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D4.4: Recommendations on Policies and Incentives for Quality Science Communication

Project QUEST – QUality and Effectiveness in Science and Technology communication

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Authors	Matteo Di Rosa, Claudia Iasillo, Ilda Mannino, Alessandra Fornetti, Enrico Costa, Roberta Villa, Fabiana Zollo
Contributors	Laura Bell, Margot Bezzi, Suzanne Franks, Jacopo Pasotti, Joseph Roche
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EXECUTIVE SUMMARY

This deliverable relates to the QUEST Task 4.3 "Recommendations on Policies and Incentives for Quality Science Communication". The task aims to identify recommendations to create the framework conditions for incentivising quality communication of science and R&I to a wide public for scientists and research institutions, as well as across different media and communicators, focusing in particular on the QUEST research strands, i.e. journalism, museums, and social media. Also, actions focusing on public engagement are considered.

The recommendations have been developed by combining desk research with the results of research conducted within the QUEST project, based on codesign activities engaging representatives of the target groups that might foster the promotion of policy and incentives at different levels (i.e. journalists, museums, scientists, communicators, policymakers, media industry, social media platforms, governance of research institutions from the public and the private sector, etc.).

In particular, the document investigates:

- the role of policy, at institutional, national and EU level, to increase quality in science communication,
- what strategies policy-makers can introduce to limit the growing spread of disinformation among citizens in favour of an increasing distrust towards public bodies,
- what specific policies and incentives promoted by funding organizations can affect public engagement with science and technology.

Our starting point has been the identification of the key challenges and obstacles to quality science communication for each target group/strand.

Table 1: Barriers and challenges to quality science communication identified for target group/strand.

Barriers for Research institutions and scientists	**Barriers for Media Sector and Journalists**	**Barriers for Museum explainers and facilitators**	**Barriers for Social media**
Marginal role of Public Engagement in institutional strategy (RB1)	Economic sustainability of the news media sector and related few work opportunities for journalists and reduced number of professionals (JB1)	Need for inclusiveness and engagement of a wider range of audiences in (science) museums (MB1)	Poor reputation of social media (SB1)
Focus on quantity instead of quality and impact in science communication assessment (RB2)	Skills and training of generalist journalists in addressing scientific issues (JB2)	Balance between dialogic approaches to engage the public and the educational role of museums (MB2)	Misinformation in social media (SB2)

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Barriers for Research institutions and scientists	Barriers for Media Sector and Journalists	Barriers for Museum explainers and facilitators	Barriers for Social media
Tensions between research institutions and the media (RB3)	Tension and communication issues between science journalists and scientific institutions/scientists (JB3)	Lack of skills and training of the museum practitioners in science communication (MB3)	Polarization phenomena (SB3)
Lack of recognition of science communication within scientists' tasks and working time (RB4)	Time availability for fact checking and debunking (JB4)		Lack of social media skills and literacy (SB4)
Lack of scientists' career reward for science communication (RB5)			Lack of time and of academic and economic rewards (SB5)
Lack of skills of in researchers and tensions with communication officers (RB6)			Platform regulatory issues (SB6)
Gender Bias in Science Communication (RB7)			
Research gaps and lack of dialogue between research in science communication and practitioners (RB8)			
Low citizens' science literacy (RB9)			
Trust in science and scientists' issues (RB10)			

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Once identified, recommendations on policies and incentives to tackle these challenges were developed.

The framework that emerges is quite complex, with several barriers, but also with recommendations of possible policies and incentives to tackle them (Figure 1).

Some of the recommendations are transversal to the different target groups and strands, such as the need to further develop scientists and communicators' capacities to engage the public with science through quality communication and the promotion of positive and stable interaction and collaborations among the different actors in the science communication ecosystem.

Policies and incentives to promote science literacy and trust of the public in science and scientists are prerequisites to ensure the engagement of the public to achieve the final goal of quality science communication.

These recommendations call to action different decision makers, from governments at EU and national level, to the funders, the governance of the institutions communicating science (e.g. research centres and universities, media institutions, museums, social media platforms) and the associations of those communicating science, i.e. scientists and communicators.

The existence of several good practices is a positive and encouraging element of the framework. The sharing of these good practices is promoted by QUEST as an important action that can provide models and inspire further initiatives supporting quality science communication.

The recommendations have been also grouped by policymaker category concerned, i.e. EU policy makers, national governments and agencies, governance of research institutions, media decision-makers and associations, museums governance and associations, to promote their dissemination and adoption.

These factsheets are also illustrated in visual form.

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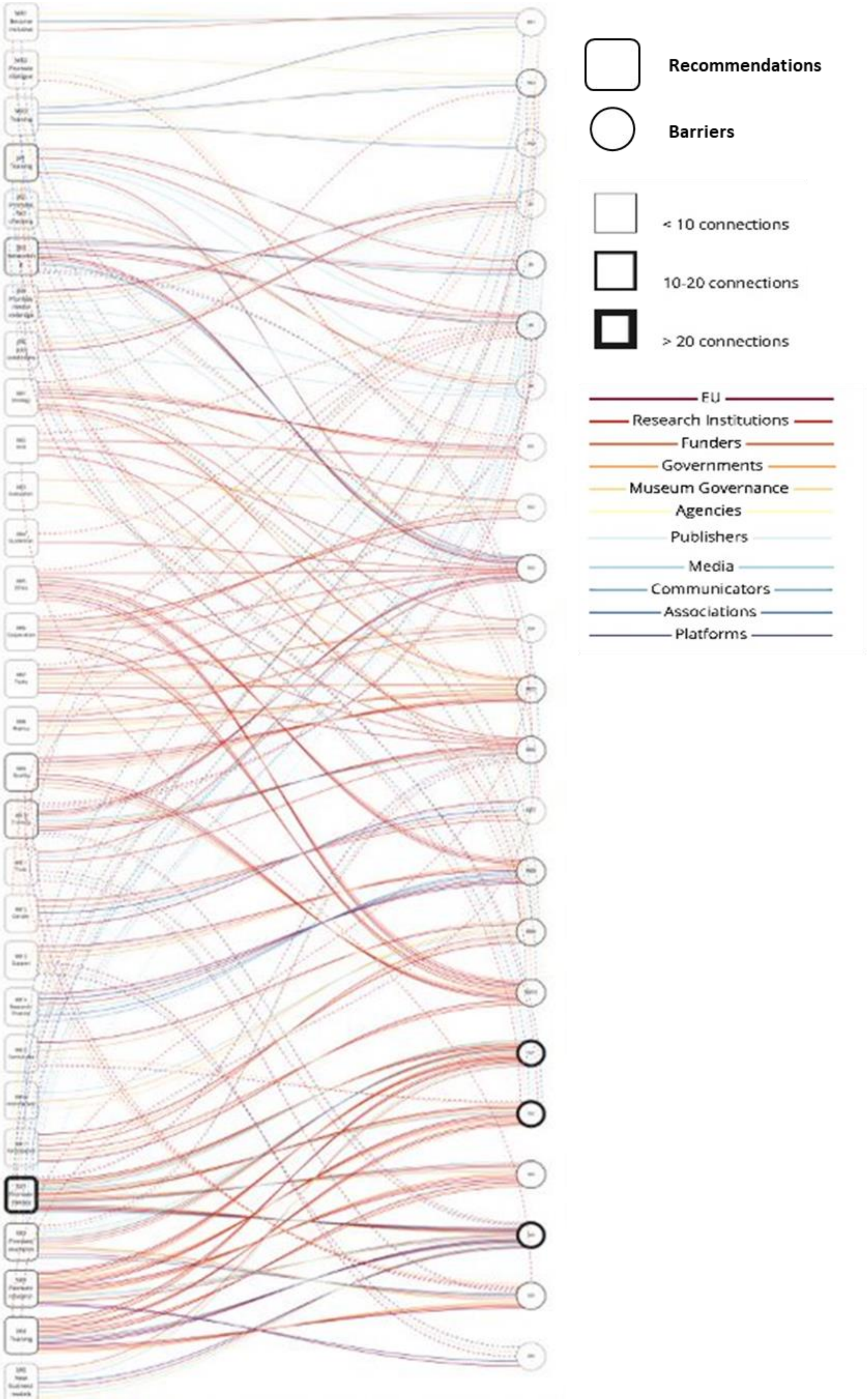

Figure 1: Map of Barriers, recommendations and policy makers for quality science communication.

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ABBREVIATIONS

ACUMEN	Academic Careers Understood through Measurement and Norms
AJSPI	French Association of Scientific Journalists of the News Press
ANVUR	Agenzia nazionale di valutazione del sistema universitario e della ricerca - Italian National agency for the evaluation of research
CONCISE	Communication role on perception and beliefs of EU Citizens Project
DORA	Declaration on Research Assessment
EU	European Union
EUPRIO	European Association of Communication Professionals in Higher Education
HE	Higher Education
JB	Barriers, Challenges and Needs for Journalists
JR	Recommendations for Journalists
JIF	Journal Impact factor
KPIs	Key Performance Indicators
MB	Barriers, Challenges and Needs for Museums
MR	Recommendations for Museums
NCCPE	UK National Co-ordinating Centre for Public Engagement
OECD	Organization for Economic Co-operation and Development
PCST	Public Communication of Science and Technology
PE	Public Engagement
PISA	Programme for International Student Assessment
PR	Public Relation
PSE	perceived self-efficacy
RB	Barriers, Challenges and Needs for Research Institutions and Scientists
REF	Research Excellence Framework
RR	Recommendations for Research Institutions and Scientists

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RRI	Responsible Research and Innovation
SB	Barriers, Challenges and Needs for Social Media
SR	Recommendations for Social media
STEM	Science, Technology, Engineering and Mathematics
US	United States of America

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SECTION 1: INTRODUCTION

There are several challenges to face to increase quality related to the different stakeholders of the science communication ecosystems, including scientists, communicators, media, social media, museums, and the public. Policy and incentives are fundamental to create the overcome these challenges creating the framework that supports quality science communication.

In accordance with project QUEST's main research strands, this deliverable focuses on policy recommendations in the following areas: *Academia / Research institutions*; *Journalism and media dealing with science*; *Museums*; *Social Media*. The relationship with the public, in particular with policy makers and citizens, is considered in relation to the different areas.

Each research area constitutes a world in itself, with its own mechanisms (economic, sociological, informational), implying very different communication mechanisms, processes, consolidated trends, specific evolution trends and raising issues. This also implies that decision makers – those who can take decisions - operate and hence make a difference in each of these areas that are different and not comparable. In some cases, they coincide with policy makers, but this is not always the case for the other areas, where private actors may be more influential or significant in promoting change.

For this reason, in the context of this work we mean as "policies" any strategy, solution or good practice, at the public or private level, that can:

- incentivize and improve science communication in terms of quantity and quality,
- promote more and better science communication, enabling to overcome obstacles identified at different levels.

Recommendations and incentives could relate to:

- existing good practices that could be spread;
- practices that are not yet in place and could be created.

We tried to reflect as much as possible the (fragmented and) varied EU landscape, which is shown in different needs or applicability levels of policies and practices amongst different Member States.

QUEST project worked to identify the barriers, challenges and need for quality science communication related to each area. i.e. research institutions and scientists, media and journalists, museums and social media (Section 3). The analysis of the barriers related to research institutions and scientists is particularly extended since it was not covered in previous QUEST deliverables.

The Section 4 reports the recommendations identified to overcome the identified barriers for all those having a decision-making role that influences each of the areas, i.e. research institutions governance, editors, policy makers at national and EU level, bringing also reference case studies. The Conclusions summarizes the key strategies to put in place for promoting quality science communication.

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SECTION 2: THE METHODOLOGY

The development of QUEST Policy Recommendations was based on:

1) the identification of barriers to quality science communication related to key stakeholders and strands in the science communication ecosystem, including scientists and their institutions, journalists and the media, museums and their facilitators, social media and citizens;

2) the definition of possible policy recommendations and incentives to overcome such barriers, taking also into consideration existing good practices.

The methodology relied on the direct engagement of the different stakeholders, i.e. scientists, communication officers, journalists, editors and publishers, social media managers, museum explainers, institutions' governance and citizens, in a series of co-designed activities run between Spring 2019 and Autumn 2020, both online and in-person.

Figure 2: Science Communication ecosystem considered in QUEST.

The co-design activities included: 62 structured and semi-structured interviews with science communication experts, 9 focus groups with 67 stakeholders (scientists, journalists and editors, museum explainers, social media content managers, university and research institute governance staff), 6 multi-stakeholder workshops with 74 participants, one online survey with the members of the European Association of Communication Professionals in Higher Education – EUPRIO, 1 survey with the participants of the Erice International School of Scientific Journalism and three online surveys, respectively for scientists and research institution governance, journalists and editors, and museums.

The stakeholders were mainly from the six countries involved in QUEST project (i.e., Italy, France, Estonia, UK, Ireland and Norway) but also from other EU and non-EU countries (e.g., Germany, The Netherlands, Belgium, Switzerland, Spain, Portugal and African countries), reached among the

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contacts of the partners and through snowball. Support systems to make the online sessions interactive were put in place, using different platforms, such as padlet, survey monkey, and slack.

Quantitative and qualitative analysis of the data collected from the different activities enabled us to identify the key challenges that science communication is facing, as perceived by stakeholders, and provided vital input for developing some recommendations on how to overcome them, through an iterative process, where each activity was built to validate and further investigate the outcomes of the previous ones.

The final step was the consolidation of the knowledge gathered, through desk and literature research, including the identification of existing good practices in relation to the recommendations, that also involved the engagement of the QUEST stakeholders.

The anonymised data and tools used are available in the QUEST data repository (https://rs.unive.it/).

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SECTION 3: BARRIERS, CHALLENGES AND NEEDS FOR QUALITY SCIENCE COMMUNICATION

QUEST project worked to identify the barriers, challenges and needs of quality science communication related to four areas. The outcomes of this analysis for each strand are presented in this chapter: i) research institutions and scientists (see 3.1 Summary of analyses and findings on research institutions and scientists), ii) media and journalists (see 3.2 Summary of analyses and findings on media sector and journalists), iii) museums (see 3.3 Summary of analyses and findings on museums) and iv) social media (see 3.4 Summary of analyses and findings on social media). The analysis of the barriers related to research institutions and scientists is particularly extended since it was not covered in previous QUEST deliverables.

3.1 SUMMARY OF ANALYSES AND FINDINGS ON RESEARCH INSTITUTIONS AND SCIENTISTS

Some important issues were identified by analysing the feedback and contributions provided by scientists and research institutions communicators and governance representatives engaged in the QUEST codesign activities. This section describes the Barriers, Challenges and Needs related to science communication and public engagement performed by Research Institutions and Scientists (RB). The list of barriers emerged both from the literature and from the interactions with universities' management and scientists:

- Marginal role of Public Engagement in institutional strategy (RB1)
- Focus on quantity instead of quality and impact in science communication assessment (RB2)
- Tensions between research institutions and the media (RB3)
- Lack of recognition of science communication within scientists' tasks and working time (RB4)
- Lack of scientists' career reward for science communication (RB5)
- Lack of skills in researchers and tensions with communication officers (RB6)
- Gender Bias in Science Communication (RB7)
- Research gaps and lack of dialogue between research in science communication and practitioners (RB8)
- Low citizens' science literacy (RB9)
- Trust in science and scientists' issues (RB10)

RB1 Marginal role of Public Engagement in institutional strategy

According to science communication experts engaged in QUEST research, there is a need for universities and research institutions to think about the emphasis and the resources they give to supporting public communication. Furthermore, that emphasis should favour quality and impact over quantity, as we will see in barrier 2 (see RB2 Focus on quantity instead of quality and impact in science communication assessment).

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When research communication is not explicitly listed among the institutional priorities and scientists do not perceive support and acknowledgment for their communication efforts, there is an obstacle to quality science communication. We could interpret this barrier as a lack of favourable context.

Universities and research institutions are increasingly active in the so-called Third Mission (Abreu et al., 2016), and, more specifically, in public communication and engagement (Kyvik, 2005); (Neresini and Bucchi, 2011); (Entradas and Bauer, 2017), which is a key element of the Responsible Research and Innovation – RRI concept (Loroño-Leturiondo and Davies, 2018). The commitment towards more frequent and effective interaction with people outside academia appears to be driven by two main forces. First, a top-down pressure derives from higher education and research bodies such as governmental evaluation agencies (e.g., REF in the UK and ANVUR in Italy), but also from national government by introducing national strategies to promote the public communication of science (e.g. China, India, South Africa and Norway). On the other hand, a bottom-up demand for communications-related services and training have arisen in recent years from researchers, in their turn invited by funding institutions to disseminate, communicate, engage society at large, and learn how to perform all those activities (e.g., the principles for researchers stated by The European Charter for Researchers, 2015).

Beyond the narrative about academia dismantling the 'ivory tower', however, little is known about the actual institutional endeavour in science communication and public engagement at a European level. Our exchange with science communication experts highlighted the importance of having public engagement explicitly embedded into science institutions' strategies. The declaration of intent, though, is a necessary but not sufficient condition to guarantee quality and effectiveness in PE initiatives. Priorities should then be translated into concrete measures (Jensen et al., 2008). All this considered, there is a clear need for policies and incentives aimed at promoting the role of quality and effective public engagement within institutional missions and strategies in all European countries (see RB2 Focus on quantity instead of quality and impact in science communication assessment). According to our interviewees, that also means to acknowledge science communication as part of researcher's tasks, as further analysed in RB4, and to counteract cultural obstacles, i.e. peers' biases.

The academic approach to communication seems to change too slowly. In 2006, scientists participating in a Royal Society survey revealed that scientists who engage are less well regarded by other scientists (20% of respondents), and cited peer pressure as a barrier (3%). Furthermore, women involved in public engagement may suffer the reinforcement of negative stereotypes (Royal Society, 2006). As Martinez-Conde confirmed in 2016, negative perceptions, backlash, obstacles to career and funding persist in academia despite institutional statements in favour of popularisation efforts (Martinez-Conde, 2016). Moreover, action at the institutional level is required to remove barriers preventing young scientists or female scientists from fully embracing the duty to communicate research and science.

To cope with these barriers, institutions should invest in creating a shared internal culture that favours science communication. Analysis on the 2014 evaluation exercise carried out in the UK through the Research Evaluation Framework confirms the efficacy of such an approach. As a NCCPE report underlined, successful departments paid attention to investing in the creation of a culture in which researchers are supported and incentivized to engage with the public (Duncan and Manners, 2017).

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RB2 Focus on quantity instead of quality and impact in science communication assessment

The EU Commission has introduced clear strategies in its research funding programs to promote science communication, by requiring the inclusion of work packages on dissemination and communication in each project they fund and clear targets and indicators to monitor the achievements. However, several of the stakeholders interviewed raised the issue that even if this strategy was very relevant to promote further science communication, it triggered more quantity than quality.

Interviewed scientists and people in managerial positions consider the lack of specific indicators focusing on quality and impact instead of quantity of activities a relevant barrier to quality science communication. There is anecdotal evidence that a shift towards impact in the evaluation mechanisms of research and research institutions can promote quality science communication and public engagement by institutions and, indirectly, their researchers.

In a column in Nature, a researcher explains that a policy initiative became a game-changer in promoting science communication within the research institutions:

> That changed five years ago, when the UK government pivoted to include scientific impact in its assessment of research quality, the Research Excellence Framework (REF). This prompted a cultural shift in UK universities. Estimated impact now accounts for 20% of quality-related research funding (this will rise to 25% in 2021) and is judged by peer reviewers and end users of research, who seek evidence that the research has reached and substantially influenced the public. (Kamau, 2019)

The Research Excellence Framework (REF), the impact evaluation that assesses the research of British higher education institutions, considers dissemination beyond academia as a component of the broader concept of public engagement, which is described as the approach to involving the public in meaningful roles in the development, uptake and/or application of research. A report by the UK National Co-ordinating Centre for Public Engagement (NCCPE) on the last completed impact evaluation of public engagement highlights a lack of competence on the identification and use of indicators related to communication activities: Usually reports on science communication limit their evidence to a list of the outlets that were used and the numbers of people engaged (Duncan and Manners, 2017).

The fact that raw numbers of people reached is not a sufficient indicator of impact, is confirmed by a case study described by the scientist who directly planned and submitted it to the REF evaluation. His key messages are:

> Raw numbers quantifying ‘reach’ of engagement lack context and often require presentation with a suitable comparator to assess them.
>
> ‘Significance’ of impact can be demonstrated by behavioural responses of target audiences that are consistent with engagement goals, triggered by specific engagement interactions. (Copley, 2018)

In Italy, the national agency for the evaluation of research (ANVUR) has included the monitoring of public engagement activities within the Third Mission assessment in 2014. However, the results of that evaluation are still not linked to funding. For the assessment period 2014-2019, ANVUR has changed focus from a mapping of the public engagement activities to the evaluation of selected case studies and their societal impact.

The comparison between the UK and Italy gives us an idea of trends in the diffusion of a culture of impact measurement among research institutions. Mattei (Mattei, 2018) reports that whilst in the UK

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and, to a lesser extent, in the Nordic countries, research assessment based on using public engagement as a measure is firmly embedded in the organisational culture of most universities since the mid 1980s, in Italy this is a fairly new policy agenda, and ANVUR seems to be steadily moving in this direction since 2014.

This overview suggests that the transition toward quality and impact is an ongoing process which deserves to be further monitored and investigated by the EU Commission.

RB3 Tensions between research institutions and the media

According to the scientists' views we collected, one of the main barriers to quality science communication resides in the relationship between science and the media. Tensions and communication issues emerge when journalists interact with scientists and research institutions (see also JB3 Tension and communication issues between science journalists and scientific institutions/scientists). In particular, scientists fear that their messages are banalized, sensationalized and/or misinterpreted by journalists, that they consider often lacking scientific knowledge useful for understanding what scientists talk about.

Shedding light on one facet of that complex dynamic, qualitative research carried out in QUEST (18 semi-structured interviews with a range of experts engaged in science journalism from across Europe) highlights experts' concern that increased levels of science public relations introduced barriers to direct access to scientists for journalists (Davies et al., 2019).

The literature has extensively investigated the scientists-journalists dialogue, in a few cases discussing the role of scientists' institutions. According to Peters, scientific communities and institutions apply ambivalent norms to that dialogue (Peters, 2013). Research organizations, he explains, usually encourage media visibility but also keep an eye on researchers' media interactions to make sure that these are in line with the organization's interests. In this context there is the risk that institutions can influence the positions that scientists express.

Research institutions invest more and more in media relations, both through direct (media relations units) and indirect (training for researchers) paths. Concerning the former aspect, the indication that we got from our surveys to journalists is that they feel overwhelmed by the amount of press releases they receive from research institutions, a practice they tend to consider branding, more than science communication.

In 2013, Autzen used data on press releases posted on Eurekalert (a nonprofit news-release distribution platform operated since 1996 by the American Association for the Advancement of Science) as an indicator of academic pressure to ensure research visibility. According to these, media coverage seems to go hands in hands with prestige: the highest ranked universities posted the highest number of press releases (Autzen, 2014).

In Europe, Alphagalileo, a service like Eurekalert, was launched in 2003, (Green, 2006). Green's commentary underlines the neglected crucial role of media liaison staff and promotes the idea of a European research media service. That service would have had two objectives: "To ensure that significantly more European research news reaches the worldwide media, and that this news is covered more effectively" (Green, 2006).

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According to literature and practice, hence, the main actors involved in the science-media relationship appear to be three: scientists, journalists, and media relations professionals. Obstacles to good science communication can affect all the interactions in that network. Science journalists, for example, may suffer the growing influence of public relations (Göpfert, 2008). In parallel, research reveals that the responsibility of inaccurate science reporting should be equally shared by journalists and PR professionals (Brechman, Lee and Cappella, 2009).

Despite differences in approaches, agendas, professional practices, targets, and contexts, a common ground among scientists, journalists, and information officers can be found in ethical principles guiding their communication acts (Willems and de Bruin, 1996). Being complementary to individual norms and values, a group ethics of science communication through mass media should be discussed and shared at a European level. Journalists apply their own deontology and should act as 'watchdogs' instead as 'cheerleaders' of science. In parallel, press officers must be aware of their responsibility to convey timely, clear, transparent, accurate, and balanced information.

That responsibility is shared with researchers, who need to ensure that press releases do not hype findings (Kwok, 2018). On their side, researchers' possible conflicts of interests should be carefully considered and eventually declared.

Early career or less media-savvy scientists could be reluctant to reach out to journalists. Their first experiences could be unsatisfying. Nevertheless, those obstacles can be easily overcome with experience and training, as Gascoigne and Metcalfe demonstrated in a seminal analysis in Australia (Gascoigne and Metcalfe, 1997).

On the side of the universities' communicators, our questionnaire to EUPRIO members revealed that they believe that scientists need more training in media relations. At the same time, they mention "Media relations'' as the more frequent focus of training activities for researchers organised within their institutions. The same need is confirmed also by the scientists participating in our survey, who expressed the willingness to learn even more on how to deal with the media and interviews highlighting that more in this concern must be done.

We will further discuss barriers related to the educational aspects in RB6 Lack of skills in researchers and tensions with communication officers.

RB4 Lack of recognition of science communication within scientists' tasks and working time

Scientists engaged in QUEST activities perceive as a very relevant barrier to quality science communication the lack of recognition of science communication among their work tasks, i.e. science communication is often not formally part of tasks in their contract. This is strictly connected to another key obstacle, that is the lack of time to carry out science communication: the fact that science communication is not always recognized among the work tasks make it an extra activity for which scientists do not have time allocated and so have to spend their spare time.

Bentley's surveys undertaken in 1992 and 2001 among faculty members at Norwegian universities show that ''academics with popular articles spend significantly fewer hours on the core activities, but significantly more hours on service and other activities and significantly more hours overall" (Bentley, 2011). This is in line with what emerges from the QUEST focus groups with scientists, that highlighted that science communication is a time demanding activity for them. However, Bentley (2011) also

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reported that “prolific scientists were more active in publishing for a lay public than less productive faculty members”, suggesting that even if popular science communication requires time, it does not seem to affect research productivity.

Despite this positive sign, the issue of lack of time for science communication by scientists comes back also in the QUEST survey carried out with the members of the European Association of Communication Professionals in Higher Education - EUPRIO that indicated it as the primary obstacle to science communication in the Higher Education (HE) institutions. This suggests that the ‘time’ issue is still far to be solved.

RB5 Lack of scientists’ career reward for science communication

The lack of career reward for science communication activities, in terms of advancement, emerged from the exchange with the scientists in QUEST as one of the main obstacles they encounter to science communication toward the wide public.

The literature confirms that the evaluation system for researchers has not been able to keep up sufficiently with the transformations in the way researchers create knowledge and communicate their research to colleagues and the public at large (ACUMEN, 2014; Moher et al., 2018). Also, in the DORA - the 2012 Declaration on Research Assessment by the American Society for Cell Biology - it is underlined that current researchers’ evaluation in academy is broadly based on the Journal Impact Factor (JIF), an indicator presenting a number of well-documented deficiencies as a tool for research assessment, neglecting other key aspects of RRI, such as the impact on society and its engagement. This old-world bibliometrics does not correspond with the goals to achieve societal impact alongside scientific impact. This issue is relevant not only in the EU scenario, but it comes back also in other countries as studies carried out for instance in the US (Olson, 2017) and in China (Mordan & Sheldon, 2018) show.

However, there are also some positive signs. Loroño-Leturiondo & Davies observed for instance that scientists perceive science communication as a social responsibility for them, embracing the RRI vision (Loroño-Leturiondo and Davies, 2018). In Olson (2017) Hoffman noted that many academic scientists believe that it is important for the public to know more about science but think that they will not benefit personally by engaging in science communication. Olson also stated that the incentive structures in higher education are changing in ways that support science communication, though much more needs to be done. Moher et al. (2018) reported about some good practices in this concern such as the web-based performance criteria and guidelines for researchers’ evaluation developed by ACUMEN consortium (Academic Careers Understood through Measurement and Norms), which tried to take into consideration also the impact of their research.

RB6 Lack of skills in researchers and tensions with communication officers

The lack of researchers’ skills in communication to the public was raised as one of the key challenges for quality science communication by the stakeholders involved in QUEST activities: communication officers of the higher education institutions, journalists, and scientists themselves see it as a relevant obstacle. As mentioned in RB3 Tensions between research institutions and the media, scientists need and want training on how the media works and how to deal with them.

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Moreover, several scientists stated they do not feel confident or skilled enough to communicate directly to the public. Even if as raised by Matthews & Mercer-Mapstone (2016) and Kappel & Holmen (2019) the literature attempting an empirical evaluation of science communications skills is scarce and does not allow to judge how good scientists are at communicating, there is a general consensus on the importance and need of having scientists skilled and trained in science communication both at graduate and undergraduate level. Their training and consequent improvement of science communication skills can be beneficial for both society and scientists themselves, that highlighted the value of their work (Leshner, 2007; Warren et al., 2007; Bubela et al., 2009; Brownell et al., 2013; Mercer-Mapstone & Kuchel, 2016; Forrester, 2017; Bankston and McDowell, 2018; Clarckson et al., 2018).

One positive aspect that QUEST research put in evidence in this concern is that science communication courses spread to most European countries, even if highly diverse and mobilizing quite different conceptual traditions, with a little agreement concerning the core concepts and skills that should be taught (Costa et al., 2019). However, what is broadly recognized is that science communication training has not become yet a mainstream practice in science curriculum at undergraduate and graduate level. This could be due, as underlined by Bankston (2020), to the fact that the current scientific system wasn't built to incorporate and value other skills besides the research ones.

Despite the recognized importance of training scientists in communicating to the wide public, some of the experts interviewed argued that not all the researchers should be pushed to communicate, since some of them may feel uncomfortable communicating their findings first-hand and forcing them to do so might have more negative effects than positive ones. If on the one side this is true, on the other side training can play an important role in making them feel more comfortable, disclosing new science communication talents. Borrowing from a model described by Bowater and Yeoman, we can cluster scientists in categories according to their willingness and ability to communicate. The model assigns low priority to those that will never take part in communication activities and lack communication skills. On the other extreme, skilful, and active scientists should be rewarded. Incentives can encourage those able but reluctant to communicate. Training plays a crucial role for scientists that would participate but lack competences: trained scientists could either acquire ability and jump to the 'top' category, or, on the contrary, confirm their scarce competence and be discouraged to communicate (Bowater and Yeoman, 2012).

Training scientists in science communication is particularly important if we consider that evidence shows that the public seem to trust scientists more than journalists (IPSOS, 2020). Also, according to the consultation carried out by H2020 Swafs19 CONCISE (2021), citizens believe that scientific institutions and scientists should play a leading role in producing information and communicating scientific findings. It is therefore strategic that these actors develop the ability to communicate effectively.

What should be taught to scientists? In 2019, we asked communicators working for several European universities which were the main needs of scientists in terms of science communication education. Social media, Media Relations and Visual Communications are the top-three results, followed by Strategic Communication. Risk Communication ranked among the less needed topics. In 41 respondents, only 4 and 2 reported courses on strategic and risk communication respectively. Those results show practitioners' focus on technical and basic skills and confirm a lack of attention to long-term goals and objectives related to the communication performed by scientists. Fostering strategic communication capacity, however, could promote a more effective communication and empower scientists to achieve more meaningful communication outcomes (Besley *et al.*, 2016). One of the

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benefits of expanding the scope of training beyond basic and technical skills, is the facilitation of a smooth and productive collaboration between scientists and communicators.

Also, several of the scientists involved in QUEST workshops confirmed that they need support to improve their skills dealing with social media (see also SB4 Lack of social media skills and literacy). If on the one side they are increasingly embracing social media in their professional lives (Social media for scientists, 2018), on the other side from QUEST research it emerges that often they do not feel very confident, do not know how to write a post and to manage the discussion, especially when dealing with opposers. For these reasons they would like more training on it. However, the indication we got from the survey with scientists and research institutions governance representatives is that researchers' training on social media is less important, even if just slightly, than training on media and public speaking, showing that the other two means are still perceived as the frontline in science communication to the public.

Communication officers in the research institutions play a key role in science communication and should facilitate scientists' communication, but QUEST research highlighted there are tensions between them and scientists (and researchers in general) from their own institutions. Those tensions emerged as perceived by both sides. One of the critical aspects in this concern seems to be the fact that their interactions happen mainly at the end of the research cycle and are not something stable and procedural, while a more structured collaboration could help to develop a positive interaction that could provide the needed support to researchers in communicating their findings.

RB7 Gender bias in science communication

Another interesting element emerged in QUEST focus groups concerning perception of communication skills by scientists, was that women seemed less confident than men in communicating science to the wide public. This indication is perfectly coherent with the literature. The "Matilda effect" - the consistent under-recognition of female scientists (Rossiter, 1993) seems inevitably to also affect their engagement and representation in science communication. What emerges is for instance that hardly any women scientists are highlighted in the popular science writings (Venkateswaran, 2013), men scientists are more likely to be speakers at events than women even after controlling for the gender and rank of the available speakers (Nittrouer et al., 2017), and they are more interviewed and quoted by journalists (The Global Institute for Women's Leadership, 2018). Kassova (2020) for instance reports that between 2005 and 2015 fewer than one in five experts globally in the news were women, this data does not match with the 30% ratio of women scientists at global level reported by the UNESCO Institute for Statistics (UIS). Also, social media seems affected by these disparities, as the analysis by Amarasekara & Grant (2018) of the 391 most popular science, engineering, and mathematics–themed channels revealed, showing a conspicuous absence of female communicators, with the hosts of just 32 of these channels presenting as female (Amarasekara & Grant 2018). The current pandemics made this aspect even more evident as reported in a study by Kassova (2020) that underlines the lack of perspectives from women in the news coverage related to the pandemic: most of the interviewed experts are men.

This underrepresentation is a very critical aspect not only in relation to science communication but also, as broadly reported in the literature, to the gender balance in science (Fogg-Rogers and Hobbs 2019). In fact, viewing same-sex in-group experts (female role models) has been shown to enhance subjective identification (Stout et al., 2011), this means that if fewer female than male experts are called to communicate or quoted by journalists, other female scientists can perceive women as not as good and entitled as men in science communication and then be undermotivated to perform science

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communication. The impact can be even wider, preventing women in the young generation to undertake STEM careers as raised by Fogg-Rogers and Hobbs (2019).

The change needed for a more gender balanced science communication requires a different perspective on the culture of science and identity traits of scientists, that science communication itself can contribute to change (Fogg-Rogers and Hobbs, 2019).

RB8 Research gaps and lack of dialogue between research in science communication and practitioners

As emerged in the work carried out in QUEST on the state of the art of science communication in Europe, the current landscape is that of a fragmented research field. Priest (2010) defines science communication as a multi-discipline, in which scholars from different traditions work on the same topic. This is probably the reason why we could not find among the interviewed experts a consensus regarding research needs. However social media were mentioned repeatedly (Davies et al., 2019) and, in this context, research to understand how science communicators might be more effective in using social media and, even more, what can be the role of social media in society or in democracy are indicated as key.

It also emerged that national context and region were important in structuring communities of both science communication research and practice and that the largely Anglophone international academic literature does not give a comprehensive account of research into science communication. Moreover, what emerged from QUEST activities with stakeholders is a separation between science communication scholars and practitioners, with those that study science communication not practicing it and those practicing it not reading research papers on science communication. As reported by Davies et al. (2019) ’’the implications of this ‘communication gap’ is that a growing knowledge base in evaluation of and innovation in science communication from researchers often did not reach practitioners, and that the majority of practice – even that funded through large scale government initiatives – was not evaluated or assessed’’.

RB9 Low citizens’ science literacy

In the literature we find a general agreement on the fact that science literacy is fundamental for informed democratic processes (Liu 2009; Babalola 2013; Martinez-Hernandez 2015; Süerdem & Çağlıyor 2016; Smol 2018; Kampourakis 2019; Siarova et al. 2019). This vision is not to be seen as the embracing of the knowledge deficit model or another proof that this model is not dead and remains an integral part of science communication research and practice (Suldovsky, 2016) or of the default position of scientists in their public activities (Trench, 2006). It has to be read instead starting from the definition that OECD gives of science literacy as ‘’the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen” (2017, p. 22). Not only does science literacy involve the comprehension of basic scientific contents, but it also concerns the importance of “falsifiability” of scientific theories and hypotheses, as well as the ability to critically engage with and make informed decisions about science-related issues (Zen, 2018; Siarova et al. 2019). Therefore, science literacy provides a context for better coping with many of its problems and making intelligent and informed decisions that will affect the quality of citizens’ lives and those of their children.

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In this context Science literacy is proposed as a key to fight misinformation spread (Siarova et al., 2019; Miller 2020).

The different stakeholders involved in QUEST research perceive science literacy still as a challenge that quality science communication must face today to be able to effectively engage the public. This is in line with the results of existing studies on this topic, consisting of large-scale assessment data and public opinion surveys on societal issues requiring an understanding of science, that can provide insights about scientific literacy. Climate change and vaccines, two of the three case studies covered in QUEST, are often used as topics on which to test public opinion and knowledge. PISA 2015, the most comprehensive comparative assessment study measuring scientific literacy of 15-year-olds, to date reports that the average share of underachievers has not reached the target set by the EU Commission for 2020, showing that efforts for increasing science literacy are still needed. As summarized by Siarova et al. (2019) and Snow and Dibner (2016), their studies highlight differences in science literacy between countries, inside and outside Europe and in terms of gender or level of study regarding students' performance and citizens' attitudes that would require further investigation.

The current pandemic has made even more evident both the importance and need of further science literacy of the public, including policymakers, to face crises, orient themselves among the multitude of information received and fight against misinformation (Braund, 2020; Cohen, 2020; Miller, 2020). As well underlined by Braund (Braund, 2020), the COVID-19 pandemic has resulted in unprecedented amounts of information communicated to the public relating to STEM, that do not go all in the same direction. The COVID also gave the occasion for an epidemic spread of disinformation and misinformation, the so called "infodemic". Raising awareness of the public about basic concepts such as science uncertainty and supporting the development of critical thinking can help citizens to not get confused by the existence of different positions, but also to distinguish uncertainty from misinformation and disinformation.

RB10 Trust in science and scientists' issues

As stated by Barber (1987) "Trust is an essential constituent of all social relationships and societies". The issue of trust is particularly relevant when we talk about science. Hendriks et al. (2016) says that "To deal with scientific information, laypeople have to trust in scientists and their findings", therefore lack of trust in science and scientists represents a key barrier for science communication to be able to engage the public, on the other side, science communication can play a key role in enforcing trust in science and scientists.

Barber (1987) distinguishes between trustfulness and trustworthiness: the former is the trust in the proficiency of someone to be able to carry out his/her tasks, the latter is the trust that someone will observe his/her fiduciary obligations.

Several studies have been carried out to investigate trust in science and scientists. According to IPSOS (2020) trustworthiness is the most interesting aspect to consider when we talk about the crisis in trust; they reported that "globally, scientists are seen as the most trustworthy profession, with 60% of people around the world trusting them". However, in the 2011 report on Innovation Union Competitiveness, the European Union (2011) indicated that since 2005 the share of Europeans experiencing a general trust in science has declined from 78% to 66%. Another interesting element to consider is that trust seems to be influenced by different factors linked for instance to affluence, education, country, but also to the scientific topics considered, e.g., climate change, vaccines, GMOs.

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The key challenges in this concern should be therefore twofold. On the one side, to increase the trust in science taking into consideration the different factors. On the other side, to promote trustworthy science and scientists. In this context, ethical principles play a crucial role.

The current pandemic, having increased the exposure of the lay public to science, can potentially also affect the trust in science, but how is still uncertain. There are several studies that are investigating this aspect. The one carried out by Eichengreen et al. (2020) on how exposure to previous epidemics affected trust in science and scientists suggests that public trust in scientists will decline in wake of Covid-19 current pandemic, even if it will have no impact on views of science as an endeavour.

Different results emerge from the 3M's 2020 Pandemic Pulse Survey: fielded in Summer 2020 among 1,000 general population adults (18+) in 14 countries, reports that appreciation for science and trust in scientists has increased significantly in 2020, compared to past years. In the same direction we find the results from the Ipsos MORI study (Skinner et al., 2020) based on a series of online surveys of UK adults aged 16+ carried out from mid-April to late August 2020, reporting that the UK public have a positive disposition towards science and scientists. However, what also emerges from this study is that this positivity is not evenly spread across different demographic groups, with low affluent and non-graduated respondents less trusting than middle classes and graduated. This could be linked to a lower literacy of the former groups (see RB9 Low citizens' science literacy).

Interesting outputs come also from the study by Battiston et al. (2020), that examines the dynamics of trust in science and experts in real-time as the high-impact epidemic of COVID-19 unfolds in Italy, by drawing on digital trace data from Twitter and survey data collected online via Telegram and Facebook. It shows an initial increase in reliance on and information-seeking from scientists and health authorities with the diffusion of the disease. However, over time and as the epidemic peaks, they detected a slowdown and turnaround in reliance and information-seeking from scientists and health authorities, which they interpreted as signs of an erosion in trust.

3.2 SUMMARY OF ANALYSES AND FINDINGS ON MEDIA SECTOR AND JOURNALISTS

This section describes the Barriers, Challenges and Needs for Journalists (JB) as summary of the important questions raised by analysis of feedback and contribution provided by scientific journalists involved in this deliverable and more in general for the project activities. They were asked about the issues influencing the quality and accuracy of journalism about science and it emerged that in the media sector there was a relatively high consensus among participants regarding the following points:

- Economic sustainability of the news media sector and related few work opportunities for journalists and reduced number of professionals (JB1)
- Skills and training of generalist journalists in addressing scientific issues (JB2)
- Tension and communication issues between science journalists and scientific institutions/scientists (JB3)
- Time availability for fact checking and debunking (JB4)

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JB1 Economic sustainability of the news media sector, related few work opportunities for journalists and reduced number of professionals

Paradoxically, while science news is expanding worldwide, science journalism is under pressure both in terms of employment and in terms of its traditional formats. All areas of journalism have been experiencing funding issues related to a decline in circulation of newspapers and magazines (Cairncross, 2019). The legacy mass media that have long served as the principal employers of science journalists – newspapers and magazines – are faltering in many countries and the science journalism is an increasingly imperilled occupation that, perversely, is needed now more than ever (Dunwoody, 2014).Yet as evidenced by our project activities there is a reduction in staff, programme budgets or freelancers' fees and often science journalists were at the front line of newsroom cuts.

This scenario is having different effects on the career of the scientific journalists, especially on the ones in their early stages:

- From some formal and informal interviews performed by project activities, it emerged that interesting science journalism needs talent. Yet, some talented science writers may prefer to go into Public Relations rather than become journalists, due to more favourable contract conditions.
- Often, freelance science journalists play a dual role as journalists and communication officers, with a potential conflict of interest.
- Non-specialized general journalists, working to a tight deadline, would not be able to distinguish between press releases announcing high quality robust science and those that do not and would be tempted by an "inflated" science story.
- Science journalists are being forced to become more entrepreneurial and to look for new ways to explain to their audiences the profound scientific developments under way. Some of these journalists have embraced social media channels – Facebook, Twitter – not only to maintain contact with sources and peers but also to build their own personal brands.
- To maintain the possibility to investigate without potential conflicts of interest, in some countries, scientific journalists are gathering in non-profit organizations.

The scenario above described, together with a limited audience and interest in the scientific content, may affect the quality of science communication.

For instance - in a world where both citizens and advertisers increasingly control their own delivery of information via online channels – publishers are pushed to reduce the space dedicated to science, especially in the traditional media channel. This affects also the traditional news business model.

Moreover, the publishers aiming to capture the attention of their target audience are willing to reduce the quality of scientific communication of their article in face of a stronger overrepresentation of the same or to publish the news before the other publishers to engage, especially online, more public, becoming more desirable for the advertisers.

In other cases, the publishers aiming to save money and time are willing to just re-publish the press releases from research centres avoiding any kind of mediation. But news media articles covering scientific research that are based on press releases are known to be problematic (Dempster, 2020). For example, it has been shown that, in science and health related news that was based on a press release, the main sources of exaggeration were the press releases themselves (Sunmer et al, 2016).

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JB2 Skills and training of generalist journalists in addressing scientific issues

Dwindling revenues for legacy media means that news corporations and publications are less likely to employ science specialists and ask general journalists to cover scientific news instead. At the same time these generalist journalists are subject to a daily bombardment of press releases and corporate communication materials whose branded content seeks to present a favourable message. Most journalists who replied to our questionnaires agree that the general journalists can find it hard to mediate this information, distinguishing a high-quality robust science story from an "inflated" science one.

Evidence from QUEST's semi-structured workshops with journalists, editors and other stakeholders have in addition revealed that general journalists handling science stories find themselves often lacking basic science literacy and the ability to interpret scientific data and statistics, especially given the pressure of deadlines and other professional time constraints[1]. In order to provide the appropriate interpretations and contexts, most journalists engaged by project activities agree that the *generalist* journalists should become more involved in science. It is expected that they do not simply translate complex science or new discoveries in clear stories, but they need to be able to distinguish scientific evidence from unwarranted claims of scientific expertise, for example from self-made online experts on issues such as climate change or vaccination (Brüggemann et all, 2020). Generally, it is expected that a *scientific* journalist is able to go by in-depth knowledge about science, including its processes and methods of knowledge production: in other words, they are expected to go 'upstream' in the flow of knowledge, and report not only on the results of studies, but also on how science is conducted. To do this, a *generalist* journalist should be able to read and interpret a scientific paper to define how to properly report it to the public.

JB3 Tension and communication issues between science journalists and scientific institutions/scientists

In recent decades, and over the past 5 years, there has been a growing commitment within academic and research organizations to engage the public audience to disseminate their own project results (Entradas et al, 2017, Leshner, 2003). Indeed, outreach and community engagement have been part of the 'third mission' of most universities around the world (Laredo, 2007) (see also RB1 Marginal role of Public Engagement in institutional strategy). Such opening up is well documented at policy level, at the level of universities, research centres or at the level of individual researchers building a public profile (Entradas et al 2020).

In this context, a crucial role is played by the central university or research centre PR offices that increase the visibility of the institution's researchers and research results through public events, and media interactions and social media.

As part of QUEST research, we have observed some tensions in the relationship between (science) journalists and scientific institutions/scientists (see also RB3 Tensions between research institutions and the media). Indeed, the scientific institutions with extensive PR operations may attempt to perceive journalists as simply purveyors of their releases. On the other hand, journalists are not willing

[1] https://questproject.eu/why-we-created-a-new-curriculum-for-science-journalism/

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to just communicate and pass on what they have been told by the scientific institutions/scientists but are prone to ask difficult questions or hold scientists and their findings to account.

Moreover, the scientists have little idea of how journalism works, and they may see journalists as manipulators of their information. On the other hand, journalists may feel that scientists are not forthcoming or helpful in explaining. Additionally, occasional misunderstandings and frictions between journalists and scientists occur due to the lack of transparency and mutual understanding about each other's working methods. For example, both may strive for objectivity, but in different ways (Post, 2015).

JB4 Time available for fact checking and debunking

In the last years, the world of journalism has been changing rapidly as online media grows, squeezing resources, and putting pressure on journalists to produce maximum output on minimum resources, while quality seems to be undervalued (Murcott et al, 2013). Although public understanding and engagement with science is key for innovation in every field, these issues apply even more to science journalism. On the contrary, since huge economic and, sometimes, political interests are at stake in many branches of science (space, health, environment, IT, etc.), some stakeholders do not want to lose control on which and how scientific results are communicated to the public. As mentioned before, science journalists and journalists in general are asked to be more explainers and cheerleaders than watchdogs on the quality of science itself[2]. However, the role of science journalists is not only to explain science to the public. As well as their colleagues specialized in other topics (politics, economics, or sport), the duty of science journalists includes both to inform and to be critical towards their sources, verifying facts and their actual meaning. They have a great responsibility in choosing which news to publish, in verifying their reliability within their own context and presenting them without any sort of oversimplification or distortion (Schäfer, 2011).

The crisis of the traditional media may explain why most journalists, nowadays, suffer for a lack of time, which not rarely leads them to report a scientist's declaration or to copy and paste press releases issued by research centres or pharma industry, without fact-checking what they publish. This is a crucial factor of the current landscape of misinformation, even in science (Schäfer, 2011).

Fact-checking is not an extra activity, but an essential part of journalism, be it general or scientific. When writing about science, one can be trapped by many biases: the authority of a scientist - which one can find hard to question - the pressure by the advertising office for not speaking ill of a drug, the political impact of science news, as it was quite clear during the Covid-19 pandemic. The point is that fact-checking is time demanding.

In common with other areas of journalism and in relation to what is described above, time pressure is so reported to be an increasing problem – making verification or fact checking and investigation of stories more difficult (Schunemann, 2013). Indeed, as part of our work we observed that several journalists complain about the lack of time, an element that undermines the good scientific quality of the editorial product.

[2] Cheerleader or watchdog? Nature 459, 1033 (2009). https://doi.org/10.1038/4591033a

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3.3 SUMMARY OF ANALYSES AND FINDINGS ON MUSEUMS

Some important issues were raised by analysing the feedback and contributions provided by museum experts interviewed for this deliverable and, more in general, for the project activities (see also QUEST D1.1 Deliverable: Summary report: European Science Communication today) to identify the Barriers, Challenges and Needs for Museums (MB) as depicted in this section. They were asked about the issues influencing the quality and accuracy of science communication in museums and the following points of discussion were raised:

- The need for inclusiveness and engagement of a wider range of audiences in (science) museums (MB1)
- The balance between dialogic approaches to engage the public and the educational role of museums (MB2)
- The lack of skills and training of the museum practitioners in science communication (MB3)

MB1 Need for inclusiveness and engagement of a wider range of audiences in (science) museums

In the literature it is highlighted as "most visitors to museums are from the dominant White ethnic majority, from upper and middle-class groups, educated to degree level, female, without a disability and based in urban areas" (Dawson, 2014). Currently, museums are communicating science disproportionately to economically privileged and ethnic majority audiences. The engagement of diverse audiences with a more social inclusive approach considers: i) the organizational aspects (e.g. infrastructure access needs or development of programmes), ii) the understanding of how things work at the museum and iii) the acceptance of practitioners of a diverse range of audiences.

However, attracting a diverse audience may not be possible without adapting existing science communication approaches to currently underrepresented groups. Furthermore, a concerted effort is needed to identify and avoid socially exclusive patterns in science communication approaches in museums. Museums are facing a challenge in understanding how to reach diverse audiences, broadening the range of activities and topics of interest to those who may be underprivileged or overlooked. Communication approaches should allow different voices to be heard and people with different perspectives should be brought together as this can support the audience to approach science with a new point of view. Science communication contents, approaches and activities should be better rooted in the visitors needs and views and diversity should be included. Alongside this process of adaptation of museum practices, it is essential for institutions to clearly define a plan to achieve equality and inclusion standards, to focus resources and efforts towards the common goal.

Overall, experts interviewed during our research agreed that science museums need to become more socially inclusive, and some suggested practical ways to do so, such as organizing exhibitions that tackle socially sensitive issues or directly address issues of societal equality (e.g., health inequities, impact of climate change on more vulnerable populations). Another suggestion was about hiring people with socially challenging backgrounds, as a powerful way to inspire younger generations by giving positive examples for their careers. As one of the experts pointed out:

> Representation is key. Museums are respected institutions in society and have the potential to hugely influence school students who visit them as part of school or personal visits.

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MB2 Balance between dialogic approaches to engage the public and the educational role of museums

The direct exchange between the public and the researchers is a growing trend in museums. In the literature it is described how museum participants can gain science-related skills and knowledge through inquiry-based approaches and developing and testing hypotheses together with museums practitioners in purposely designed dialogic formats within the museums (Hohenstein & Moussouri, 2018; Pedaste, 2012). This science communication approach is in line with the less formal and structured kind of communication that takes place in museums, that allows the developing of several formats (Jensen & Buckley, 2014). A two-way dialogue between audience and museum practitioners is considered effective to encourage non experts in getting involved in science, much more than top-down approaches where the communicators simply ‘explain’ science without opportunities of discussion or interaction. However, this leads to a tension between needing to keep the engagement high and the educational role of museums and finding the right balance between the two visions. As one of the experts we interviewed pointed out:

> This can lead to shallow and sometimes counter-productive communication. An example is the proliferation of science show demonstrations that are used as an exciting attraction without thought of how they frame science (often as 'magic' or specialized knowledge for 'special' people, rather than learnable by everyone).

To engage the audiences, the format counts as well. Museum practitioners need to make content interactive and exciting to stimulate the dialogue and they need to experiment with new tools and approaches (e.g., games, maker spaces, etc.), keeping in mind what could be perceived as exciting by the participants. The challenge for museums’ practitioners is to understand how to improve content interactions, excitement, and relevance for specific audiences to ensure the effectiveness of various methods. This requires efforts to improve their usual practices and to understand the audiences, keeping in mind the need to consider how to engage a wider and socially representative community. Overall, all the experts we engaged in QUEST research pointed out how public engagement plays a crucial role in their activities within museums community, and there was a consensus about the importance of pedagogy in designing learning, and at the same time engaging activities in museums. Some also pointed out the importance of establishing synergies and partnerships between formal and informal learning organizations. As one of the experts stated in their interview:

> In overall it would be interesting to find as much synergies between education and public engagement in science as possible. So, the budget and work put in the programs can have a more focused impact.

MB3 Lack of skills and training of the museum practitioners in science communication

In our QUEST research, training of communicators was mentioned many times as essential for helping communicators to tackle challenges ahead them. Museum practitioners engaged in our research expressed a general consensus over the need to have dedicated training for museum practitioners, in particular regarding the production of engagement materials (including presentations, exhibitions, etc). Training and innovation in content development - programmes that connect scientists, artists, exhibition designers, educators, festivals, and theatre producers, etc. - is considered essential to develop new science communication formats.

With the words of one of the museum practitioners engaged in QUEST research:

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> Training, and the adoption of common training expectations would improve matters. Recognising that universities are not necessarily the prime source of expertise in every domain would also help.

3.4 SUMMARY OF ANALYSES AND FINDINGS ON SOCIAL MEDIA

Social media are increasingly being used for science communication by institutional communicators, scientists, journalists, museum explainers, and the public (Davies et al. 2021, Brossard 2013, Brossard & Scheufele 2013, Mewburn & Thomson 2013, Davies & Hara 2017), both for communicating and as a source of information. These different groups can sometimes face different barriers, even if most issues are common to all of them.

Our work in the QUEST project highlighted some of these Barriers, Challenges and Needs for Social Media (SB), which emerged from both the scientific and grey literature and stakeholders' interviews and surveys all over Europe. The scientific literature on science communication through social media is however limited. Most studies are limited to one topic, short in time frames, focused on a single social media platform or use small datasets (Hargittai et al. 2018, Corley et al. 2011, Anderson et al. 2010, Huber et al. 2019, Colson 2011, McGowan et al. 2012, Knight & Kaye 2016, Collins et al. 2016, Su et al. 2015, Pearce et al. 2014, Lörcher & Neverla 2015). Evolution in the field is also very fast so that grey literature and stakeholders' opinions can provide a more accurate picture of the status of science communication through social media in Europe.

The following main issues emerged:

- Poor reputation of social media (SB1)
- Misinformation in social media (SB2)
- Polarization phenomena (SB3)
- Lack of social media skills and literacy (SB4)
- Lack of time and of academic and economic rewards (SB5)
- Platform regulatory issues (SB6)

SB1 Poor reputation of social media

Despite several examples of excellent science communication through social media all over the world, social media channels still have a **poor reputation** in some parts of academia (Van Eperen, 2011). They are often considered by scientists not as a "serious" channel of communication but as tools of entertainment, gossip, or shallow topics.

> Many scientists perceive Facebook and Twitter, for example, as unprofessional platforms that may compromise or threaten years of life-changing research (Van Eperen, 2011).

The fast and somehow "emotional" kind of communication usual on social media seems opposite to the scientific style.

Scientists can easily look like influencers: this can be positive to involve the public, but insidious when dealing with complex issues. Social media are regarded with suspicion also because they can easily provide **popularity** that is not necessarily correlated with the scientific value of a researcher. This gap

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has been described and is measured by the “Kardashian index,” or “K- index”, based on the direct comparison of numbers of citations and Twitter followers, ironically proposed by the British geneticist Neil Hall in 2014. The K-index, recalling the H-index – the metric related to the productivity and citation impact of the publications of a scholar – is named after Kim Kardashian, a social media celebrity who is said “to be famous for being famous”: *“despite having not achieved anything consequential in science, politics or the arts, [...] she is one of the most followed people on Twitter and among the most searched-for person on Google”* Hall writes (Hall 2014).

Popularity on social media is not always correlated with relevance in the scientific community. *“The K-index”* – the cardiologist Robert Califf has recently commented – *“is an oblique way of addressing an issue that is bothersome to researchers who have paid the hard price of designing, conducting, analyzing. His effort can take many years and often yields disappointing results despite the research team’s best efforts—the truth is often painful with respect to theories and beliefs. Another person who may have an only casual knowledge of what is involved in the research may then make a comment that attracts enormous attention. People with a high K-index may be those who thrive by commenting on the work of others rather than doing their own work” (*Khan 2020, Califf 2020). *“If Kim Kardashian commented on the value of the ENCODE project, her tweet would get more retweets and favorites than the rest of the scientific community combined”* Califf adds. It is easy to understand how frustrating that can be.

This aspect can have a double and opposite effect on science communication through social media: on the one side it raises aversion among scientists in the use of social media, on the other side it can promote the use of social media and an impactful way to give visibility to scientists and their research.

SB2 Misinformation in social media

Social media are often blamed for playing a key role in what is called “**information disorder**”, a term that covers fake news, mis- and dis-information, typical of our contemporary digital society (Wardle and Derakhshan, 2017).

This is confirmed by more than 40% of responders to our QUESTionnaire to stakeholders from universities and other research institutions, media, and museums, thinking that social media are important or very important in spreading misinformation, while one out of 5 deems them somewhat important. One of the comments received is:

> The most important source of science fake news is the social media. To regulate it is a very delicate question.

The same perspective seems to be embraced also from the public, as emerged from CONCISE project consultations, highlighting as social media are often seen as breeding grounds for fake news (CONCISE, 2021).

A minority of stakeholders thinks the contrary:

> I don’t think social media are so relevant for misinformation. They are relevant for information in general, increasing the level of information we get. If we want to tackle the issue, we have to increase the number and frequency of trustable science information on social media, we have to change the contents, not the box. On the other hand, I strongly support the freedom of choice, and I don’t want someone else to decide for me what I should read or not.

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Despite the common perception, current research on misinformation in our society does not support the idea that social media are entirely to be blamed (Tsfati 2020). Misinformation, disinformation, and fake news have always existed. The internet and the social media can only foster their spreading. Of course, they have a great pervasiveness and speed in spreading any kind of information, be it correct or not, but they are just tools, which can be used in a bad or a good manner as well as traditional printed press or TV. These traditional, mainstream media are also often vehicles of unwanted misinformation and/or deliberate disinformation, in part because of the problems described in the chapter on journalism (see **Errore. L'origine riferimento non è stata trovata.**, in particular JB1 Economic sustainability of the news media sector, related few work opportunities for journalists and reduced number of professionals and JB4 Time available for fact checking and debunking), in part in response to economical and/or political interests, due to the scarce independence of each outlet in some countries.

SB3 Polarization phenomena

The internet allowed the public to access almost any piece of human knowledge directly, without the intervention of an expert. This **disintermediation** is a great opportunity for improving people's literacy, in science as well as any other field, but it also implies the risk that those uninitiated may misunderstand or take out of context what they figure out (Fountain 2017, Fountain 2019). The success of some scientists, science journalists, and communicators on social media shows that a need for "reintermediation" is felt by the public, especially when dealing with complex issues.

The advent of social media, later, allowed a fast, deep, and wide spread of any piece of information, again without any filter by experts: regardless of the quality of it, the overwhelming quantity of information reaching everyone daily may be confusing, and it is considered a factor favouring the spread of disinformation and misinformation ("i**nfodemic**") (Zarocostas 2020).

With social media, the gap between science and the public can be reduced. The lay person can ask the expert any question directly, and the expert can have an idea of what people think, doubt, and are afraid of, so that he/she can adapt his/her communication consequently. At the same time, the fact that they play somehow on the same field, that the social media user can be unaware of the competence or the stature of his/her counterpart, often does not acknowledge his/her authority and objects to his/her statements can make this dialogue hard for the scientist, causing **conflicts**. This is especially true when scientists have a top-down approach to science communication and think to be there to give lessons to a world that does not share the same background, the same knowledge, and even the same language.

Such a gap in respect and understanding recently led a Swedish scientist to leave his study on Covid-19 because of the harsh attacks received online about it (Torjesen 2021). *"To strengthen academic freedom, the Swedish government has proposed a new amendment that points out that education and research must be protected to enable people to freely discover, research, and share knowledge."* Matilda Ernkrans, Sweden's minister for higher education and research, said.

Conflicts can be worsened by another intrinsic characteristic of social media, which can be an obstacle to science communication. Because of their structure and of specific algorithms to filter content according to users' preferences, debates on social networks tend to **polarize** (Sunstein 2002, Del Vicario et al. 2016, Zollo & Quattrociocchi 2018, Schmidt et al. 2017). On any topic, users are unintentionally pushed towards extreme positions, making a quiet and fruitful debate difficult to carry on. Haters and trolls can intervene, both challenging a calm, fruitful debate and sometimes questioning

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the science communicator's knowledge, competence, and authority. This may be very stressful and discouraging for experts when they feel that this is the reward for dedicating their time to explain science to the public. This is not only about scientists. Also, journalists in our interviews (Davies et al., 2019) reported a worrying increase in personal attacks on them via social media, because of the science they were reporting.

Another consequence of polarization is that along with some of its topics, the image of science itself can be depicted as a black-and-white, false-or-true issue. Science communicators can fall into this dynamic, betraying the uncertainty, the doubts, the nuances feeding science. In the long run, this can endanger trust in science and scientists, instead of enforcing it (Ruths, 2019).

SB4 Lack of social media skills and literacy

A **lack of skills** by potential science communicators can hinder their use of social media (see also SB6 Platform regulatory issues). According to our EUPRIO survey, most HE professional communicators feel they have some need for training on social media, but the same interviewees think that most researchers have a high or very high need for this. Despite this, only about 50% of their institutions provide some training in this field.

From other interviews with stakeholders and previous research, we can say that this scarce familiarity with social media can raise concerns related to:

- **Lack of self-confidence** in using social media because of lacking skills and knowledge of the tools.
- **Mistakes** in tone or content, either on the side of keeping an "academic", top-down approach, or, on the other side, posting and commenting "by gut instinct", without fact-checking, selling certainties, using rude language, maybe in reaction to readers' attacks. This can hinder their reputation.
- **Reputation:** The poor reputation of social media mentioned before can discourage especially older scientists from getting out there and engaging in science communication in this field. They can fear being misjudged for something that can be considered narcissistic, frivolous, or as a waste of time. They can also have concerns related to a possible disruption of their privacy and personal posts or pictures shared by others damaging their public image.
- **Choice of platform:** There are so many social networks, each one with its own characteristics, target, (often not-written) rules, and approach: one should know them before engaging and the choice is not always easy. According to our research (Davies et al., 2021), EU countries show preferences in platforms choice and audience engaged. Popularity on one platform does not guarantee popularity in the other.
- **Plagiarism:** Social media are very useful to create networks and exchange data and ideas, but, as emerged in events hosted by Jobs.ac.uk: *"some people, perhaps especially researchers, are uncomfortable with the idea of posting work or other information online. They might be afraid someone will steal their work or ideas, for example. But this is an increasingly outdated concept in this digital age. There is an ever-growing movement towards open access and the democratization of knowledge. Promoting yourself on the internet is now essential for your long-term career success"*. (Cragg 2017). Again, a better knowledge of social media can help overcome this, as well as other, hurdles.

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The same barriers are related to the public. Science communication often has to face a **lack of critical thinking, science and social media literacy** in the population, impairing the reception of messages and so discouraging communicators to engage in these media.

SB5 Lack of time and academic and economic rewards for science communication on social media

In all our surveys, workshops and interviews, **lack of time and of academic/economic rewards** are considered the greatest barriers for non-professional social media communicators to engage with science communication in general (see RB4 Lack of recognition of science communication within scientists' tasks and working time and RB5 Lack of scientists' career reward for science communication) and specifically on these platforms. Science communication on social media is very time-consuming and researchers' agenda is very full, so some incentives are required to overcome this hurdle (EDIT 2018).

Despite years of research and surveys on how much the public looks for information on social media, these tools do not yet have the same dignity as books or conferences for communicating science.

Most activities by researchers in this field is on a voluntary basis, eroding family or leisure time, and often criticised.

For most researchers interviewed within the QUEST project, a lack of time and reward for their science communication activities, both in person and on social media, is a crucial barrier to engage (see RB4 Lack of recognition of science communication within scientists' tasks and working time).

For many academic policymakers and research managers, it is not clear that researchers who communicate on social media do not only promote themselves, but also their institution. They should therefore encourage researchers that wish to use social media for science communication, whose effectiveness is much greater with personal than with institutional profiles.

In some cases, science communicators on social media also can undergo, as reported by Reidy, "naked **intimidation**" by their universities or institutions, when, leading with controversial issues, they detach from the official communication strategies (Reidy 2020). While radio/TV interventions and press interviews are usually mediated by press offices, on social media each researcher feels free to take his/her own position and make it public. Sometimes this can go against the institution's communication policy or unveil conflict of interests. Even if this does not actually happen, some researchers can fear possible consequences on their careers.

Lack of economic rewards is even more relevant for freelance science journalists and communicators, who have been conveying science through several social media for years, but with a business model that is not very clear and consolidated. If they are journalists, their ethical code on conflict of interests should prevent them from adopting the prevalent business model of social media influencers, which is sponsorship by different brands. In fact, they often do this for free, in their spare time, or with a reward that is just in terms of sales of their books or of visibility that can provide them with paid conferences, articles, courses, media training for researchers. All of this is characterized by great precariousness, hindering their willingness to do this as the main job. The amount of time dedicated to this activity is dependent on this and can influence the quality of the work done.

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SB6 Platform regulatory issues

Between policymakers and the public, there is a third crucial actor in science communication on social media. Platforms' owners, such as Facebook (with WhatsApp, Messenger, and Instagram) and Google (which owns YouTube and is the main provider of information for hundreds of millions of people) have in fact a key role and a growing, huge power in information and news consumption worldwide. The policies and algorithms implemented by these platforms may indeed have a strong impact on political and societal issues, by their algorithms and policies.

> When just a few companies have control over the private communications and personal data, photos, and videos of billions of people, they wield enormous power over markets, our experience of the open Web (or lack thereof), global public discourse, free speech, and our personal lives. How we hold them accountable, and whether we have the information to do so, is crucial to the health of the Internet (Internet Health Report 2018).

A strong debate is therefore ongoing on **platform regulatory issues** that can hamper the use of social media.

Any proposal of regulation collides with ethical issues, such as the freedom of thought and speech, and the different accents that these rights have all over the world. Given the global widespread use of social media platforms, rules should be shared by all and transnational.

However, even before putting limits, and discussing if social media platforms' owners should be kept or not liable for the content posted by users - just as editors are - researchers need to be able to study the information dynamic on the platform itself.

The first point is therefore about **data access** and regards the tricky balance between users' right to privacy and the need to access them for **research**. Research about social media, their use, and information dynamics on them is essential to understand these new tools and make the best use of them. Several stakeholders interviewed within QUEST project deem this research key both to understanding how science communicators might be more effective and, even more, what can be the role of social media in society or in democracy. In the wake of leaks of users' data, regulation had limited such access, but recently some platforms let researchers get some access to data.

With regard to democracy and society as a whole, another issue is the role of platforms towards **fake or inappropriate content**: is users' banning censorship or governance? Are platforms liable for content as editors or not? These questions are important also when it comes to science communication and to the will to counteract fake news potentially dangerous, for example for health or the environment.

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SECTION 4: RECOMMENDATIONS FOR POLICIES AND INCENTIVES

Based on the barriers, challenges and needs highlighted in the previous section for the different strands and stakeholders, a set of **recommendations** for policies and incentives that could create the framework for supporting quality science communication have been identified for research institutions and scientists (RR - Recommendations for Research Institutions and Scientists), media sector and journalists (JR – Recommendations for Journalists and the media sector), museums (MR – Recommendations for Museums) and social media (SR - Recommendations for Social Media) and citizens. Each recommendation is referred to the specific issue they tackle (indicated in parentheses), with some of them addressing more barriers at the same time, in some cases also related to different strands and stakeholders.

The recommendations on social media are transversal to the different areas since each stakeholder can use social media in the science communication context.

As regards citizens, some recommendations focus on how to promote their science literacy and trust in science and scientists, as the basis for effective science communication.

Attention has been given also to underline what **decision makers** play the role of implementing those strategies and, when possible, to bring existing **good practices** (presented in the boxes) as pragmatic examples of possible ways to implement the recommendations proposed.

4.1 RECOMMENDATIONS FOR RESEARCH INSTITUTIONS AND SCIENTISTS

RR1 Further acknowledge science communication and public engagement within institutions policy and strategic documents (RB1, RB4, RB2, RB5) (MB2)

Albeit not sufficient, the formal acknowledgement of the ethical and strategic role of science communication and PE by research institutions is fundamental (RB1). Governments at national and EU level can play a role in introducing regulation that promotes this approach. Strategic plans should state the level of institutional commitment in that field. Specific plans and policies (e.g., PE within the research strategic plans) should then translate the purpose into actions, foreseeing adequate funding. The investment should comprise the monitoring and the impact evaluation of each action, accompanying the transition towards a systematic assessment of institutional PE practice (see RR3 Promote the definition and adoption of a common evaluation framework for public engagement (RB2, RB5)). The acknowledgment of science communication by institutions could bring the recognition of science communication among researchers' tasks (RB4) and career reward for those carrying it out (RB5). This acknowledgment should and could promote quality communication instead of quantity (RB2). On this aspect also the evaluation agencies would play a fundamental role. Implementing science communication and public engagement in collaboration with museums would bring dialogic approaches to engage the public in this context (MB2).

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RR2 Establish dedicated unit for science communication within research institutions (RB1, RB3, RB6) (JB3) (SB5)

The establishment by research institutions of units devoted to research communication and/or public engagement activities, and related training for scientists, is recommendable to better activate effective public engagement (RB1). This organisational measure is not common across Europe. Its widespread adoption, though, might drive the recruitment of qualified professionals and steer masters' curricula in the same direction. Research institutions should also invest in professional development of their communicators and as part of their tasks include the provision of training to scientists (RB6). The presence of these units could facilitate interaction with the media (RB3, JB3) as well as communication through the social media (SB5).

A good practice in this concern is reported in the box below.

IIT unit for communication of projects

In 2016, the Italian Institute of Technology (IIT) established a unit devoted to the communication of competitive projects, which is part of the Communication Directorate. The science communicators involved in that unit support scientists and consortia in drafting the proposals' contents related to communication and dissemination activities. Once the project is funded, the unit participates in its implementation, coordinating or supporting the communication strategy, managing the communication channels (e.g. social media accounts) and media relations. Where needed, they also design the project's communication plan. One of the IIT's goals is to provide visibility to European research and technology. "The ERC and other European bodies do a lot in terms of communication. However, the synergy with the network of research institutions is crucial", says the coordinator of the unit. IIT experience is peculiar and noticeable for three other reasons. Firstly, thanks to the new unit the institute facilitates the networking not only among scientists, but also among communication and PR professionals from all partner institutions. At an organisational level, having a dedicated unit guarantees the adherence to projects' rhythm and needs, avoiding overlaps with the institutional agenda. Furthermore, the close and constant collaboration between the unit and the researchers promotes a mutual learning experience: the communicator learns about scientific and technological state-of-the-art research, while the scientist is trained on how to deal with interviews, on writing for the lay public, and public engagement.

RR3 Promote the definition and adoption of a common evaluation framework for public engagement (RB2, RB5)

As Vargiu highlighted, *"the debate about the evaluation of teaching and research is quite advanced and so are assessment instruments and techniques"* while *"confrontation on the assessment of public engagement lags behind, although some significant advancements exist"* (Vargiu, 2014). There is a need to go beyond traditional quantitative metrics to gain a more in-depth assessment of the value of academic institutions, in order to be able to identify the societal value (e.g., public funding of higher education institutions and the impact of the research conducted) of academic institutions. We recommend pursuing the advancement of the reflection on indicators for quality public engagement, igniting a European-wide effort toward a "Third Mission" rooted in RRI principles and PE approaches to reach impact. Research, dialogue among agencies and governments, proactivity by research institutions are needed to achieve a European evaluation framework for PE and science communication activities. The adoption of such metrics would bring also career recognition for those researchers that carry out quality science communication (RB5).

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RR4 Promote the adoption of guidelines for researchers on how to interact with media (RB3) (JB3)

Scientists willing or prompted to interact with the media should find useful basic advice in resources provided by their research institution (e.g., guidelines and/or policies for media relations). Those documents should aim not only to support a positive interaction between scientists and the media, but also to share a culture of transparent and responsible communication. Clear norms should also help in preventing and reducing tensions between scientists and journalists as well as between scientists and communicators (RB3, JB3).

RR5 Promote critical and ethical approach to science communication within institutions (RB10, RB3, RB6, RB8) (JB3)

In a 2019 joint statement addressed to the Ministry of Education and Research, the German humanities, cultural and social science Societies pointed out:

> Science produces evidence-based insights, but it also produces - methodologically controlled - complexity, doubts, preliminary and new questions. Both approaches are to be fed into the process of science communication. It would be fatal to reduce science to useful factual production. It would also be fatal to make false promises to the public in this regard. If you want science communication, you have to expect the production and relevance of uncertainty, criticism, complexity and nuance. The undersigned specialist societies are convinced that this, in turn, makes sense and is constructive as a social education.

Mistakes, failures, and even frauds are part of the life of science communities. All these complex aspects should be taken into account in reflecting about communication strategies promoted by institutions, but also by the EU and funders of research. For example, media relations activities should not exaggerate science results, nor hide complexity and nuances, or, very critically from an ethical point of view, make statements to merely support the institution's interests. This would strengthen the trust in science (RB10), but also the relationship between scientists and their institutions and the media (RB3, JB3), as well as the relationship between researchers and the communication officers (RB6) and the practitioners (RB8).

RR6 Favour cooperation over competition among institutions (RB2, RB3, RB6, RB10) (JB3)

Incentivized by several factors, institutions may be pushed to invest simply in producing more science communication and/or to increase the quality just in sake of a good reputation, possibly better than the competitors' reputation. We recommend inter-institutional cooperation over competition instead. That means to invest in initiatives aimed at communicating e.g. the science, the network's results, the methods, the scientific community, the higher education system, the research agenda, etc., rather than promoting the single university, centre, research, or scientist. That approach would favour trust in science (RB10) and science literacy. Moreover, that approach would lead to promote a quality science communication (RB2), but also to support better interaction with the media (RB3, JB3), as well as support the development of scientists' communication skills (RB6).

The European Researchers' Night is a well-known example of the kind of public engagement initiatives we endorse. There are examples regarding the journalistic sphere too. The Conversation, for instance,

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is a journalistic project which involves universities as founders and partners but safeguarding the newsroom's independence. At a more 'business to business' level, Science Media Centres can play an important role. These peculiar media relations service that involves the whole national research system are already present in several countries. Science Media Centres aim to promote quality journalism improving coverage of science and scientists' expertise. However, seen as centres of mediatic power, they have attracted criticism: their approach could be perceived to be too aggressive and not as independent as declared (Callaway, 2013; Tatalović, 2014).

In this context, we recommend research institutions devise new models of cooperation in science communication, within the academic system and with different stakeholders, and to participate in those already available at national, transnational, and international level. The EU Commission, but also national and local governments can play a role in promoting cooperation initiatives at the different levels.

The Conversation journalistic project for research based news

The Conversation is a journalistic project launched in Australia in March 2011. It has expanded into editions in the United Kingdom in 2013, United States in 2014, Africa and France in 2015, Canada in 2017, Indonesia in 2017, and Spain in 2018. On their website theconversation.com, The Conversation claim to be "the world's leading publisher of research-based news and analysis". What is interesting from our perspective is the business model. The funding comes from partners from the university and research sector, philanthropic organisations, and individual donors. Research institutions pay annual memberships to support the initiative. In the newsrooms, journalists commission articles to be written by scientists, receive and select pitches from institutions and scientists, edit and publish pieces, and manage the interactions with readers. Each article, hence, has an author (the scientist) and an editor (the journalist). The latter is supposed to work independently, in the readers' interest. Each edition is published in the national language, reaching a diverse and global public.

See for reference the French edition: https://theconversation.com/fr

RR7 Include science communication in the portfolio of researchers' tasks (RB4, RB3, RB5, RB6) (JB3)

Tasks assigned to researchers usually contain a clear indication of what they must carry out and, especially in higher education institutions, of the balance between research, teaching and other activities. Considering the constraints due to national regulations, HE and other research institutions should count science communication and also the time scientists invest in developing communication skills within the other possible activities (RB4). That means that not everybody would be requested to communicate to the wide public, but for those that are able and willing to do it the time spent should be recognised. This would promote on the one side also the reward of science communication activities (RB5) and on the other side the development of skills (RB6). Moreover, it would lead to better interactions with journalists (RB3, JB3).

RR8 Revise evaluation metrics for researchers (RB5, RB4)

As well stated by Moher et al. (2018) "*how we evaluate scientists reflects what we value most and don't in research and powerfully influences scientists' behaviour*". It therefore becomes fundamental,

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widening the scope of activities worthy of academic recognition and career reward to include science communication among the criteria applied (RB5) and rewarded in different ways (RB4) to promote this activity among scientists. Encompass tenure and promotion would work as formal incentive to increase what Moeher (2018) defines as extrinsic motivation. However, to be sure that this moves toward quality science communication, we recommend the assessment focuses on quality more than quantity. QUEST project made an effort in this direction by defining a set of KPIs (see QUEST D2.1), but further research in this context is needed to develop common metrics.

The introduction of the new metrics requires the collective efforts of funders, journals' publishers, and regulators, however individual research institutions will ultimately have to be the crucibles of innovation, serving as models for others. As suggested by Scheufele in National Academy of Sciences (2018), revision of tenure guidelines should move toward integrated systems that combine elements of public outreach, traditional tenure criteria, and a candidate's overall impact on a field. Moreover, institutions can play a key role in monitoring and sharing the results of their initiatives (Moher et al. 2018).

ACUMEN performance Portfolio

Academic Careers Understood through Measurement and Norms (ACUMEN) is a European research collaboration aimed at understanding the ways in which researchers are evaluated by their peers and by institutions, and at assessing how the science system can be improved and enhanced.

Among its outputs it produced a tool for evaluators and for individual academics to refer to in situations in which their academic work or career is being evaluated. In particular, the portfolio includes communication among the expertise to assess, proposing public engagement as subcriterion, expressed in terms of media interview, videos, podcast and other.

More information:
http://research-acumen.eu/

RR9 Reward quality science communication practices (RB5, RB10) (SB5)

Introducing specific rewards for excelling in communicating the research to the public can play an important role in promoting and valorising these activities among scientists (RB5), also in relation to social media (SB5). As promoted by Ngumbi (2018) PhD students, postdoctoral fellows, early career and seasoned scientists that passionately and consistently engage in science communication should be rewarded. Many professional organizations have yearly awards for scientists for excelling in their respective disciplines. Rarely there are specific awards for excelling in doing both research and publicly sharing the research to the public (Ngumbi, 2018), while these could work as an interesting incentive. The reward can have different formats and be established at different levels: at research institutions, but also at international, national, or local government level or other funders. Sharing good practices within the home institution can be for instance a form of reward, since it gives visibility to the researchers carrying out successful practices, thus, according to Moher (2018), it works as informal incentives to extrinsic motivation for scientists to communicate their findings to the wide public. At the same time sharing these good practices can inspire other peers to follow their example.

There are already some good practices in rewards promoted by institutions at different levels and using different prizes, e.g. the recent European Research Council's (ERC) Public Engagement with

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Research Award to recognize ERC grantees who have demonstrated excellence in public engagement and outreach that includes a trophy; or the monetary prizes introduced in India by the Department of Science and Technology (DST) for PhD scholars and early career scientists who write articles about their work for mainstream outlets; in Australia, the University of New South Wales awards yearly five early career scientists for their passion for communicating their research with a two-week media residency.

There are also instances around the world of introduction of awards for science communication, e.g. the Outreach and Engagement Award of the UK Royal Society of Biology assigned since 2009, the Science Communication Awards assigned by the American Institute of Physics since 1968 to journalists, authors, reporters, and other diverse writers for their efforts in science communication, or the Indian Augmenting Writing Skills for Articulating Research initiative (see the box). In all these cases the prize consists of a certificate of appreciation and a monetary recognition, but there are also other initiatives in which the reward includes, directly or indirectly, opportunities of training in science communication for those that showed either interest or ability in it. This is the case of the Prime Minister's Science Communication Prize, a monetary prize offered in New Zealand, half of which must to be used to carry out a programme of activities to further the winners' understanding of science communication (see the box) and of the Australian Top 5 science communication program, that rewards the winner early career researchers with a two-week media residency at the ABC - Australian Broadcasting Corporation.

Further initiatives in this direction could have a relevant impact in incentivising science communication.

European Research Council's (ERC) Public Engagement with Research Award

The European Research Council's (ERC) has launched in 2020 the first ERC Public Engagement with Research Award 2020, that is designed to recognize and celebrate ERC grantees who have demonstrated excellence in public engagement and outreach.

This prize is meant to recognize those who engage with audiences outside their domain to communicate their research funded by the European Union.

The prize for each winner includes a trophy, complimentary registration to the EuroScience Open Forum (ESOF) 2020, reimbursement for attending the award ceremony and visibility at the award ceremony. In addition, winning projects are featured prominently in the ERC communication channels, expanding the visibility of the project, for several months after the award.

Providing visibility appears as the main incentive in this case.

More information:
https://erc.europa.eu/managing-your-project/public-engagement-research-award

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Augmenting Writing Skills for Articulating Research (AWSAR)

The Augmenting Writing Skills for Articulating Research initiative has been launched in 2019 in India by the Department of Science and Technology (DST) in an effort to encourage and equip PhD scholars and post-doctoral fellows with skills to communicate science with lay people by rewarding students who write popular articles about their research.

In this case the incentive adopted is monetary, with the AWSAR initiative each year rewards 100 best articles by PhD students and the 20 best articles by post-doctoral fellows with cash prize and a certificate of appreciation.

More information:
//www.thehindu.com/sci-tech/science/novel-initiative-to-encourage-science-communication/article24068354.ece

New Zealand Prime Minister's Science Communication Prize

This Prize is part of the Prime Minister's Science Prize, introduced in 2009 as a way of raising the profile and prestige of science among New Zealanders. It is assigned every year to either a practising scientist who can demonstrate an interest, passion and aptitude for science communication and public engagement, or to a person who has developed expertise in public engagement with, or communication of complex scientific or technological information to the public. It includes a trophy and cash prize of $100,000, half of which is to be used to carry out a programme of activities to further their understanding of science communication. In this case further development of communication skills is part of the incentive.

More information:
https://www.pmscienceprizes.org.nz/about-the-prizes/
https://www.royalsociety.org.nz/what-we-do/medals-and-awards/the-prime-ministers-science-communication-prize/

RR10 Train researchers on science communication on the basis of their needs and with a special focus on women (RB6, RB3) (JB3) (SB4)

Basic communication skills should be provided by research institutions to all scientists as part of their curriculum at undergraduate and graduate level, through training focusing on both theory and practice. National and EU policies can mainstream this practice. Training can work as a formal incentive to extrinsic motivation of scientists. Topics such as public speaking, how media works and social media can be some of the focuses (RB3, JB3, SB4). Particular attention should be devoted to the training of women scientists to improve both their ability in science communication and their perceived self-efficacy (Trench and Miller, 2012, Fogg-Rogers and Hobbs, 2019).

The development of standard modules covering different aspects of science communication, the sharing online of this learning material as well as of tools supporting science communication can be useful references for scientists to improve their science communication skills, particularly when easy

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to access for free. Projects funded by the EU have been particularly productive in this concern. The ESConet modules on science communication and the tools on science communication within RRI-tools.eu represent some examples. Also, the toolkits produced by QUEST aim to give a contribution in this direction (see QUEST D4.3).

To make these sources very impactful their dissemination becomes of fundamental importance.

CERN digital communication office trainings

The CERN media and digital communication office organizes courses each year to support its researchers in dealing with the media. Some of the courses are given by external trainers, with whom the media office works to prepare and deliver a one-on-one tailor-made course for upcoming needs and also provides a generic introductory course.

The course "special communication training for the Theory department" and ad-hoc advice and mock interview preparation are led directly by the media office. The courses, that are attended on a voluntary basis, see a high adhesion by the CERN experts.

In addition to formal training courses, the media and digital communication team can provide ad-hoc advice to experts who are complete beginners with media interviews, top advice for media interviews about sensitive or political aspects.

Beyond supporting the development of skills of CERN researchers, these activities promote stable and positive interactions between the researchers and the communication office: they help the researchers understand how the press office can assist them, and also help the media office understand which experts are interested in answering media requests, as well as their level of experience.

ESConet modules for communication by the scientists

Under the Sixth Framework Programme (FP6), the European Science Communication Network (ESCconet) developed a set of twelve modules aimed at helping to address the needs of scientists to communicate, by providing trainers the framework material for running training workshops.

The modules cover issues such as communication target and objectives, media writing, talking to the media, public science on the web, how the media cover science, presenting science to policy makers, communicating risk, the social sciences for science communication, science and controversy, talking science and listening, science in culture.

Based on these modules, ESConet delivered under FP7 two series of three-day workshops in both 'basic' science communication practices and advanced, deliberative communication and engagement around key and controversial issues.

More information:
https://esconet.wordpress.com/about/

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RRI-Tools.eu

RRI Tools is a project funded under the Framework Programme FP7 (2007-2013), that developed a set of digital resources to advocate, train, disseminate and implement RRI under Horizon 2020. Among the topics under the RRI umbrella, it covers public engagement and science education, gathering tools that can be useful for supporting the research community.

Despite the end of the project, the resources are still available and currently updated, thus offering a useful reference for scientists and communicators.

More information:
www.rri-tools.eu

RR11 Promote trust and collaboration between scientists and their institutions' communicators (RB6, RB3) (JB3) (SB4, SB5)

Most of the research institutions nowadays have established communication offices. However, what is often still missing is trust and a continuous collaboration between scientists and the communication officers, based on a cooperative approach. We recommend the definition and implementation of a clear and stable exchange process to promote a more positive interaction. That includes having exchanges since the beginning of a new research and periodic updates with teams of research.

This could give great support to scientists in identifying when and what it is worth communicating and how. Moreover, this interaction could help communicators understand the key aspects of the research.

Moreover, communication officers should promote training activities that aim at developing science communication skills, as part of their routine.

RR12 Promote gender balance in public events and the media (RB7) (MB1)

Having more women scientists communicating to the public would be important to increase the perceived self-efficacy (PSE) of other women experts in carrying out science communication and in the young generation in undertaking STEM careers. As Bandura states, people with high PSE are more likely to continue performing an action (Bandura, 2004), PSE being a measure of perceived ability rather than actual performance (Bandura 1977).

Promoting a gender balance among speakers in public events, scientists involved in museums' activities, and those represented and quoted on the media and social media can be of support in this concern (RB7, MB1).

There are recent initiatives going in this direction, like building a database of leading women scientists in their field and open to engage with the media, e.g. "100esperte.it", an Italian databank launched in 2016, and the most recent international database "Request a Woman Scientist platform", launched in 2018. It would be important to have such platforms at EU level and in every country.

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Furthermore, conferences that value the role of women in science, e.g., Inspire Future Women in Science, are means to achieve gender balance.

Within QUEST, we put in practice this strategy involving mainly women in our podcast series (https://questproject.eu/podcast/).

Request a Woman Scientist

A global online register of women scientists, ready to share their science, was established by a cohort of volunteer women from the grassroots organization 500 Women Scientists on January 17th, 2018. In less than one year, the database "Request a Woman Scientist" comprised over 7,500 women from 174 scientific disciplines and 133 countries. The database is built upon a voluntary questionnaire regarding career stage, degree, scientific discipline, geographic location, and other self-identifying dimensions of representation. The information is visualized using the software platform Tableau, with dropdown menus that help query the database and output a list of names, email addresses, and websites. (McCullagh et al. 2019)

Some positive results have been already registered, with 11% of the scientists in the database contacted by journalists, journal editors, and conference organizers to give interviews, conduct peer review, and serve on panels since including their information in the database.

More information:
https://500womenscientists.org/request-a-scientist

RR13 Strengthen the support both towards science communication practice and research (RB8) (SB6)

QUEST outcomes highlighted that further research in the science communication field is needed, defining a coherent and reference framework at European level of aspects and issues to further investigate in different domains (RB8, SB6). To this purpose funding institutions can play a key role in further supporting not only communication of the results of the research projects they fund, but also research projects on science communication. Moreover, the European Commission, governments, but also social media platforms can support research introducing regulations and providing data that can facilitate it.

RR14 Promote the synergy between research in science communication and the practice (RB8)

To create an actual impact of research in science communication it is fundamental to further promote the interaction between scholars and practitioners. The organization of events where they can meet and discuss can play an important role in this sense. The Public Communication of Science and Technology - PCST conference is an example of a network and events bringing together the different science communication stakeholders. In this context, we see specific sessions gathering the different actors to discuss the new findings in research and how to use them in practice as key to promote.

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The strategy of the EU Commission to bring together in the H2020 projects multi-stakeholder groups, as it was the case in QUEST project, can play a key role in this concern.

Another way where research institutions, media and their associations, can play a leading role, is to promote training for scientists involving both scholars and communication practitioners, as well as to promote workshops gathering scholars and practitioners together.

PCST Network Conference

Public Communication of Science and Technology - PCST network gathers members from different background, including scholars in science communication, communication staff working for research organizations, staff at science centres and museums, science journalists, students on the ethics and philosophy of science and the public, writers and editors of scientific material, web designers, scientists who communicate with the public, visual and performing artists working on science themes.

Every two years PCST Conferences take place, bringing together practitioners, educators and researchers in the diverse and growing field of science communication. The conferences include elements of academic and professional conferences, including presentation of research, reflections on practice, and practical workshops and demonstrations, providing opportunities of exchange, discussion, and interaction for the science communication wide community.

More information:
https://pcst.co/

RR15 Promote science literacy in formal education (RB9) (SB2)

According to Zen (2018) ‘’science-education strategies should focus on the more general problem of increasing the science literacy of the lay public (rather than the recruitment of future scientists) (RB9). This counterattack misinformation in all contexts (SB2). The EU Commission can play a key role promoted by Siarova et al. (2019) ‘’to further support Member States by strengthening the evidence base for national reform and consider setting scientific literacy benchmarks for different levels of education in the context of the next strategic framework for European cooperation in education and training by 2030. The Commission should also develop guidelines to support Member States in the implementation of the European Reference Framework of Key Competences for Lifelong Learning and further elaborate on what ‘competence in science’ implies for education policy and practice in relation to the concept of scientific literacy’’ (Siarova et al., 2019).

RR16 Promote science literacy through informal education (RB9) (MB2)

Informal science education is also relevant for promoting science literacy (Crowley et al., 2014; Filippoupoliti & Koliopoulos, 2014) to diverse groups. In this concern Science Museums could play an important role that, as emerged from QUEST research, is not fully exploited yet. As informal learning environments, science museums can promote scientific literacy through a dialogic approach (MB2) by raising the interest of the lay public in science (Crowley et al., 2014). The combination of art and science

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offers an interesting opportunity in this context that can be promoted at EU as well as national level in the different member states.

Television can be used as a tool for informal education on science, particularly relevant considering that, as emerged from CONCISE research (2020), it is the most used channel among the traditional media for finding information on science. Primetime science programmes on TV, as promoted also in the CONCISE policy brief (2020), can be an effective strategy. Both national governments and media institutions can promote this practice.

RR17 Promote the dialogue on science between scientists and citizens through participatory initiatives (RB10, RB9) (MB2)

To promote a dialogic approach in science communication and at the same time the trust of citizens in scientists and science, we promote participatory initiatives that involve scientists and citizens, as proposed also by CONCISE (2020). These initiatives can be organized by researchers, research institutions, museums or their associations as part of their third mission. Governments and other institutions con create opportunities to discuss with the lay public science and key societal challenges.

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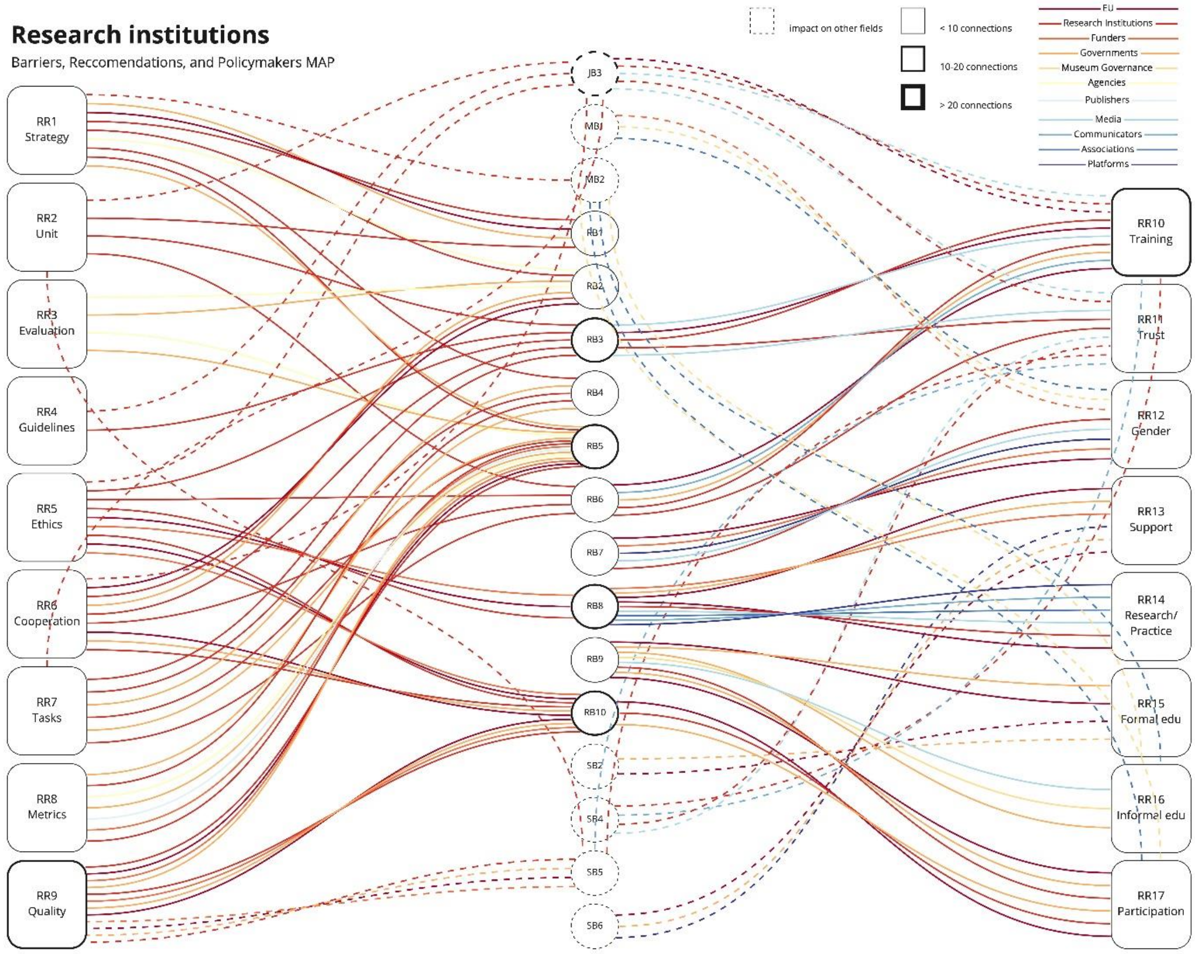

Figure 3: Barriers, recommendations and policy makers for Research institutions and Scientists (Barriers mentioned in the figure: . Marginal role of Public Engagement in institutional strategy (RB1); Focus on quantity instead of quality and impact in science communication assessment (RB2); Tensions between research institutions and the media (RB3); Lack of recognition of science communication within scientists' tasks and working time (RB4); Lack of scientists' career reward for science communication (RB5); Lack of skills of in researchers and tensions with communication officers (RB6); Gender Bias in Science Communication (RB7); Research gaps and lack of dialogue between research in science communication and practitioners (RB8); Low citizens' science literacy (RB9); Trust in science and scientists' issues (RB10); Tension and communication issues between science journalists and scientific institutions/scientists (JB3); Need for inclusiveness and engagement of a wider range of audiences in (science) museums (MB1); Balance between dialogic approaches to engage the public and the educational role of museums (MB2); Misinformation in social media (SB2); Lack of social media skills and literacy (SB4); Lack of time and of academic and economic rewards (SB5); Platform regulatory issues (SB6)).

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4.2 RECOMMENDATIONS FOR MEDIA SECTOR AND JOURNALISTS

JR1 Training activities to increase the science literacy of journalists (JB2, JB3, JB4) (RB3) (SB2)

Scientific literacy of generalist journalists is a key element in increasing the overall quality of science communication and to better communicate with the researchers avoiding some kind of conflict that can come to light. Training activities should be organized by universities and associations with the support of governments and European institutions. The main aim should be to provide journalists with the instruments to better understand the issues of science, to investigate it and translate complex science in engaging stories. In other words, the training activities are needed to transform the journalist from "cheerleaders" to "watch dog".

Specific curriculum for science journalists should be also introduced to provide future professionals with the skillset needed in the 21st century in a bid to offer clear and untainted information to the public about scientific facts. The curriculum developed within QUEST (see D4.2) aims at addressing this need. The main competence of emerging and future science journalists should be related to multi-media and digital production, numeracy, multi-disciplinarity and understanding of social media. They should be able to penetrate the social, political, and economic dimension of knowledge-based society being the curator and generator of new knowledge (Pitrelli, 2017).

Better trained generalist and science journalists (including specific trainings on 'fake news' if any is possible, or on science mechanisms) will do their job better and in the long run that would help avoiding the spreading of inaccurate information which can feed misinformation in social media.

Australian Academy of Science production of fact checked contents for news

The Australian Academy of Science is helping to overcome a shortage of specialist science skills in the newsroom by creating rigorously fact-checked content that news media can republish and share under a fair use policy.

The content creation programme sees scientists and mainstream media professionals closely collaborate with the aim of making science more accessible to the public, including those with no experience or direct interest in the field. It has found traction with news organizations in Australia and beyond, which during COVID-19 have regularly republished articles and explainer videos.

The Australian Academy of Science is an independent organization representing Australia's leading scientists, and its content production is characterized by close collaboration between science and media professionals, as well as a rigorous review process.

More information:

https://wan-ifra.org/2020/12/collaborate-and-boost-science-expertise-the-australian-way/

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JR2 Promote and support fact checking and mining of sound science news (JB4) (RB10) (SB2)

Fact checking represents a fundamental activity for quality science communication through the media and to fight the misinformation and the disinformation, thus increasing the trust issues in science and scientists, but it is also very time demanding and this conflicts with the current pace of the media industry. Journalists and in particular generalist journalists that usually also lack the scientific background that can help them in this process, need support to carry it out in an effective way. This support should arrive from the media companies, through the establishment of units specifically devoted to this activity but also from governments, to promote the watchdog role of journalists. The support of scientific institutions can facilitate the mining of relevant and trustable science news.

Interesting initiatives have been already developed in this concern as reported in the boxes below.

"Dokumentation" team for fact checking

German media company Spiegel-Gruppe has had a fact-checking team since the 1950s, several years after its print weekly, Der Spiegel, published its first issue. In 2010 Der Spiegel was employing the equivalent of 80 full-time fact checkers, which the Columbia Journalism Review called "most likely the world's largest fact checking operation"[3]. The team, called dokumentation, is organized by experts that cover different topics, such as: politics, science, economics, foreign affairs, culture and sports. The backbone of dokumentation is a database of text articles and official information about notable people, enterprises or topics that could be useful for the journalists at Spiegel-Gruppe. Each week, the database automatically adds another 60,000 articles from German and international media and other official sources like government documents. Here, these journalists also act as in–house experts who already assist during the creation of a text. Their background knowledge and the information gleaned from the author's research often complement each other to create a more multifaceted and complete image (Schäfer, 2011).

More information:
https://en.wikipedia.org/wiki/Der_Spiegel
https://ed.spiegel.de/unterrichtsmaterial/fact-checking-und-recherche
https://digiday.com/media/inside-spiegels-70-person-fact-checking-team/

The Zero Canada Project to deal with the pandemic

A partnership with The Royal Society of Canada enabled the Globe and Mail to tap scientific researchers' expertise on COVID-19, while bringing the society's perspectives to a wider audience.

With The Zero Canada Project, The Globe and Mail created a dedicated online resource, bringing together in-depth reporting and analysis as well as helpful and actionable insights designed to help Canadians deal with the pandemic and reduce its spread. In partnering with The Royal Society of

[3] https://en.wikipedia.org/wiki/Der_Spiegel

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Canada, it gained access to the knowledge and expertise of the society's members as well as its COVID-19 task force, while increasing the reach of the society's perspectives.

More information:

https://wan-ifra.org/2020/12/david-walmsley-journalism-is-about-having-the-wherewithal-to-recognise-what-you-dont-know/

JR3 Organize networking events to lighten the tension between journalists and researchers (JB3, JB2) (RB3, RB6)

The organization of networking events could be very useful to lighten the tension between journalists and researchers (or communication offices) and also to improve the skills of generalist journalists in addressing scientific issues. They should be organized mainly by University and Research institutions - as a sort of Corporate Social Responsibility (CSR) - to promote transparency and integrity in the relationship among them. These events should be built in a way showing to journalists the constraints with which the researchers work and vice versa. Thus, journalists and researchers would have the possibility to understand many things about each other.

French Association of Scientific Journalists of the News Press researchers- journalists exchange initiative

The French Association of Scientific Journalists of the News Press (AJSPI) has been organizing an exchange between researchers and journalists for a dozen years. For a scientist, spending a week in an editorial office is ideal for understanding the issues and requirements of the profession of science journalist. And for a journalist, spending a week in a laboratory and in the field is the best way to get to know the daily life of the research community. The period we are going through shows the importance of the dialogue of trust that must be established between the world of research and that of the scientific media.

More information:

https://www.ajspi.com/vie-association/echanges-chercheurs-journalistes/participation-13e-echange-chercheurs-journalistes-ajspi/

JR4 Promote science coverage by media (JB1, JB4) (RB9)

The promotion by governments at EU and national level of coverage of science in the media can play a double role: on the one side it increases job opportunities for science journalists, thus incentivising the uptake of this career; on the other side it supports science literacy of the public. Coverage percentages assigned to science news, also on prime time on television could be a possible strategy.

Additionally, policies should be implemented at national and European level, by governments and European institutions, in order to: i) to better regulate the adaption of media to the online

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environment; ii) establish some taxations where the revenues from online advertising are shared more fairly among the different involved actors.

JR5 Enhance the job conditions of general and scientific journalists (JB1, JB4) (RB3)

Policies should be implemented to better regulate the job condition of generalist and scientific journalists. Media owners, directors, chief editors, etc. need to understand the importance of allocating enough time to report production. For written media: pay by the hour, not per word, and give the ability to really dive into a subject, but the need for that first has to be understood by those paying the salaries and setting up the timetables. This can work only if the entire news system is revised, including the citizens that should be ready to wait a bit more to read well done news and governments, at EU and national level, that should support the watchdog role of scientists. Better work conditions would loosen the pressure on journalists, and thus could have a positive effect also to slacken the tensions between research institutions and the media.

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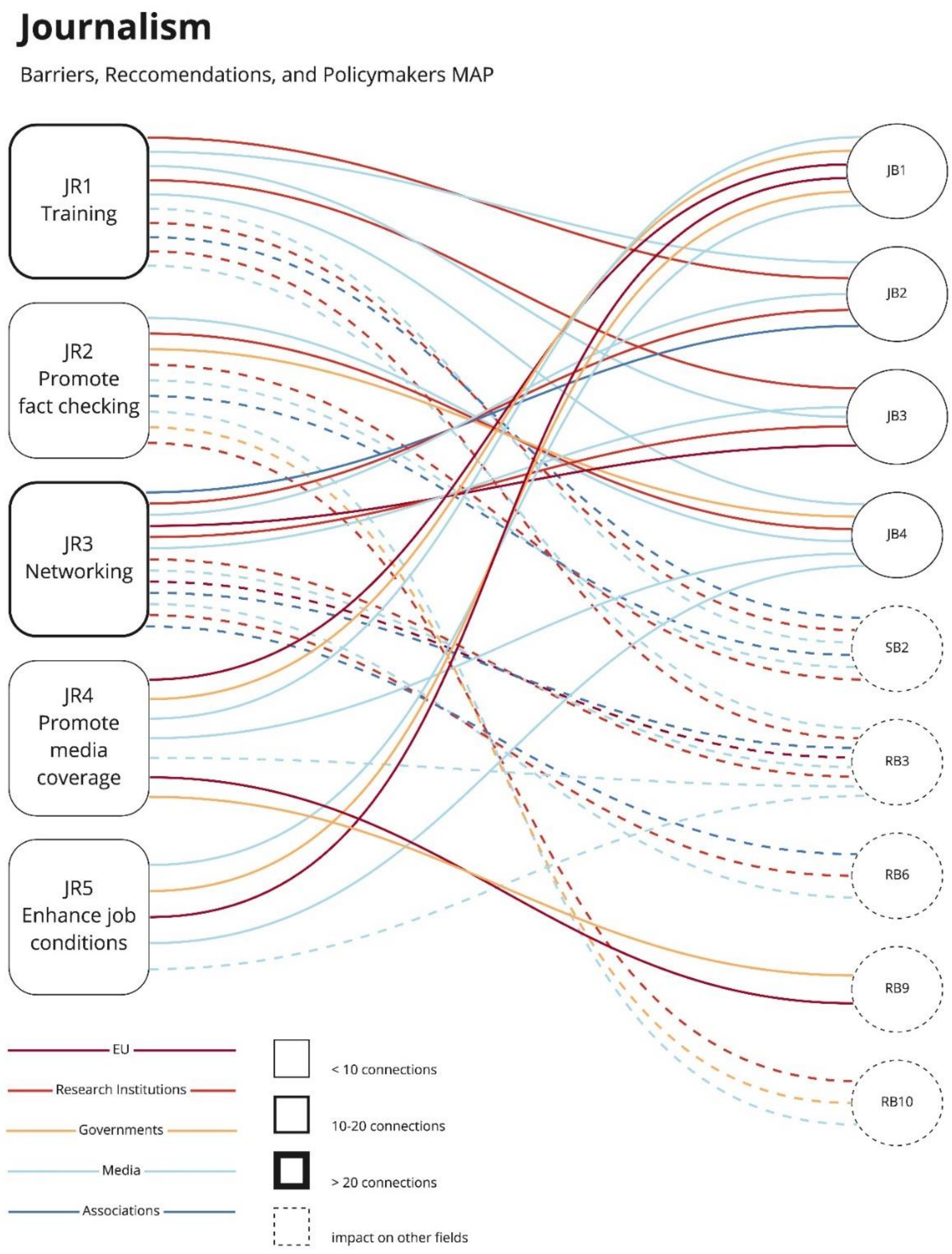

Figure 4: Barriers, recommendations and policy makers for Media sector and Journalists (Barriers mentioned in the figure: Economic sustainability of the news media sector and related few work opportunities for journalists and reduced number of professionals (JB1); Tension and communication issues between science journalists and scientific institutions/scientists (JB3); Skills and training of generalist journalists in addressing scientific issues (JB2); Time availability for fact checking and debunking (JB4); Tensions between research institutions and the media (RB3); Lack of skills of in researchers and tensions with communication officers (RB6); Low citizens' science literacy (RB9); Trust in science and scientists' issues (RB10); Misinformation in social media (SB2)).

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4.3 RECOMMENDATIONS FOR MUSEUMS

MR1 Encourage museums to become a more socially equal and inclusive space (MB1) (RB7)

Museums have a responsibility to be an equitable and accessible resource for all of society, and to make a concerted effort to engage with communities traditionally ignored and pushed out by the academic and cultural elite for centuries. A support system to museums working to be a more socially equal and inclusive space should be designed by the museums' governance bodies, museums associations and funding agencies (public or private both at national and international level) to support the science museum community in the fulfilment of its role in society. The support could be based on **reward mechanisms** that may include allocation of funds based on factors such as staff **trained** in diversity, equality, and inclusion (including the gender dimension) and/or the organizations of **exhibitions** on socially relevant issues or considering organizational aspects of the museum structures designed with a socially inclusive and gender balanced perspective. The support could also be the encouragement of the definition of a publicly available **social inclusion policy by science museums** and the establishment and the promotion of working groups on diversity, equity, and inclusion.

Science Museum of Minnesota public statement on equity and inclusion

An example of how museums can publicly state their position on equity and inclusion is demonstrated by the Science Museum of Minnesota with a public statement on EQUITY & INCLUSION approved by the Science Museum's Board of Trustees in 2018. The statement acknowledges the Museum's role in creating systems of injustice and inequity. The Trustees, senior leaders, and staff are working to change the Museum, themselves, and their companies to be part of the change that society needs now.

The museum commits to using STEM as a tool to advocate for justice and equity. It will:

- INSPIRE LEARNING by including, collaborating, and lifting up the voices of people who have been overlooked or excluded
- INFORM POLICY by illuminating unfairness, inequality, and power imbalances
- IMPROVE LIVES with productive dialogue on topics related to equity, inclusion, and public access to STEM

More information:
https://new.smm.org/equity

MR2 Promote dialogic approaches in museums in line with their educational role (MB2) (RB9, RB10, RB1)

Dialogic approaches should be encouraged within science museums by the Museums' governance bodies. The top-down approach in developing museums activities should become more porous and open to experimentations and collaboration outside the field. Informal science education (as the one taking place in museums) should be supported by recognizing the crucial role that it plays in the overall learning landscape for young people and the value it can bring in **science education**. Dialogic approaches and informal education are considered essential to improve citizens' science literacy (RB9)

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and to help bridge the gap between science and society (RB10). Partnerships with universities, schools and other museums should also be encouraged to build a common framework for engagement of diverse audiences in line with the learning objectives of museums. Research Institutions could take advantage of partnerships with science museums to update their institutional strategies by giving a more prominent role to Public Engagement (RB1).

Sparks project promotion of RRI

Sparks – Rethinking innovation together is a three-year EU-funded research project, started in July 2015 and finished in June 2018, aiming to promote Responsible Research and Innovation (RRI) in the field of technology shifts in health and medicine. Coordinated by Ecsite, Sparks promoted RRI through an interdisciplinary and interactive exhibition as well as participatory activities using innovative formats (i.e. science cafés, pop-up Science Shops, incubation activities and scenario workshops) which took place across Europe. These formats, still openly available at https://www.ecsite.eu/activities-and-services/resources/sparks-toolkit can be of reference for museums to promote the dialogic approaches.

More information:
https://www.ecsite.eu/activities-and-services/projects/sparks
https://cordis.europa.eu/project/id/665825

MR3 Training activities for museums practitioners (MB1, MB2, MB3) (RB9)

Museum practitioners should benefit from dedicated trainings on the skills and aspects essential for their role as science communicators, promoted by museums governance bodies and museums associations in collaboration with academia. Trainings should be organized on the production of engaging materials and formats but also on innovative content development, by promoting the collaboration with artists, exhibition designers, etc, to allow museum practitioners to better combine engagement and learning objectives in their activities. Moreover, specific trainings on diversity, equality and inclusion should be organized to support the inclusive role of museums in the society. Overall, better trained museums practitioners will better contribute to their mission of communicating science to the public and this will help to improve citizens' science literacy.

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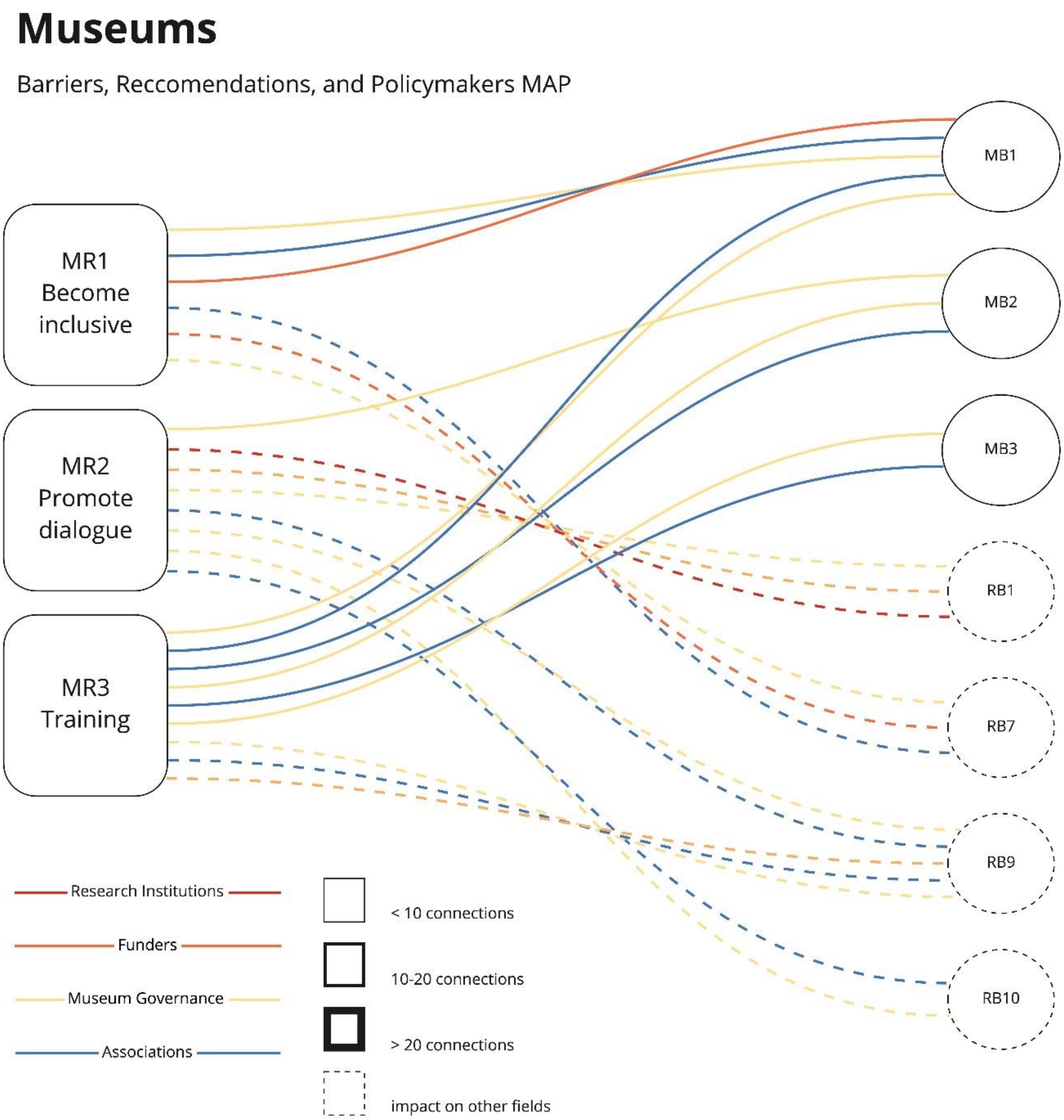

Figure 5: Barriers, recommendations and policy makers for Museums (Barriers mentioned in the figure: Need for inclusiveness and engagement of a wider range of audiences in (science) museums (MB1); Balance between dialogic approaches to engage the public and the educational role of museums (MB2); Lack of skills and training of the museum practitioners in science communication (MB3); Marginal role of Public Engagement in institutional strategy (RB1); Gender Bias in Science Communication (RB7); Low citizens' science literacy (RB9); Trust in science and scientists' issues (RB10)).

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4.4 RECOMMENDATIONS FOR SOCIAL MEDIA

SR1 Promote social media literacy at all levels (SB1, SB2, SB3, SB4) (RB6) (JB2) (MB3)

The limited knowledge of social media dynamics, misperception of social media as the main cause of misinformation, and the lack of skills in using them impair their possible, fruitful use as versatile tools of science communication, able to reach diverse targets that are sometimes inaccessible to traditional tools of communication (youth, people with lack of time, clear interest, previous science literacy, etc.).

A better knowledge of good practices and state of the art on these issues by practitioners as well as by decision-makers in supranational, national, and research institutions is primarily needed to create a better environment for all those who wish to engage and communicate science on the social media. The first four barriers described above (SB1, SB2, SB3, SB4) can all be overcome mostly by better social media literacy at any level, involving every group of stakeholders, from policymakers to common citizens. This can be achieved through education and training in the use of these specific tools: only if scientists, journalists, communicators know well the different social media, their peculiar characteristics, the best way to approach them, they could overcome their limits and make the best out of them for science communication. Very relevant, for the experts interviewed within QUEST project, is education about the way human beings interact with new technologies, their biases, and awareness of the dynamics involved.

The education of citizens on digital and social media may promote awareness and a more responsible use of these channels and help to counteract misinformation spreading.

This goal can be achieved with several concrete actions, addressed to different stakeholders:

- Provide **open remote courses** on EU platforms to improve professionals' use of social media. (SB2, SB3, SB4)

- Recommend academic and professional courses in journalism and science communication to include the use of social media in their **curriculum** (SB4).

- Promote the development of **learning games** (Bioglio 2018) and the design of **cartoons**. These tools, already used in innovative approaches to education, could be specifically designed to help new generations use social media in the best way.

- **Organize a communication campaign** at the European level targeted to adults to promote their best use and counteract misinformation spread through social media as well as the misperception of social media as the only cause of misinformation (PB, SB1).

Go Viral! Understanding misinformation during a pandemic

GO VIRAL! is a 5-minute game designed in partnership by Cambridge University and the UK government that helps the public to protect itself against COVID-19 misinformation. This is not focused on what is true or false, but on teaching users some of the most common strategies used to spread false and misleading information about the virus. The players are introduced to the basics of online manipulation providing a simple guide to common techniques: using emotionally charged language to stoke outrage and fear, deploying fake experts to sow doubt, and mining conspiracies for social media Likes. Understanding these tricks allows people to resist them the next time one

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comes across them online, even in other subjects. In fact, it teaches how to recognize manipulative content, regardless of the issue of social media communication.

The game is a tool for “prebunking”, a sort of “vaccination against misinformation” that elicits “mental antibodies” against strategies of disinformation (Basol 2020, Maertens 2020). Go Viral! is based on a previous experience, when the same researchers designed Bad News, a game which has been played over a million times since its 2018 launch. A test found that just one play reduced perceived reliability of fake news by an average of 21% compared to a control group (Roozenbeek 2019). These two examples could be followed by other games and tools to aim at the same goal.

https://www.goviralgame.com/en?gclid=Cj0KCQiA7NKBBhDBARIsAHbXCB6-Mmomv9mSZrThjXctzgG4kb2_q59O-jSH18mCMtxrrvH3zrXWMEQaAqeBEALw_wcB

SR2 Promote good examples of science communication on social media (SB1, SB5) (RB6) (JB2) (MB2, MB3)

Rewarding and disseminating through European, national, and institutional channels good examples of scientists, journalists and communicators who do a good job in communicating science on social media can play multiple roles. It can on the one side incentivise the communication on social media by scientists, winning the poor reputation of this media comparing to more traditional one in the research context; on the other side, it could help counteract the misperception of social media as environments doomed to misinformation. Moreover, it can provide good models and formats to follow, and encourage researchers to engage.

Awarding **prizes for science communication on social media**, at the single institution, local, national, and international level, can work as good incentive both to encourage scientists, science journalists, and communicators, and to make their example more visible to the public. For instance, the annual **Science Communication Prize** given by the European Commission in the past is a good initiative that could be renovated, including social media.

SR3 Promote further research on quality and efficacy of science communication on social media, spread of mis- and dis- information and the effects of different approaches to counteract them (SB1, SB2, SB3, SB4, SB6)

Social media are relatively new platforms, and the dynamic of information, misinformation, and communication on them still needs a lot of research. A deeper understanding of science communication through these channels is key for counteracting risks related to their peculiar characteristics.

This goal can be achieved with several actions, addressed to different stakeholders:

- **Support** research on science communication on social media, including these issues in the EU, national, local calls for funded projects (SB2, SB4, SB6).

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- **Encourage** studies about science communication on social media within universities, establishing interdisciplinary courses in different programs, since this is a new landscape to discover not only as far as science communication is concerned, but also by sociological, psychological, and technological points of view (SB2, SB4, SB6).

- Provide researchers with **data access**. This is the first and main recommendation from experts interviewed during the QUEST project, because this is key to quantitatively studying the dynamics of these new information environments and to understand how science communication, among the rest, is spread on them. This is an essential precondition for any possible solution to existing problems, especially in terms of misinformation (SB2, SB5, SB6).

- **Support research on the role of platforms in counteracting misinformation.** Facebook, Twitter, YouTube have been experimenting with different approaches to fact-checking content, especially when related to public health, such as during the current pandemic. Research is needed because easy solutions have their downside: removing content considered as "fake news" leads to the question of who is entitled to establish what is true or false, especially in a situation of uncertainty and evolving knowledge such as a pandemic; censoring or reducing the distribution of some content can be arbitrary and hamper the scientific debate, which must be free. If China hadn't stopped the first rumours about strange cases of pneumonia in Wuhan tagging them as fake news, a better and quicker control of the pandemic might have been achieved. Censorship is very risky even when helped by professional fact-checkers, both for a matter of timing and for the specific competencies requested. Not less insidious is tagging as suspect any content diverging from mainstream (SB2, SB3, SB6).

Providing a link to good, certified information and encouraging easy access to quality science communication seems a better approach than censorship to discourage misinformation.

Especially when economic and geopolitical interests are at stake, any limit of freedom of expression can have risks. Rapidity and invasiveness of social media serve "true" as well as "false" information, and falsities can be more easily debunked when a free circulation of ideas is allowed.

Data for good

The huge amount of data gathered by Facebook can be used for humanitarian reasons. Joining the "Data for good" initiative, for example, Facebook provides maps on population movement that researchers and nonprofit organizations use to better understand the coronavirus crisis and which measure can be more efficient in stopping it. Data are given in an aggregate format to protect people's privacy.

"Not only can the data help in identifying and even potentially predicting infection clusters, but it can also help policymakers understand the extent to which social capital and online interactions between different areas can facilitate social distancing, slowing the spread of COVID-19 by having people interact online instead." Ben Charoenwong, Assistant Professor of Finance at the National University of Singapore, explained.

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SR4 Train and support scientists involved in science communication on social media, acknowledging that the time spent on this activity is an important part of their work (SB1, SB2, SB3, SB4, SB5) (RB4, RB6)

According to our surveys several research institutions all over Europe are achieving a better understanding of the importance of social media for the promotion of science in general and of an institution's research, along with that of a scientist.

Many have already started projects with this aim, hopefully bound to be followed by many others. The hurdles set by the pandemic in promoting in-person events, conferences and engagement activities with the public encouraged a growing awareness of the social media potential, waiting to be exploited in science communication.

This goal can be achieved with several actions, addressed to different stakeholders, among which we suggest:

- **Consider science communication on social media within working hours** of researchers, through national laws and/or institutional rule (SB5).
- **Provide training and support** by communication officers to scientists willing to engage (SB4).
- **Never intimidate nor consider a researcher as a spokesperson** for the institution's agenda. Their freedom of speech must be totally respected, also on social media. In case the institution's management should not agree with any statement, it can dissociate, but repercussions or threats of them should not be considered (SB5).

ETH helps its scientists

During the workshop "Train the scientist", organized by QUEST in Venice, on 1st October 2019, Gian-Andri Casutt, Head of Communications of the Board of the Swiss Federal Institutes of Technology ETH in Zurich, provided a good example of how institutions could help their researchers to communicate science, also on social media.

First, not all researchers can, want, or should communicate their science to the public. The communication office teaches those who are interested and helps them to engage through social media in a dialogue, not only to the public, but also to peers, journalists, opinion leaders and especially politicians.

In Switzerland, Italy and other European countries, Twitter is mainly used by these groups, who can be a very useful target for a sort of "marketing of science": going to Twitter lets them know what a scientist and its institution do, which are the scientific reasons for one political decision or why funding research is so important.

They started some years ago and a very successful example is the social media behaviour of climate scientist Reto Knutti. He has become very famous on Twitter and is now invited to TV and interviewed on environmental issues, providing a scientific approach to this controversial theme, even in front of far-right media and politicians.

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ETH scientists who go out to social media do not have to respect guidelines and are free to write and say what they want, though they, of course, need to remember that they are professors of the institution.

SR5 Encourage new business models for science communicators on social media (SB4, SB1) (JB1)

Besides scientists and science journalists employed in big outlets, a lot of science communicators are freelance, who need to earn a living and cannot afford spending hours on social media without economic rewards. To support their precious activity new business models are needed.

In this concern, we suggest designing new **crowdfunding platforms** where science communicators on social media are **endorsed by authoritative institutions**. This can be a guarantee for donors and help communicators to support everyday work. These professionals can often gather passionate communities, willing to pay for the quality of their divulgers' work. Easy ways to donate even small amounts of money without bureaucratic obstacles should be encouraged.

Through Patreon anyone can support science videos on YouTube

Kurzgesagt – In a Nutshell is an initiative started by a German student, who created a simple video to explain evolution, and put it on YouTube. He had a lot of success and started to gather other people to help him. Their animated educational content is very appreciated, so that their YouTube channel became very famous and is currently followed by more than 14 million people. Though YouTube rewards creators according to the number of visualizations, this is not enough for the big staff now engaged. So, they decided to use Patreon, a platform where followers can get access to special content with very cheap subscriptions (1-4,5 euros per month). This platform is used for many uses, and it is not specific for science communication. Anyway, through it, their fans can support them, helping to produce more and better content for YouTube, which is totally free.

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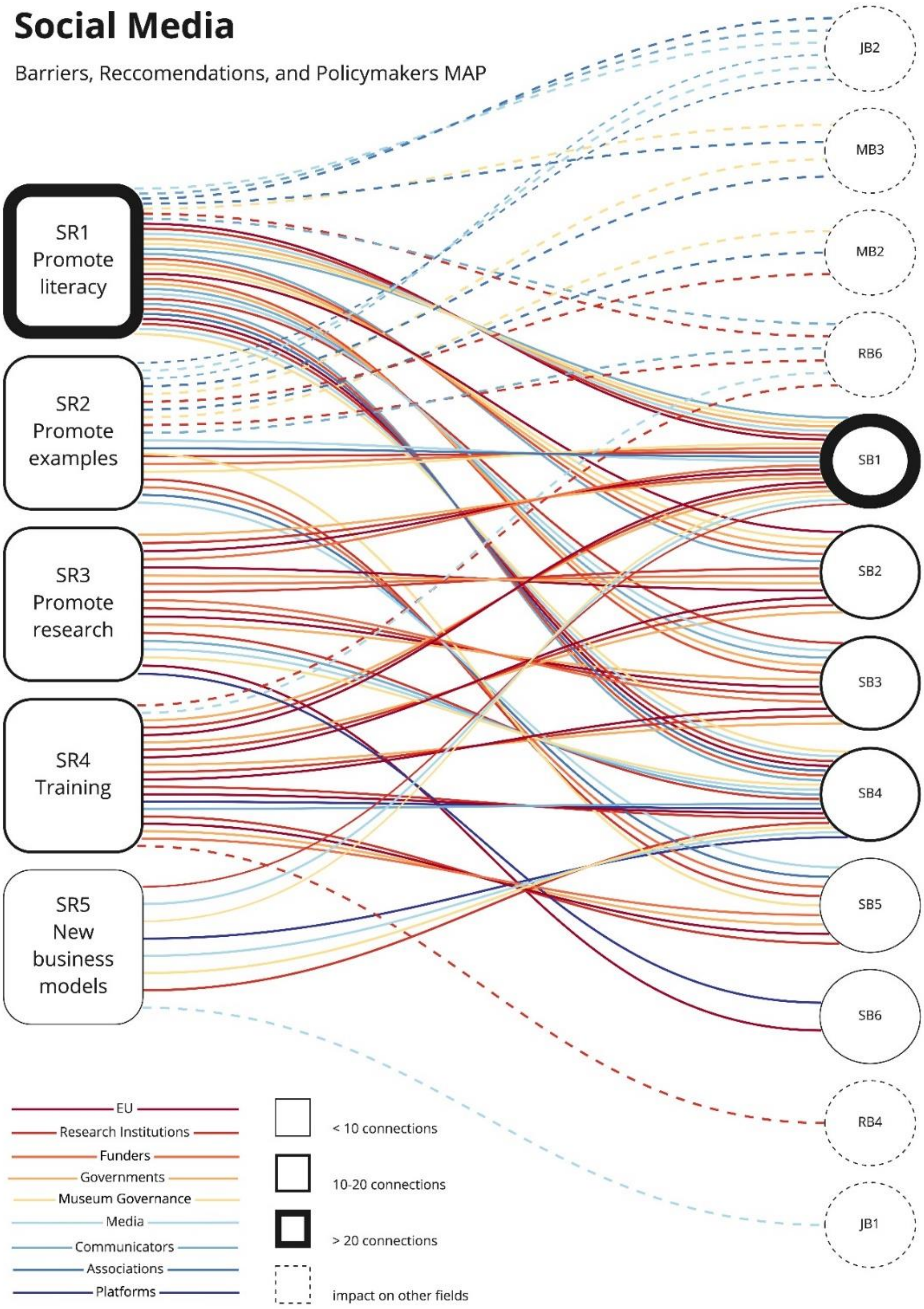

Figure 6: Barriers, recommendations and policy makers for Social media. (Barriers mentioned in the figure: Poor reputation of social media (SB1); Misinformation in social media (SB2); Polarization phenomena (SB3); Lack of social media skills and literacy (SB4); Lack of time and of academic and economic rewards (SB5); Platform regulatory issues (SB6); Lack of recognition of science communication within scientists' tasks and working time (RB4); Lack of skills of in researchers and tensions with communication officers (RB6); Economic sustainability of the news media sector and related few work opportunities for journalists and reduced number of professionals (JB1); Skills and training of generalist journalists in addressing scientific issues (JB2); Balance between dialogic approaches to engage the public and the educational role of museums (MB2); Lack of skills and training of the museum practitioners in science communication (MB3)).

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SECTION 5: RECOMMENDATIONS FOR POLICY MAKERS CATEGORY

The recommendations have been also grouped by policymaker concerned, i.e. EU policy makers, national governments and agencies, governance of research institutions, media decision-makers and associations, museums governance and associations, to promote their dissemination and adoption.

5.1 QUEST POLICY AND INCENTIVE RECOMMENDATIONS FOR EU POLICY-MAKERS

RR1 Further acknowledge science communication and public engagement within institutions' policy and strategic documents

RR5 Promote critical and ethical approach to science communication within institutions

RR6 Favour cooperation over competition among institutions

RR9 Reward quality science communication practices

RR10 Train researchers on science communication on the basis of their needs and with a special focus on women

RR12 Promote gender balance in public events and the media

RR13 Strengthen the support both towards science communication practice and research

RR14 Promote the synergy between research in science communication and the practice

RR15 Promote science literacy in formal education

RR17 Promote the dialogue on science between scientists and citizens through participatory initiatives

JR3 Organize networking events to lighten the tension between journalists and researchers

JR4 Promote science coverage by media

JR5 Enhance the job conditions of general and scientific journalists

SR1 Promote social media literacy at all levels

SR2 Promote good examples of science communication on social media

SR3 Promote further research on quality and efficacy of science communication on social media, spread of mis- and dis- information and the effects of different approaches to counteract them

SR4 Train and support scientists involved in science communication on social media, acknowledging that the time spent on this activity is an important part of their work

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5.2 QUEST POLICY AND INCENTIVE RECOMMENDATIONS FOR NATIONAL GOVERNMENTS AND AGENCIES

RR1 Further acknowledge science communication and public engagement within institutions policy and strategic documents

RR3 Promote the definition and adoption of a common evaluation framework for public engagement

RR6 Favour cooperation over competition among institutions

RR7 Include science communication in the portfolio of researchers' tasks

RR8 Revise evaluation metrics for researchers

RR9 Reward quality science communication practices

RR10 Train researchers on science communication on the basis of their needs and with a special focus on women

RR12 Promote gender balance in public events and the media

RR13 Strengthen the support both towards science communication practice and research

RR15 Promote science literacy in formal education

RR16 Promote science literacy through informal education

RR17 Promote the dialogue on science between scientists and citizens through participatory initiatives

JR2 Promote and support fact-checking and mining of sound science news

JR4 Promote science coverage by media

JR5 Enhance the job conditions of general and scientific journalists

MR2 Promote dialogic approaches in museums in line with their educational role

MR3 Training activities for museum practitioners

SR1 Promote social media literacy at all levels

SR2 Promote good examples of science communication on social media

SR3 Promote further research on quality and efficacy of science communication on social media, spread of mis- and dis- information and the effects of different approaches to counteract them

SR4 Train and support scientists involved in science communication on social media, acknowledging that the time spent on this activity is an important part of their work

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5.3 QUEST POLICY AND INCENTIVE RECOMMENDATIONS FOR GOVERNANCE OF RESEARCH INSTITUTIONS

RR1 Further acknowledge science communication and public engagement within institutions policy and strategic documents

RR2 Establish dedicated unit for science communication within research institutions

RR4 Promote the adoption of guidelines for researchers on how to interact with media

RR5 Promote critical and ethical approach to science communication within institutions

RR6 Favour cooperation over competition among institutions

RR7 Include science communication in the portfolio of researchers' tasks

RR8 Revise evaluation metrics for researchers

RR9 Reward quality science communication practices

RR10 Train researchers on science communication on the basis of their needs and with a special focus on women

RR11 Promote trust and collaboration between scientists and their institutions' communicators

RR12 Promote gender balance in public events and the media

RR14 Promote the synergy between research in science communication and the practice

RR17 Promote the dialogue on science between scientists and citizens through participatory initiatives

JR1 Training activities to increase the science literacy of journalists

JR2 Promote and support fact-checking and mining of sound science news

JR3 Organize networking events to lighten the tension between journalists and researchers

MR2 Promote dialogic approaches in the museums in line with their educational role

SR1 Promote social media literacy at all levels

SR2 Promote good examples of science communication on social media

SR3 Promote further research on quality and efficacy of science communication on social media, spread of mis- and dis- information and the effects of different approaches to counteract them

SR4 Train and support scientists involved in science communication on social media, acknowledging that the time spent on this activity is an important part of their work

SR5 Encourage new business models for science communicators on social media

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5.4 QUEST POLICY AND INCENTIVE RECOMMENDATIONS FOR MEDIA DECISION-MAKERS AND ASSOCIATIONS

JR1 Training activities to increase the science literacy of journalists

JR2 Promote and support fact-checking and mining of sound science news

JR3 Organize networking events to lighten the tension between journalists and researchers

JR4 Promote science coverage by media

JR5 Enhance the job conditions of general and scientific journalists

RR8 Revise evaluation metrics for researchers

RR10 Train researchers on science communication on the basis of their needs and with a special focus on women

RR11 Promote trust and collaboration between scientists and their institutions' communicators

RR12 Promote gender balance in public events and the media

RR12 Promote the synergy between research in science communication and the practice

RR16 Promote science literacy through informal education

SR1 Promote social media literacy at all levels

SR2 Promote good examples of science communication on social media

SR3 Promote further research on quality and efficacy of science communication on social media, spread of mis- and dis- information and the effects of different approaches to counteract them

SR5 Encourage new business models for science communicators on social media

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5.5 QUEST POLICY AND INCENTIVE RECOMMENDATIONS FOR MUSEUMS GOVERNANCE AND ASSOCIATIONS

MR1 Encourage museums to become more socially equal and inclusive spaces

MR2 Promote dialogic approaches in museums in line with their educational role

MR3 Training activities for museum practitioners

RR12 Promote gender balance in public events and the media

RR16 Promote science literacy through informal education

RR17 Promote the dialogue on science between scientists and citizens through participatory initiatives

SR1 Promote social media literacy at all levels

SR2 Promote good examples of science communication on social media

SR3 Promote further research on quality and efficacy of science communication on social media, spread of mis- and dis- information and the effects of different approaches to counteract them

SR5 Encourage new business models for science communicators on social media

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CONCLUSIONS

The work we carried out in QUEST highlighted several challenges to promoting quality and effective science communication. To tackle them we identified recommendations for policies and incentives, based on the literature and exchange with stakeholders as well as on good practices already existing, that show how it is possible to put them in practice.

In some cases, the relevance of recommendations developed are strand/stakeholder specific.

In particular, for **research institutions and scientists**, the need to make science communication and public engagement really embedded in the strategic documents of the research institutions is particularly important. These strategies have to promote a science communication that supports institutional third mission based on responsible research and innovation principles (RRI) instead of on marketing goals. Other important policies are those meant to revise the criteria for assessing research also on the basis of science communication activities, rewarding quality and impact over quantity. At the same time, to make science communication really effective, it is crucial to consider the role of the public and increase the literacy of the audience, but also trust in science, building a constructive dialogue between scientists and the public.

For the **media sector and journalists**, policies and tools that promote fact checking and mining of sound science news are proposed as fundamental for quality science communication. Another interesting strategy to be implemented by governments and by the media themselves that got the support of the stakeholders can be the promotion of science coverage by the media, thus ensuring to give enough room to science. This can also positively affect the sustainability of science journalism as a field of practice, with new job opportunities and better conditions for journalists, bringing also more time for fact checking and debunking. Ultimately, by making the public more exposed to science, those improvements could play a role in increasing science literacy as a form of informal education.

Concerning **museums**, the specific policies recommended by QUEST focus on the importance of an approach engaging and inclusive towards diverse audiences. Establishing a dialogue with the public implies going beyond the educational role traditionally played by museums.

As regards the **social media**, we highlighted the importance of strengthening the study and the support of research, particularly in relation to misinformation and polarization issues. Furthermore, we suggest incentivising the sharing of good practices of science communication through social media. Particularly important is also to increase social media literacy of the users, to tackle the misinformation spread: knowing how this media works can help in detecting more easily the fake news.

Beyond the strand specific recommendations, some of them are very transversal. One recommendation that comes back for each strand and stakeholders is the **need of training**:

- scientists have to be provided with at least the basics for science communication from their earliest studies, including on how to deal with the different media;
- journalists need to be trained in particular on scientific issues;
- museum explainers need to develop further capacities to promote inclusiveness and the dialogue with the public;
- finally, there is a common need for training to learn how to communicate science effectively through social media and increase social media literacy.

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We also detected, both in the literature and talking directly with the stakeholders, several **tensions among the science communication stakeholders**:

- between scientists and their institution communication offices, linked mainly to a discontinuous exchange among them;
- between the media and/or journalists and scientists and research institutions, the former complaining about the marketing action of research institutions that submerge them with press releases, the latter fearing to get their messages misreported, banalized or sensationalized;
- but also the limited current interaction between museums and scientists;
- or the lack of trust of the public in scientists, media and in institutions.

What becomes essential in this concern is to introduce policies and incentives to promote positive and stable exchanges and networking between the above-mentioned actors. The governance bodies of the different institutions (research institutions, media, museums) are those that should act in the first place. Nevertheless, governments and funders in general can play an important role supporting these strategies. Some good practices in this concern already exist. We presented cases of exchanges between media and scientists funded by national governments. Other networking activities have been carried out to promote the mutual knowledge, collaboration and trust between the public, the scientists and the various communicators.

In terms of relations among the different stakeholders, we also identified the need for further research on quality and effective science communication, that has be complemented with the promotion of the interaction among researchers and practitioners, so that the knowledge can really support quality science communication.

As seen, what is particularly interesting to notice, both for the strand specific and transversal recommendations is that each policy and incentive we suggested requires the action of more than one stakeholder to be introduced and implemented successfully: different institutions themselves (research centres and universities, media institutions, museums, social media platforms), governments, funders, scientists, and communicators all play a fundamental role in introducing the identified recommendations.

Moreover, each policy and incentive can impact on different challenges, not only within the same strand, but also beyond it. The recommendations on the promotion of dialogic approaches in museums and on the organisation of networking events among journalists and researchers are good examples of this interrelationship: both contribute to overcoming obstacles identified in other fields, especially in research institutions, on top of barriers relevant to museums or the media. This example brings out the value of the effort to study and identify the barrier-solutions relationships both vertically - on the same strand - and horizontally - among different strands.

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