt, R., Brunger, F., Critchley, C., Einsiedel, E., … Caulfield, T. (2009). Science communication reconsidered. *Nature Biotechnology 27*, 514–518. doi:10.1038/nbt0609-514

Caerols Mateo, R., Verdú Ruiz, S. & Viñarás Abad, M. (2017). Arts in higher education: an evaluation of fine arts research activity in Spain through quality indicators. *Revista Española de Documentación Científica 40* (4), e191. doi:10.3989/redc.2017.4.1394

Cañibano, C., Vilardell, I., Corona, C. & Benito-Amat, C. (2018). The evaluation of research excellence and the dynamics of knowledge production in the humanities: the case of history in Spain. *Science and Public Policy 45* (6), 775–789. doi:10.1093/scipol/scy025

Carson, S. H., Peterson, J. B. & Higgins, D. M. (2005). Reliability, validity, and factor structure of the creative achievement questionnaire. *Creativity Research Journal 17* (1), 37–50. doi:10.1207/s15326934crj1701_4

Chen, A., Zhang, X. & Jin, J. (2023). The Sagan effect and scientists' public outreach participation in China: multilayered roles of social norms and rewards. *Science Communication 45* (1), 12–38. doi:10.1177/10755470221143077

Collver, J. & Weitkamp, E. (2018). Alter egos: an exploration of the perspectives and identities of science comic creators. *JCOM 17* (01), A01. doi:10.22323/2.17010201

Daneke, G., Priscoli, J. D. & Garcia, M. (2019). *Public involvement and social impact assessment*. New York, NY, U.S.A.: Routledge. doi:10.4324/9780429303432

Davies, S. R., Halpern, M., Horst, M., Kirby, D. & Lewenstein, B. (2019). Science stories as culture: experience, identity, narrative and emotion in public communication of science. *JCOM 18* (05), A01. doi:10.22323/2.18050201

De Silva, M., Gokhberg, L., Meissner, D. & Russo, M. (2021). Addressing societal challenges through the simultaneous generation of social and business values: a conceptual framework for science-based co-creation. *Technovation 104*, 102268. doi:10.1016/j.technovation.2021.102268

Delgado-López-Cózar, E., Ràfols, I. & Abadal, E. (2021). A call for a radical change in research evaluation in Spain. *Profesional de la Información 30* (3), e300309. doi:10.3145/epi.2021.may.09

Entradas, M. (2022). Public communication at research universities: moving towards (de)centralised communication of science? *Public Understanding of Science 31* (5), 634–647. doi:10.1177/09636625211058309

Erikson, K. T. (1962). Notes on the sociology of deviance. *Social Problems 9* (4), 307–314. doi:10.2307/798544

Feist, G. J. (1998). A meta-analysis of personality in scientific and artistic creativity. *Personality and Social Psychology Review 2* (4), 290–309. doi:10.1207/s15327957pspr0204_5

Fleerackers, A., Brown Jarreau, P. & Krolik, J. (2022). Why create SciArt? An investigation into science artists' goals and professional journeys. *JCOM 21* (06), A05. doi:10.22323/2.21060205

Foschi, M. (2000). Double standards for competence: theory and research. *Annual Review of Sociology 26*, 21–42. doi:10.1146/annurev.soc.26.1.21

Fritzsche, A. & Dürrbeck, K. (2020). Technology before engineering: how James Bond films mediate between fiction and reality in the portrayal of innovation. *Technovation 92–93*, 102080. doi:10.1016/j.technovation.2019.05.006

Goffman, E. (1963). *Stigma: notes on the management of spoiled identity*. Englewood Cliffs, NJ, U.S.A.: Prentice Hall.

Hackel, L. M., Zaki, J. & Van Bavel, J. J. (2017). Social identity shapes social valuation: evidence from prosocial behavior and vicarious reward. *Social Cognitive and Affective Neuroscience 12* (8), 1219–1228. doi:10.1093/scan/nsx045

Halpern, M. K. & Rogers, H. S. (2021). Art-science collaborations, complexities and challenges. In M. Bucchi & B. Trench (Eds.), *Routledge handbook of public communication of science and technology* (3rd ed., pp. 214–237). doi:10.4324/9781003039242

Hicks, D., Wouters, P., Waltman, L., De Rijcke, S. & Rafols, I. (2015). Bibliometrics: the Leiden Manifesto for research metrics. *Nature 520* (7548), 429–431. doi:10.1038/520429a

Illingworth, S. (2022). *Science communication through poetry*. Cham, Switzerland: Springer. doi:10.1007/978-3-030-96829-8

Irwin, A. & Wynne, B. (Eds.) (2012). *Misunderstanding science? The public reconstruction of science and technology*. Cambridge University Press. doi:10.1017/CBO9780511563737

Jensen, P. (2011). A statistical picture of popularization activities and their evolutions in France. *Public Understanding of Science 20* (1), 26–36. doi:10.1177/0963662510383632

Jensen, P., Rouquier, J.-B., Kreimer, P. & Croissant, Y. (2008). Scientists who engage with society perform better academically. *Science and Public Policy 35* (7), 527–541. doi:10.3152/030234208X329130

Johnson, Z., Massiah, C. & Allan, J. (2013). Community identification increases consumer-to-consumer helping, but not always. *Journal of Consumer Marketing 30* (2), 121–129. doi:10.1108/07363761311304933

Jones, F., Burke, R. J. & Westman, M. (Eds.) (2013). *Work-life balance: a psychological perspective*. London, U.K.: Psychology Press. doi:10.4324/9780203536810

Jonsson, A. & Grafström, M. (2021). Rethinking science communication: reflections on what happens when science meets comic art. *JCOM 20* (02), Y01. doi:10.22323/2.20020401

Kappel, K. & Holmen, S. J. (2019). Why science communication, and does it work? A taxonomy of science communication aims and a survey of the empirical evidence. *Frontiers in Communication 4*, 55. doi:10.3389/fcomm.2019.00055

Kirby, D. A. (2016). Film, radio, and television. In B. Lightman (Ed.), *A companion to the history of science* (pp. 428–441). doi:10.1002/9781118620762.ch30

Lam, A. (2020). Hybrids, identity and knowledge boundaries: creative artists between academic and practitioner communities. *Human Relations 73* (6), 837–863. doi:10.1177/0018726719846259

Lamb, C. T., Gilbert, S. L. & Ford, A. T. (2018). Tweet success? Scientific communication correlates with increased citations in Ecology and Conservation. *PeerJ 6*, e4564. doi:10.7717/peerj.4564

Laursen, K. & Salter, A. (2006). Open for innovation: the role of openness in explaining innovation performance among UK manufacturing firms. *Strategic Management Journal 27* (2), 131–150. doi:10.1002/smj.507

Lesen, A. E., Rogan, A. & Blum, M. J. (2016). Science communication through art: objectives, challenges, and outcomes. *Trends in Ecology & Evolution 31* (9), 657–660. doi:10.1016/j.tree.2016.06.004

Lorenz, L. (2020). Addressing diversity in science communication through citizen social science. *JCOM 19* (04), A04. doi:10.22323/2.19040204

Maia Loureiro, P. & Horta, H. (2024). Who engages whom? — Deficit communication in participatory science governance as democratic deficit. *Science and Public Policy 51* (4), 721–733. doi:10.1093/scipol/scae014

Marozzo, V., Crupi, A., Abbate, T., Cesaroni, F. & Corvello, V. (2024). The impact of watching science fiction on the creativity of individuals: the role of STEM background. *Technovation 132*, 102994. doi:10.1016/j.technovation.2024.102994

Matias, A., Dias, A., Gonçalves, C., Vicente, P. N. & Mena, A. L. (2021). Science communication for social inclusion: exploring science & art approaches. *JCOM 20* (02), A05. doi:10.22323/2.20020205

Mattsson, P., Sundberg, C. J. & Laget, P. (2011). Is correspondence reflected in the author position? A bibliometric study of the relation between corresponding author and byline position. *Scientometrics 87* (1), 99–105. doi:10.1007/s11192-010-0310-9

Merton, R. K. (1968). The Matthew effect in science: the reward and communication systems of science are considered. *Science 159* (3810), 56–63. doi:10.1126/science.159.3810.56

Metcalfe, J. (2022). Science communication: a messy conundrum of practice, research and theory. *JCOM 21* (07), C07. doi:10.22323/2.21070307

Mihalache, O. R., Jansen, J. J. P., Van den Bosch, F. A. J. & Volberda, H. W. (2014). Top management team shared leadership and organizational ambidexterity: a moderated mediation framework. *Strategic Entrepreneurship Journal 8* (2), 128–148. doi:10.1002/sej.1168

Milotay, N. (2017). *Briefing: Measuring social impact in the EU* [Members' Research Service PE 603.930]. EPRS — European Parliamentary Research Service.

Muscio, A. (2023). The ambiguous role of science and technology in Marvel superhero comics: from their 'Golden Age'to the present-day. *Technological Forecasting and Social Change 186*, 122149. doi:10.1016/j.techfore.2022.122149

Neresini, F. & Bucchi, M. (2011). Which indicators for the new public engagement activities? An exploratory study of European research institutions. *Public Understanding of Science 20* (1), 64–79. doi:10.1177/0963662510388363

Parks, P. & White, L. (2021). Foregrounding backgrounds: how scientists conceive art to express the invisible. *Science Communication 43* (4), 435–459. doi:10.1177/10755470211011166

Parry, S. (2020). *Science in performance: theatre and the politics of engagement*. Manchester, U.K.: Manchester University Press.

Ranga, M., Perälampi, J. & Kansikas, J. (2016). The new face of university–business cooperation in Finland. *Science and Public Policy 43* (5), 601–612. doi:10.1093/scipol/scw044

Reale, E., Avramov, D., Canhial, K., Donovan, C., Flecha, R., Holm, P., … Van Horik, R. (2018). A review of literature on evaluating the scientific, social and political impact of social sciences and humanities research. *Research Evaluation 27* (4), 298–308. doi:10.1093/reseval/rvx025

Reinsborough, M. (2020). Art-Science collaboration in an EPSRC/BBSRC-funded synthetic biology UK research centre. *NanoEthics 14*, 93–111. doi:10.1007/s11569-020-00367-3

Rios, P. & Negrete, A. (2013). The object of art in science: science communication via art installation. *JCOM 12* (03), A04. doi:10.22323/2.12030204

Root-Bernstein, R., Allen, L., Beach, L., Bhadula, R., Fast, J., Hosey, C., … Weinlander, S. (2008). Arts foster scientific success: avocations of Nobel, National Academy, Royal Society, and Sigma Xi members. *Journal of Psychology of Science and Technology*, 51–63.

Root-Bernstein, R. & Root-Bernstein, M. (2013). *Sparks of genius: the 13 thinking tools of the world's most creative people*. Boston and New York, U.S.A.: Houghton Mifflin Harcourt.

Rossi, F., Rosli, A. & Yip, N. (2017). Academic engagement as knowledge co-production and implications for impact: evidence from knowledge transfer partnerships. *Journal of Business Research 80*, 1–9. doi:10.1016/j.jbusres.2017.06.019

Rushforth, A. & de Rijcke, S. (2015). Accounting for impact? The journal impact factor and the making of biomedical research in the Netherlands. *Minerva 53* (2), 117–139. doi:10.1007/s11024-015-9274-5

Sætra, H. S. (2024). Science fiction, sustainability, and scenario use: comprehensive scenarios for improved strategy development and innovation. *Technovation 132*, 102976. doi:10.1016/j.technovation.2024.102976

Sanz Merino, N. & Tarhuni Navarro, D. H. (2019). Attitudes and perceptions of Conacyt researchers towards public communication of science and technology. *Public Understanding of Science 28* (1), 85–100. doi:10.1177/0963662518781466

Shema, H., Bar-Ilan, J. & Thelwall, M. (2012). Research blogs and the discussion of scholarly information. *PLoS ONE 7* (5), e35869. doi:10.1371/journal.pone.0035869

Simis, M. J., Madden, H., Cacciatore, M. A. & Yeo, S. K. (2016). The lure of rationality: why does the deficit model persist in science communication? *Public Understanding of Science 25* (4), 400–414. doi:10.1177/0963662516629749

Sivertsen, G. & Meijer, I. (2020). Normal versus extraordinary societal impact: how to understand, evaluate, and improve research activities in their relations to society? *Research Evaluation 29* (1), 66–70. doi:10.1093/reseval/rvz032

Smit, J. P. & Hessels, L. K. (2021). The production of scientific and societal value in research evaluation: a review of societal impact assessment methods. *Research Evaluation 30* (3), 323–335. doi:10.1093/reseval/rvab002

Stevens, C. & O'Connor, G. (2015). Combined art and science as a communication pathway in a primary school setting: paper and ice. *JCOM 14* (04), A04. doi:10.22323/2.14040204

Stier, J. & Smit, S. E. (2021). Co-creation as an innovative setting to improve the uptake of scientific knowledge: overcoming obstacles, understanding considerations and applying enablers to improve scientific impact in society. *Journal of Innovation and Entrepreneurship 10*, 35. doi:10.1186/s13731-021-00176-2

Tajfel, H. & Turner, J. C. (1979). An integrative theory of intergroup conflict. In W. G. Austin & S. Worchel (Eds.), *The social psychology of intergroup relations* (pp. 33–47). Monterey, CA, U.S.A.: Brooks/Cole.

Tajfel, H. & Turner, J. C. (1986). The social identity theory of intergroup behaviour. In S. Worchel & W. G. Austin (Eds.), *Psychology of intergroup relations* (pp. 7–24). Chicago, IL, U.S.A.: Nelson-Hall.

Thune, T., Reymert, I., Gulbrandsen, M. & Aamodt, P. O. (2016). Universities and external engagement activities: particular profiles for particular universities? *Science and Public Policy 43* (6), 774–786. doi:10.1093/scipol/scw019

Tiffany, L. A., Hautea, S., Besley, J. C., Newman, T. P. & Dudo, A. (2022). Effect of context on scientists' normative beliefs. *Science Communication 44* (1), 86–107. doi:10.1177/10755470211048186

Tingay, S. (2018). Indigenous Australian artists and astrophysicists come together to communicate science and culture via art. *JCOM 17* (04), C02. doi:10.22323/2.17040302

Tur-Porcar, A., Salas-Vallina, A. & Azagra-Caro, J. M. (2024). The positive effect of social support in the relationship between emotion and motivation of people in science. *The Journal of Psychology 158* (6), 492–510. doi:10.1080/00223980.2024.2325081

van Dijck, J. (2003). After the "Two Cultures": toward a "(multi)cultural" practice of science communication. *Science Communication 25* (2), 177–190. doi:10.1177/1075547003259540

Van Looy, B., Ranga, M., Callaert, J., Debackere, K. & Zimmermann, E. (2004). Combining entrepreneurial and scientific performance in academia: towards a compounded and reciprocal Matthew-effect? *Research Policy 33* (3), 425–441. doi:10.1016/j.respol.2003.09.004

Weingart, P., Joubert, M. & Connoway, K. (2021). Public engagement with science — origins, motives and impact in academic literature and science policy. *PLoS ONE 16* (7), e0254201. doi:10.1371/journal.pone.0254201

Weiss, P. S. (2012). Who are corresponding authors? *ACS Nano 6* (4), 2861. doi:10.1021/nn301566x

Wren, J. D., Grissom, J. E. & Conway, T. (2006). E-mail decay rates among corresponding authors in MEDLINE: the ability to communicate with and request materials from authors is being eroded by the expiration of e-mail addresses. *EMBO reports 7* (2), 122–127. doi:10.1038/sj.embor.7400631

Yang, G. (2024). Knowledge element relationship and value co-creation in the innovation ecosystem. *Sustainability 16* (10), 4273. doi:10.3390/su16104273

Zaelzer, C. (2020). The value in science-art partnerships for science education and science communication. *eNeuro 7* (4). doi:10.1523/ENEURO.0238-20.2020

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