Opportunities and barriers for strengthening the quality of interaction between science and society

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Executive Summary

The RETHINK project aims to enhance science communication so that it creates and supports open and productive interactions between science and society. This aim is motivated by two recent and interrelated developments that highlight the need for rethinking science communication, namely the blurring boundaries between science and society and digitalization.

In order to meet this need, it is crucial to understand more about the science communication ecosystem: Who communicates what to whom, how, why and on which conditions? How do people make sense of complex science-related problems? How are professional science communicators trained? And what is 'good' quality science communication in a digital media landscape? In order to address these questions, this report provides a cross-cutting analysis of the research done in RETHINK on these areas so far, with the aim of creating a solid foundation for future development of science communication fostering a more fruitful interaction between science and society in general. This research is based on a multiplicity of methods and investigations that has been conducted over the past two years by partners across Europe.

The report shows that the science communication ecosystem in the recent years has become more complex and diverse in terms of the amount of actors, information, interactions, practices, etc. As a consequence, a number of both opportunities and barriers for strengthening the quality of interactions between science and society has arisen.

Opportunities identified:

- A diversity of science communication actors exist using a variety of platforms and formats that can potentially enrich conversations on science-related topics.
- A majority of science communicators play the role of convenor and aim to create conversations between researchers and the public.
- A majority of science communicators regularly use mainstream social media providing the potential to reach a broader audience in new ways.
- Sensemaking practices are dynamic and continuous, which in principle enable science communication to facilitate openness and reflexivity.
- Many scientists feel an intrinsic motivation and sense of responsibility to engage in science communication and want to democratize science.
- Scientists indicates that the fast-paced nature of online communication can facilitate more conversations.
- Academic science communication programs overall *aim* to provide their graduates with specific knowledge, competences and attitudes that will help them to serve as professional communicators in an increasingly complex science communication environment.
- Some science communication programs also *convey* a perception of science communication as an interaction between science and society including co-production in a complex digital environment.
- Some science communication programs emphasize critical thinking.
- Most science communication scholars point to dialogue and two-way communication as important quality criteria.
- Science communication scholars point to the quality of communication being dependent of the context in which it takes place.

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- Science communication scholars point to many possible ways to strengthen quality standards.
- Increasing science communication training of scientists and the growing demand for outreach and public engagement activities seems to have led to an overall normative acceptance of quality promotion by professional science communicators.

Barriers identified:

- The digital communication environment is complex and social media algorithms and APIs limit the sources that one is exposed to online.
- A majority of science communicators play the role of conduit and aim to inform the public about science, which implies deficit thinking.
- Science communicators experience a lack of time and resources for engaging in science communication.
- A majority of science communicators aim to reach audiences with a pre-existing interest in science and undeserved audiences are seldom the focus of their activities, which reproduces inequalities in access to knowledge.
- Science communicators experience a sense of disconnect with their audiences, which is demotivating.
- Sensemaking practices are heavily dependent on people's personal situation, emotions, a priori beliefs.
- There is a potential mismatch between the desires of some scientists to inform the public, the interpretation of some scientists that audiences are not responsive to facts and organizational guidelines that are not focused on informing, which can demotivate the scientists to engage in science communication.
- Scientists experience bad and non-constructive interactions online causing them to stop engaging in conversation.
- Scientists experience a lack of time, organizational support and professional incentives for engaging in science communication.
- Academic science communication programs differ with regard to the extent to which the programs are aware of and adapt to a changing communication environment characterized by digitalization.
- Some science communication programs convey a more traditional perception of science communication as a one-way process in which the public is informed.
- Science communication scholars do not reflect upon new communication settings to the same degree that they reflect upon more traditional settings.
- Science communication scholars don't agree on how and if we should strengthen quality standards.
- We still know little about training in dialogue-based science communication outside the universities' academic programs. To what extend are science knowledge brokers like journalists, health care professionals, communication officers, staff at museums and NGOs equipped to deal with the complex digital science communication environment?

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1. Introduction

The overall aim of the RETHINK project is to enhance science communication so that it creates and supports open and productive interactions between science and society, as this is vital for a healthy democracy. This aim is motivated by two recent and interrelated developments that require us to rethink science communication.

First, the boundaries between science and society have become blurred meaning that the public is confronted with a vast amount of information from a variety of sources, some including biases and vested interests (Nowotny et. al, 2001). Consequently, opinions are increasingly becoming mixed with facts and scientific issues are becoming politized, which highlights the importance of how the public makes sense of science.

Second, science communication has become heavily digitalized, fundamentally changing the relationship between science and society. On the one hand, it creates new opportunities to quickly and easily accessscientific findings. On the other hand, it poses new challenges such as the emergence of echo chambers and misinformation (Bubela et. al, 2009).

In order to address these developments and meet the need to rethink science communication in a way that fosters fruitful interactions between science and society, we need to understand more about:

1. The landscape of communicators in terms of who communicates what to whom, how, why and on which conditions, as the internet has created a more pluralistic, participatory and social ecosystem that influences the status, structure and mechanisms of science communication (Fahy and Nisbet, 2011, p.778).
2. How people make sense of complex science-related problems, as this is crucial to the effectiveness and relevance of science communication.
3. Science communication training and quality, as the changing science communication landscape requires new competences and approaches to communicate science.

This report provides a synthesis of the research into these areas already conducted within RETHINK. This research is based on a multiplicity of methods and investigations conducted across Europe. At the heart of the RETHINK project are the 'Rethinkerspaces', communities of science communication practice that are involved in research and act as testbeds for innovative approaches to communication that arise from it. They include scientists and other R&I stakeholders, practitioners such as journalists and public engagement professionals, and citizen enthusiasts such as bloggers and DIY scientists – and located in seven countries across Europe: The UK, the Netherlands, Italy, Poland, Serbia, Sweden and Portugal.

Within RETHINK, the Rethinkerspaces are involved in three phases of inquiry; understanding the science communication landscape, developing and experimenting with new roles and strategies, and synthesizing recommendations and guidelines for scientists, practitioners and policy-makers.

More specifically, this report draws on findings more fully reported elsewhere in the RETHINK deliverables:

- D1.1 Scoping Report on the Science Communication Ecosystem
- D1.2 Report on the Working Practices, Motivations and Challenges of those Engaged in Science Communication

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- D1.3 Investigating the Links between Science Communication Actors and between Actors and their Audiences
- D2.1 Report on Incentive and Disincentive Structures for Research and Innovation Stakeholders to Engage in Science Communication
- D2.2 Making Sense of the COVID-19 Pandemic – An Analysis of the Dynamics of Citizen Sensemaking Practices across Europe
- D2.3 Report on the Barriers and Opportunities for Opening Up Sensemaking Practices
- D3.1 Analysis of the Status Quo and Demands for Science Communication Training
- D3.2 Report on Experts' Views on Current Science Communication Quality and Demands

This report aims to draw together key strands of this research and take stock of the findings so far in RETHINK. In doing so, it aims to provide insights into the state-of-the-art of current structures and practices in contemporary science communication that will provide a solid foundation for developing frameworks and recommendations in the future of the RETHINK project, which can foster a more fruitful interaction between science and society. Within this report, this will be undertaken in five steps:

First, the theoretical approach of the project that guides the research and synthesis of RETHINK is outlined, fleshing out concepts such as sensemaking, roles and repertoires, reflexivity and openness.

Second, the mapping of the ecosystem in terms of who communicates what to whom, how, why and on which conditions is analyzed, showing the complexity of the ecosystem as well as the opportunities and barriers that it creates for strengthening the quality of interactions between science and society.

Third, the interactions at the science-society level in terms of science communicators (dis)incentives to engage in science communication and citizens' sensemaking practices are analyzed, showing that there might be different mismatches between communicators and citizens about why and how science should be communicated.

Fourth, the status quo of science communication training and potential quality criteria for science communication in a digital media landscape are analyzed, demonstrating that it is challenging to identify generalizable competences, skills and quality criteria for science communication in such a landscape.

Fifth, the synthesis is concluded and preliminary suggestions for how to potentially foster a more fruitful interaction between science and society are outlined, providing a steppingstone for future work in the RETHINK project.

2. Theoretical Approach

Science communication builds a bridge between science and society and enables the public to access and understand science as well as the relation between science and society. This is a vital function in fostering a healthy modern democracy, in which rules are based on the will of the people and informed by the best available knowledge, and in fostering responsible research responsive to the perspective of citizens (von Schomberg, 2011).

Understanding science, however, is a challenging task, which makes high demands for science communication, especially in a digital knowledge society where people are constantly exposed to an abundance of information. A recurrent notion in science communication is the idea that some disagreement and opposition to scientific knowledge is caused by ignorance or a lack of information and

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that this ignorance can be countered by the provision of scientific knowledge. This notion is known as **the deficit model** in accordance with which science communication becomes a matter of transferring knowledge to people with knowledge deficits. In other words, science is assumed to speak for itself and to be interpreted by audiences in similar ways, which is why the role of the communicator predominantly becomes to ensure accurate transmission between science and society (Nisbet & Scheufele, 2009).

In contrast to this model, recent research suggests that scientific knowledge is not self-evident, stable or fixed. Instead, people's understanding and interpretation of science is influenced by their beliefs and backgrounds. They arrive at different interpretations of science depending on their values, interests, motivations and contexts (Sinatra et. al, 2014). For this reason, the concept of **sensemaking** is central to RETHINK. According to the sensemaking theory, gaps in knowledge are a human condition, which is why knowledge is never complete. People are constantly making sense trying to bridge the gaps in their knowledge as they are moving through time and space. In order to so, they draw on a variety of sources such as previous experience, expectations, emotions, values and interest (Dervin, 2010).

This insight into the contextuality of knowledge is especially important in a digitalized communication environment, as it increases access to scientific knowledge and the number of actors and networks in the communicative space, thereby increasing the number and diversity of sensemaking practices. In other words, digitalization increases the demand for and importance of science communication but also demands that science communicators reconsider their roles, as the conditions for supporting citizens in understanding science and maintaining the trust between science and society have changed (Bubela et. al, 2009). For this reason, another set of central concepts to RETHINK is **roles and repertoires**. Just like scientific knowledge can be interpreted in different ways, it can be communicated in different ways. According to the notion of roles, there is no one single objective way of communicating. Instead, communicators inevitably need to choose between different potential roles to play in different contexts. In other words, the term is used to describe a characterization of the activities of an individual engaged in science communication (Pielke, 2007). Depending on which role a communicator plays, the communicator draws on different repertoires representing a certain perspective on the relation between knowledge production and use as well as a set of work-related activities that complement these (Turnhout et. al, 2013).

Informed by these theoretical insights, RETHINK aims to foster closer, more effective interactions between science and society in meeting the need of rethinking science communication. This includes contributing to the enhancement of openness and reflexivity, which crucial to letting the contextual knowledge of citizens play a central role in the shaping of future developments. Moreover, it helps to handle the potential societal conflicts and controversies that the partiality of scientific knowledge and roleplaying nature of science communicators might cause in a digitalized world.

Here, **reflexivity** is understood as the capacity or action to consciously and critically consider one's own context, motivations, assumptions, expectations, positions etc. and how they relate to and influence the understanding of scientific knowledge (Salmon et. al, 2015). It "means holding a mirror up to one's own activities, commitments and assumptions, being aware of the limits of knowledge and being mindful that a particular framing of an issue may not be universally held" (Stillgoe & Macnaghten, 2013). In other words, reflexivity constitutes a self-awareness or second order reflection that, on the one hand, requires communicators to actively consider how their communication is received, what they include and exclude and why and, on the other hand, requires the audience to actively consider on what grounds they base their opinions and world views and why. Relatedly, **openness** is understood to be the willingness to both attend to new information and sources, to open up reflections to dialogue and new perspectives, and

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potentially change one's view. This way, one takes in more diverse amounts of information, which may immediately conflict either internally or with one's previous intuitions (Carpenter et. al, 2018).

The above concepts will be used throughout the report to explore the current role and practice of science communication and the interactions between science and society in a digital media landscape.

3. Analysis

In order to take the first steps toward rethinking science communication and improving the quality of interaction between science and society, the following analysis aims to synthesize the findings of RETHINK so far. This synthesis is structured in three parts aligning with the structure of the project and its research outputs.[1]

First, the landscape of communicators is analyzed drawing on a mapping of the actors, the platforms they use and the nature of their communication, as well as an investigation into their working practices and motivations and also the links between communicators and their audiences.

Second, the science-society interfaces are analyzed drawing on an investigation into the (dis)incentivestructures for scientists to engage in science communication and research into the sensemaking practices of European citizens.

Third, science communication training and quality are analyzed, drawing on an exploration of the nature of current science communication education programs and an investigation of quality criteria in the digital media landscape.

Each part ends with a section taking stock of the findings so far, providing lists of potential opportunities and barriers for strengthening the quality of interactions between science and society.

3.1 Scoping the science communication ecosystem (D1.1)

Digitalization has created a more fragmented and pluralistic communication landscape (Fahy and Nisbet, 2011). In order to understand the nature of this landscape, identifying its risks and opportunities, the RETHINK scoping study maps the actors engaged in science communication online, the nature and format of what they are communicating, and the platforms they are using within seven European countries: the UK, the Netherlands, Italy, Sweden, Portugal, Poland, and Serbia. In order to narrow down the scope of the study, three science-related topics were chosen as case studies, namely climate change, artificial intelligence, and healthy diets. The study is based on an online search for science-content available in each of the countries using a common search protocol.

The mapping shows that the online science communication ecosystem is characterized by a broad and diverse group of **actors** that is different between science topics as well as between countries and includes, among others, media organizations, journalists, governmental agencies, policy makers, NGO's, activists, think tanks, foundations, interest organizations, science museums, universities, research centers,

[1] The insights of D2.3 Report on the barriers and opportunities of opening up sensemaking practices are included throughout the analysis and are not treated separately.

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scientists, businesses, and non-professional communicators such as bloggers and influencers. In other words, it includes a variety of institutions and individuals.

Moreover, the communicators use a variety of different **platforms** across countries and science topics e.g. websites, blogs, LinkedIn, Facebook, Instagram, Twitter, YouTube, podcasts, Reddit, and fora in order to share content and links, tell stories, and express personal or professional opinions and explanations. This is done via **formats** such as text, photos, charts, infographics, videos, cartoons, drawings, and memes. The choice of platform and format often relates to the nature of the topic communicated. For example, Instagram is used more in relation to food because the platform allows food to be communicated in a visual way.

In sum, the mapping shows that the online ecosystem is different in different countries in terms of platforms and communicators. It also shows that it is different across science topics in these respects too. While overall the ecosystem is complex, diverse and democratized in the sense that it is not dominated by one single actor, platform or format, the ecosystem can look quite different depending on where you live and which topic you are engaging with online. Still, the mapping confirms that science journalists are no more "the principle arbiters of what scientific information enters the public domain and how it does it" (Trench, 2007: 141). The internet allows users to encounter an abundance of information, opinions and sources, which both enables rich and nuanced conversations as well as misinformation and misinterpretation and thus raises questions of trust and reliability: How should and could one assess and navigate all the information and distinguish correct from incorrect? Furthermore, by describing the complexity of the science communication ecosystem, the mapping illuminates the potential breadth and size of the task of rethinking science communication and nurturing a science-society relationship that is more open and reflexive.

3.2 Working practices, motivations and challenges of actors engaged in science communication (D1.2)

Having gained an insight into the diversity of actors in the online science communication ecosystem, the question of which roles they might play and what this means to the science-society relationship arises. Consequently, RETHINK has described the roles and repertoires of science communicators by investigating how and why they communicate. Here, Fahy and Nisbet's (2011) role typology is used in order to characterize the activities of the communicators, i.e. whether they are conduits, agenda-setters, watchdogs and so on. Furthermore, Turnhout et. al's (2013) notion of repertoires is used to characterize the communicators' perspective on the science-society relationship and activities implied by there actions that complement these, i.e. whether the communicators see themselves as supplying, bridging or facilitating information.

A survey with a total of 459 respondents mainly from the UK, the Netherlands, Italy, Sweden, Portugal, Poland, and Serbia asks questions about their professional roles, what they communicate, what they are trying to achieve when communicating, what aspects they think are important to communicate, what motivations they have for communicating, what barriers there are for communicating, how they communicate, what digital media they use to communicate, how they choose what to cover and what sources they trust. Although the respondents included a great variety of communicators, both professional, non-professional, full-time and part-time, most of the respondents were 'traditional' communicators such as journalists, press officers, researchers, and lecturers.

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The answers to the above questions show that the respondents take on a variety of roles but mainly the ones of:

1. Conduits: Explaining or translating science from experts to non-specialists.
2. Convenors: Bringing together scientists and non-specialists to discuss science-related issues.
3. Civic educators: Informing non-specialists about methods, aims and limits of their scientific work.
4. Watchdogs: holding scientists, industry and political organizations to scrutiny.

The role of **conduit** is the most prevalent, as many respondents described the primary aim of their communication as being either informing the public about science or educating the public. These aims were also reflected in that many communicators thought that new research and scientific information and facts were the most important aspects of science to communicate and that many respondents were motivated to communicate because they were keen to educate others about science.

Yet, a majority of the respondents also described the aim of their communication as creating conversations between researchers and the public, which indicates the presence of a **convener** role acknowledging the importance of public engagement.

Lastly, there is evidence of many science communicators taking on the role of **civic educator** and **watchdogs**, respectively. In the role of civic educator, many respondents thought that it was important to communicate scientific processes and methods as well as the enjoyment and enthusiasm of doing science. In the role of watchdog, many respondents aimed to counter misinformation.

Taking into consideration these roles and the motivations of the respondents, it is notable that relatively few aim to reach underserved audiences (22,7 %, n=105). This poses a challenge to reaching a more equal and close science-society relationship.

Turning to the repertoires of the respondents, their answers translate into differing conceptions of the science-society relationship. First, the role of conduit corresponds with a **supplying repertoire** according to which experts supply knowledge users with answers to questions, thus suggesting the existence of clear boundaries between science and society. Second, the role of convenor corresponds to **bridging repertoire** according to which experts mediate and translate between science and society blurring the boundaries. However, the latter repertoire is less prevalent among the respondents.

Besides the roles and repertoires, the study also shows that a majority of the respondents use mainstream social media regularly to communicate in one way or the other, i.e. on behalf of their organization, in a professional capacity, in a personal capacity etc. However, they are mostly used to disseminate written formats, whereas audio, visual, and collaborative formats are less present.

Finally, respondents indicated that lack of time and resources are the most important reasons for why they do not engage more in science communication, which raises questions of the perceived value of science communication as well as the organizational support for undertaking it.

In sum, the study shows that despite the diversity of actors in the science communication ecosystem, the roles that surveyed science communicators assume and their perspectives on the science-society relationship tend toward being traditional, implying the deficit model to a certain extent. That is, the respondents' motivations align more with one-directional forms of communication and written formats than with dialogical forms of communication and newer formats enabled by digital media. However, this does not mean that the deficit approach applies to all communicators (as highlighted above many were convenors). Moreover, the tendency should also be seen in context of the extent to which two-way

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dialogue is feasible or appropriate in different forms of science communication and the context of science communicators experiencing a lack of time and resources for engaging further in communication activities. The incentives and disincentives for engaging in science communication are further elaborated later. In other words, the study illuminates that the roles science communicators play is partly influenced by their own motivations and perceptions and partly influenced by the conditions under which they operate.

3.4 Links between science communication actors and their audiences (D1.3)

In order to open up science, it is not just important to know who the science communicators are, how they communicate, and which roles they play. It is also important to know how they relate to their audiences, which is why REHINK has investigated the audiences that science communicators seek to reach and who they believe they reach in seven European countries: UK, the Netherlands, Italy, Sweden, Portugal, Poland, and Serbia. The study investigates the nature of the connections between communicators and audiences as well as the barriers that communicators' experience in forming or developing these connections based on the survey used in D1.2 and workshops in the Rethinkerspaces.

The survey has a total of 459 respondents and asks questions about which audiences the respondents aim to reach, whether they believe these audiences are already interested in science, where their audiences are from, in what language they communicate to their audience, whether they produce or curate content and whether this content is evaluated. Although the respondents covered a great variety of communicators, both professional, non-professional, full-time and part-time, most of the respondents were 'traditional' communicators such as journalists, press officers, researchers, and lecturers.

The answers from the survey show that science communicators seek to reach a wide range of audiences with variations across professional roles and countries. Yet, almost all of the communicators seek to reach non-specialists and many seek to reach university students and school teachers. The communicators also show a high degree of focus on audiences with a pre-existing interest in science and target mainly national and international audiences.

Only a minority of the respondents seek to reach underserved audiences, but this varies across countries and might therefore be related to differences in policies. However, it cannot be excluded that there could be gaps between science communication policies towards reaching underserved audiences and actual practices.

Finally, the survey shows that a majority of the respondents both produce, curate and evaluate content. The latter is done by e.g. checking analytics on websites or social media or carrying out questionnaires and it is done both in collaboration with others and individually.

In addition to the survey, workshops in the Rethinkerspaces show that science communicators experience several barriers to connecting with audiences. The nature of these barriers is influenced by the role of the science communicator, their intended audience and the medium of communication employed. For example, communicators experience that on digital platforms such as social media that seemingly enable interaction with their audiences, interaction simply does not take place. Relatedly, communicators lack feedback that can generate a dialogue and enable them to learn more about what their audiences want and how they receive their communication, which altogether creates a sense of disconnect. They also have a hard time breaking with the existing (infra)structure that they are part of organizationally and digitally to reach a broader audience. Furthermore, time is a big constraint both in terms of the time communicators have to engage with their audiences and the time audiences have for engaging with

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communicators. Relatedly, communicators sometimes experience a lack of interest from their audiences as a barrier.

In sum, the study shows that despite the blurring boundaries between science and society and the potential of digital media to reach a larger audience and to stimulate two-way communication, science communicators generally aim to reach an audience of non-specialists, already interested in science and may end up using digital media as a one-way medium in many instances. However, the workshops in the Rethinkerspaces show that even though communicators seek to establish interaction and dialogue with their audiences, they still experience barriers in their attempts to reaching them and, hence, feel disconnected with them. Moreover, the workshops show that communicators might have intentions to reaching broader audiences and engage in dialogue with them, but do not always have the time and resources to do so.

3.5 Taking stock of the science communication ecosystem

Considering the above mapping of the science communication ecosystem as a whole, investigating who communicates what to whom, how, why and on which circumstances, it shows that the ecosystem has been digitalized and democratized in the sense that it includes a great variety of actors communicating on a great deal of different platforms using a broad palette of formats. The mapping also shows that the conditions for opening up science and creating a constructive relation between science and society is, in principle, present. It is technically possible for both experts and non-experts to communicate science and it is possible for people to consult a large variety of sources, which altogether provides a potential for enriching communication and conversations on different science-related topics thereby facilitating openness and reflexivity. However, the results indicate that this potential is not being fully taken advantage of in all circumstances, and the potential also depends on the topic communicated, as not every field is equally diverse in terms of actors and the platforms and formats that they use.

On the other hand, the plethora of communicators, platforms and formats poses some challenges in terms of figuring out what is trustworthy and what is not, what is valid and what is not etc. In other words, the science communication landscape contains the potential for misinformation to spread broadly in the matter of no time and the potential to limit sources that one is presented with as a consequence of social media algorithms and search engine APIs. Thus, the diverse science communication ecosystem might not be as open in practice as it looks and demands a strong reflexive capacity or ability to constantly consider the circumstances under which information is communicated and understood.

Taking a closer look at the actual working practices, motivations and links between communicators and audiences, they seem to be characterized by a tendency toward informing rather than engaging with audiences, focusing on facts rather than processes, writing and presenting rather than showing via alterative formats, seeking interested rather than disinterested audiences, and communicating with somewhat typical science communication audiences rather than those who are underserved etc. In other words, a majority of the surveyed and interviewed communicators seem to approach their communication activities in a slightly traditional way that implies deficit thinking to some extent and does not necessarily take advantage of the potential in the digitalized and democratized landscape to foster two-way communication, reaching a broader audience and using alternative formats. This tendency might risk limiting the communicators exposure to the perspectives of others enabling them to see how their own context has a bearing on their assumptions. It might also limit the perspectives and information that the communicators take into account.

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However, this is not to say that efforts to engage in dialogue with a wider audience in multiple ways are completely absent. There are indeed two-dialogues happening in online science communication, also with underserved audiences, and some communicators strive to establish these dialogues but find it challenging even though the digital platforms in principle enable it. For example, a large number of communicators aim to convene discussions between experts and non-specialists, which bridges two domains and supports the enhancement of openness and reflexivity. Moreover, it should be taken into consideration that two-way dialogue and reaching wide audiences is not always appropriate and feasible in different types or formats of science communication, that the respondents of the surveys carried out were dominated by traditional communicators such as journalists, press officers, researchers, and lecturers and that the mapping is mainly descriptive and exploratory, offering only few indications as to why the landscape looks like it does. Some of these indications, however, point to the fact that science communicators lack time and resources for engaging further in communication activities and that science communication is not perceived as being valuable. Moreover, science communicators feel disconnected from their audiences and sometimes experience a lack of interest as a barrier for engaging in communication activities, which seems to correspond with the fact that communicators mainly target audiences that already have an interest in science. These indications are worth noting as they might pose a challenge for engaging a broader audience in reflecting on scientific knowledge. Furthermore, they show there might be both individual, structural, and cultural factors influencing what the landscape looks like. This is further elaborated in the study on the (dis)incentives of engaging in science communication described later.

To summarize, the intention to enhance open and reflexive science communication is achieved to varying degrees keeping in mind that there are national differences. Yet, there is a great deal of potential and opportunities for opening up science and fostering fruitful interactions between science and society as well as concrete barriers that can be addressed.

Opportunities for improving the quality of interaction between science and society

- A diversity of science communication actors exist using a variety of platforms and formats that can potentially enrich conversations on science-related topics.
- A majority of science communicators play the role of convenor and aim to create conversations between researchers and the public.
- A majority of science communicators regularly use mainstream social media providing the potential to reach a broader audience in new ways.

Barriers for improving the quality of interaction between science and society

- The digital communication environment is complex and social media algorithms and APIs limit the sources that one is exposed to online.
- A majority of science communicators play the role of conduit and aim to inform the public about science, which implies deficit thinking.
- Science communicators experience a lack of time and resources for engaging in science communication.
- A majority of science communicators aim to reach audiences with a pre-existing interest in science and undeserved audiences are seldom the focus of their activities, which reproduces inequalities in access to knowledge.
- Science communicators experience a sense of disconnect with their audiences, which is demotivating.

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3.6 Incentive and disincentive structures for scientists to engage in science communication (D2.1)

Based on RETHINK's mapping of the science communication ecosystem, it seems that the conditions for opening up science and strengthening the interaction between science and society in principle exist. Furthermore, there are indications that communicators are also willing and able to utilize the opportunities of digitalization to some extent. In order to get a deeper insight into the motivations of especially scientists to engage in science communication, RETHINK has investigated their incentives and disincentives or facilitators and barriers for doing this. The study investigates these (dis)incentives within five spheres that are both internal and external to the communicator and constitutes:

1. The individual sphere
2. The interpersonal sphere
3. The organizational sphere
4. The science communication and policy sphere
5. The societal sphere

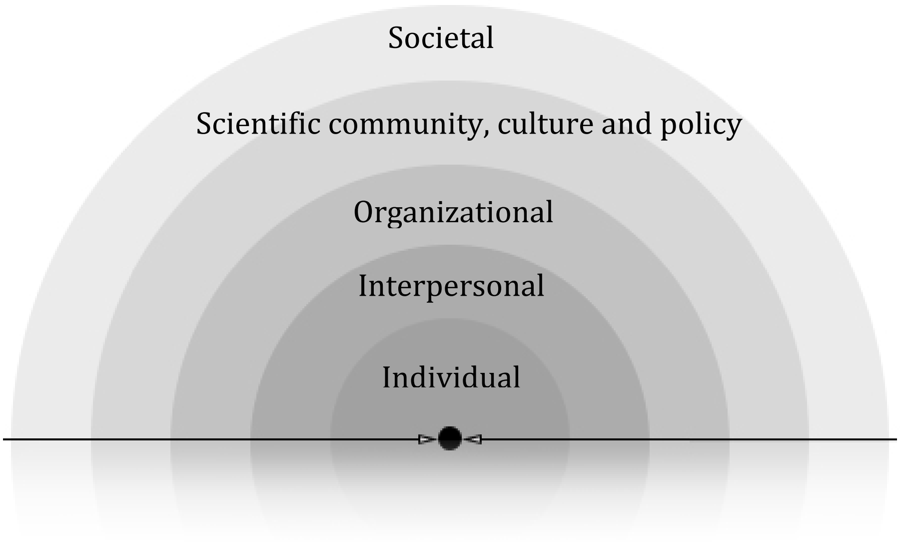

Figure 1 Disincentives, incentives, facilitators and barriers in the various spheres influence scientists' motivation to engage in (science communication) activities (D2.1)

The study is based on a literature review as well as interviews with 26 scientists within the fields of artificial intelligence, healthy diets and climate change in the seven European countries: the UK, the Netherlands, Italy, Sweden, Portugal, Poland, and Serbia.

The literature review shows that, in the **individual sphere**, both personal and professional factors are important to the engagement of scientists in science communication. The personal factors include intrinsic motivation and self-perceived capability, whereas the professional factors include visibility and

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networking with peers, personal development through challenges and interest in learning more about the public's opinions and needs. In relation to this, it is important to the scientists that their communication does not blur the boundary between their personal and professional roles. In the **interpersonal sphere**, (dis)encouragement from peers is important for the willingness to engage in science communication. In the **organizational sphere**, employers' attitude toward whether science communication is a voluntary activity, i.e. whether there is time and support for the activities, plays a big role. Finally, in the **societal sphere**, the anticipated public response and the potential use or misuse of one's content is important to scientists' engagement in science communication.

In addition to the literature review, the interviews undertaken within RETHINK show that, in the **personal sphere**, scientists think that communicating science is a very important activity that they feel a certain responsibility to undertake. These activities are both facilitated and prevented by the opportunity to communicate online. On the one hand, the fast-paced nature of online communication enables communication activities despite the time constraints that scientists face. On the other hand, the pace of online communication increases the risk of being misunderstood and interactions on online media are perceived to be more shallow than offline interactions.

In the **interpersonal sphere**, the scientists often use online and offline platforms to become visible and to network with peers. They even believe that online platforms provide more opportunities for finding like-minded people, especially when they do not have direct colleagues on their topic at their own institutions.

In the **organizational sphere**, scientists express that universities and research institutes prioritize scientific output over communication, which is why science communication to non-peers is often done voluntarily, especially when it is online. This does not mean that scientists do not feel supported, but that they think that their organizations lack clear and transparent strategies and guidelines for interacting with audiences online.

In the **science community and policy sphere**, the scientists believe that science communication activities are often downgraded as a priority and difficult to receive funding for. For that reason, some scientists propose that a change in scientific culture toward appreciating and valuing science communication is necessary.

Lastly, in the **societal sphere**, scientists indicate that their main motivation for engaging in science communication is to inform or educate audiences with different goals within different scientific fields such as democratizing science, deploying critical thinking, changing the world for the better. In general, they have a drive to contribute to societal discussion in order to add scientific facts to the discussion, change people's behavior and support collective action. On the other hand, scientists also receive a lot of personal, negative comments online, which has caused some of them to stop their online communication activities, and some scientists even think that online platforms are not the right place to communicate about science in the first place.

To summarize, scientists are in principle motivated to engage in science communication. However, they meet barriers in different spheres in terms of time constraints, lack of support, lack of recognition of the value of science communication, poor conversation quality, non-constructive interactions etc. These factors hamper their motivation and keep them from engaging further in science communication. Moreover, scientists experience blurring boundaries between science and society. For example, some scientists indicate that there are more possibilities to connect with the public, while others fear online interactions that are more focused on their persons than on the topic. Yet, they still keep research-related and society spheres mentally separated, which indicates presence of the deficit model demonstrated by

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the felt importance to educate or inform the public. However, there might be a mismatch between this desire and a feeling that online interactions are not on topic but directed to them personally, which is sometimes perceived as a lack of interest in or responsiveness to facts. Furthermore, there might be a mismatch between this desire and organizational or societal regulations, guidelines and collaborations that are not focused on informing. Both of these mismatches might potentially affect scientists' motivation to engage in science communication negatively.

3.7 The dynamics of citizen sensemaking practices across Europe (D2.2)

Up until know, the focus has been on the landscape of communicators in terms of who communicates what to whom, how, why and on which conditions. However, as mentioned in the introduction, in order to meet the need of rethinking science communication and foster a fruitful relationship between science and society, it is also necessary to understand how people make sense of complex science-related information and questions. Consequently, RETHINK has investigated the sensemaking processes of European citizens in COVID-19 using Brenda Dervin's sensemaking methodology (Reinhardt & Dervin, 2011), in which the following dimensions of the sensemaking process are analyzed (see also figure 2 below):

1. The personal situation and social context, which constitutes one's point of departure in a sensemaking process.
2. The gap, which emerges when one is confronted with a complex, ambiguous science-related issue.
3. The sources and their evaluated relevance that one draws on when trying to make sense of a science-related issue.
4. The bridge that one needs to establish between different inputs and information in order to make sense of science-related issues.
5. The outcome of the sensemaking process, which is one momentary understanding of a science-related issue based on the above.

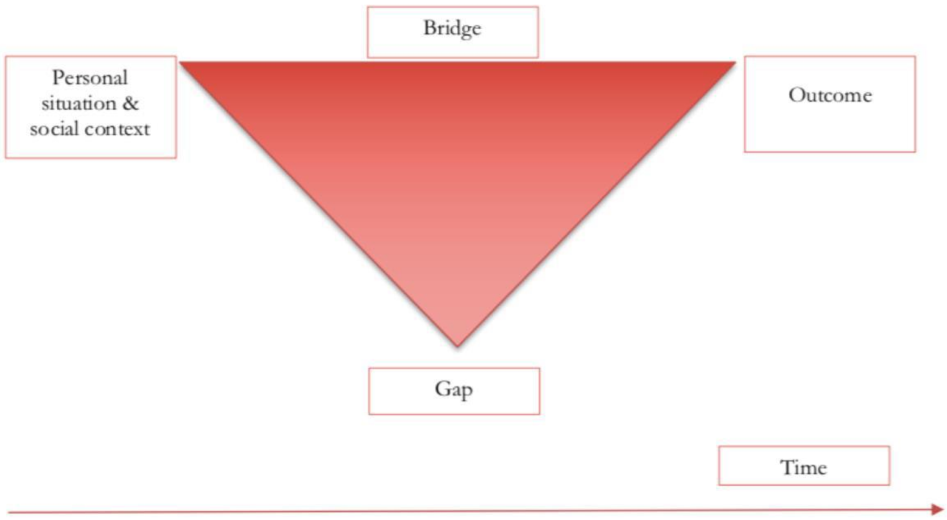

Figure 2 Mirco-moment triangle that illustrates the five dimensions of the sensemaking process (modelled after Reinhardt & Dervin, 2011)

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The study is based on interviews with a total of 81 citizens from the UK, the Netherlands, Italy, Sweden, Portugal, Poland, and Serbia about 'micro moments' - concrete and specific moments in which individuals are confronted with information, a conversation, an emotion, a thought etc. that they need to make sense of.

Overall, the study shows that one's **personal situation** is a decisive factor in how one makes sense of COVID-19 especially in relation to closeness to COVID-19, as there is a great difference between the sensemaking practices of those who have experienced or witnessed COVID-19 and those who have not. Second, the vulnerability of ourselves and our loved ones to COVID-19, as there is a great difference between the sensemaking practices of those who perceive themselves or their loved ones to be vulnerable to COVID-19 and those who do not. Third, one's professional occupation or developmental path, which relates to both closeness to COVID-19 but also to closeness to or experience with science in general. Thus, there is a great difference between the sensemaking practices of those who have experience with science and those who have not. Fourth, one's circle of friends and family plays an important role in sensemaking, as there is a great difference between the sensemaking practices of those who have family or friends working in the healthcare sector and those who have not. In fact, the study shows that citizens' personal situations are so important that they sometimes outweigh the insights and information provided by science communicators.

In terms of the **gaps** that citizens face in relation to coronavirus, these can be characterized as either uncertainties or ambiguities. The uncertainties relate to the nature, characteristics and origin of the virus, whereas the ambiguities relate to the proportionality or appropriateness of the response to the pandemic at both an individual and governmental level. These gaps primarily emerge from one being presented with a large amount of internally inconsistent and contradictory information from the national authorities and in interpersonal interactions. This mix of constant uncertainty, ambiguities and new, sometimes inconsistent, information seems to cause a great deal of frustration among the citizens.

In order to **bridge** these gaps, the citizens mainly draw on 1) a priori beliefs and ideas about institutions leading citizens to either trust the government and take advice or to be skeptical of the government contesting their advice, 2) information mostly passively received through media but also actively sought out and 3) emotions in relation to which anxiety, anger and frustration play a big role.

Regarding the **sources** that citizens draw on and evaluate the relevance of in their sensemaking practices, two dominant themes emerge. On the one hand, citizens draw on information from institutions that play a big role in the pandemic mostly the authorities and media that are either considered reliable or unreliable. On the other hand, they draw on perspectives of family and friends, which most citizens consider relevant.

Finally, the **outcome** of the sensemaking practices can be divided into two main categories. On the one hand, the sensemaking practices lead the citizens to form and reinforce viewpoints in terms of understanding the nature, danger, and impact of COVID-19 and assessing the government's response compared to this understanding. The latter manifests itself in a spectrum between those who trust the government and those who think that COVID-19 is made up. On the other hand, sensemaking practices lead to behaviors adopted, actions taken and decisions made, which results in most citizens following the advice of the authorities. Furthermore, sensemaking is a dynamic and continuous process and most of these outcomes are an expression of how stressful it is to constantly make sense of the pandemic. Consequently, some look for acceptance of the situation while others stop following news and avoid information because it is too tiring, thereby challenging the uptake of science communication.

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In sum, the study shows that emotion, trust, personal context and worldviews are crucial to how citizens make sense of COVID-19. The way citizens make sense of science-related issues such as COVID-19 are not merely influenced by access to knowledge or getting the facts straight. It is heavily dependent on which personal contexts these facts are put into, how they relate to what people already know and believe and what the relationship between the communicator and the audience is, i.e. whether one trusts the source or not. Moreover, the sensemaking practices are dynamic, which is why communicating and discussing science is not just a one-off affair but a continuous process.

3.8 Tacking stock of the dynamics at science-society interfaces

Looking at the above studies of science-society interfaces investigating (dis)incentives of scientists to engage in science communication and how citizens make sense of COVID-19, there are indications of both potential mismatches within these interfaces, posing challenges as well as ways to improve the science-society relationship.

First, citizens' sensemaking practices are heavily dependent on their personal situation, emotions, a priori beliefs and trust in the source. Moreover, citizens are exposed to an abundance of information online and offline from a variety of sources that are mostly passively received and whose reliability they reflect on to a varying degree depending on their personal situation, a priori beliefs and social context. This importance of the personal context compared to the objective content of information when trying to make sense of a scientific issue poses a potential challenge to strengthening the quality of interactions between science and society, as it might limit the influence of science communication on people's levels of openness and reflexivity, which in some people seems to be low. This influence might be further limited when people are exposed to an abundance of information that are contradictory and inconsistent, as it seems to cause frustration and strengthen the importance of personal situations to sensemaking practices. Furthermore, the importance of the personal context indicates that the concept of audience needs to be very granular and raises the question of what role science communication can play in people's sensemaking practices? On the other hand, sensemaking practices are very dynamic and every bridge constructed leads to a new gap in one's sensemaking practice. In other words, every communicative interaction may lead to new questions and new bridges to be constructed, which creates an opportunity for science communicators to facilitate openness and reflexivity insofar as they pay attention to the context of the audiences' sensemaking practices. Thus, it seems that in order to be effective, science communication has to take into account audiences' personal situations and maybe even be personalized to some extent so that they connect to various sensemaking practices and meet the audiences at eye level.

Second, scientists experience a number of barriers in both the interpersonal, organizational, science and policy, and societal spheres for carrying out communication activities. This challenges the opportunities for being more alert to the audiences' personal situations and personalizing the communication and ultimately to enhance openness and reflexivity. On the one hand, time constraints, lack of organizational support and lack of recognition of the value of science communication might prevent especially scientists from engaging further in science communication and perhaps even mean that they abstain from carrying out communication activities. On the other hand, scientists' bad experiences with negative comments and non-constructive interactions might cause them to either restrict their communication online or withdraw from online communication in fear of how the audience might react. Moreover, the insights into scientists (dis)incentives to engage in online science communication indicate that some of their motivations to carry out communication activities could imply deficit thinking to some extent, meaning that they are motivated to provide facts and want to keep their own personality separate from their professional expertise. In

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other words, there might be a mismatch between what scientists have resources for and are motivated to communicate, on the one hand, and what connects to the sensemaking practices of citizens, on the other. To the extent that this mismatch and disconnection is interpreted by the scientist as a lack of interest in science among the audience or a lack of responsiveness to facts, this might further demotivate scientists to carry out communication activities. Nevertheless, many scientists still express an intrinsic motivation to and feeling of responsibility for communicating science, which is an essential condition for building a closer connection between science and society.

Comparing the findings from the studies of (dis)incentives for scientists to engage in science communication and sensemaking practices with the mapping of the science communication ecosystem, it becomes apparent how challenging it is for both citizens and science communicators to navigate the ecosystem and transform its potentials into constructive interactions. With regard to citizens, they tend to be overwhelmed by the abundance of information made available through the complex and diverse ecosystem rather than using it actively in support of more nuanced conversations. With regard to science communicators, there is a correspondence between the studies of working practices, motivations, links between communicators and audiences and (dis)incentives for scientists to engage in science communication. First, many communicators seem to aim at and be motivated by providing facts and informing the public, thereby playing the role of conduit or civic educator. Second, the communicators experience a disconnect with their audiences and sometimes a lack of interest, which is both demotivating and behaviorally moderating in terms of targeting pre-interested audiences and avoiding certain types of formats or online platforms. Third, communicators lack time and resources and meet limited support for engaging in dialogue-based science communication within their organizational and professional spheres, devaluing communication activities. Thus, new opportunities and barriers for improving the quality of interaction between science and society can be added to the list in section 3.5.

Opportunities for improving the quality of interaction between science and society

- Sensemaking practices are dynamic and continuous, which in principle enable science communication to facilitate openness and reflexivity.
- Many scientists feel an intrinsic motivation and sense of responsibility to engage in science communication and want to democratize science.
- Scientists indicates that the fast-paced nature of online communication can facilitate more conversations.

Barriers for improving the quality of interaction between science and society

- Sensemaking practices are heavily dependent on people's personal situation, emotions, a priori beliefs.
- There is a potential mismatch between the desires of some scientists to inform the public, the interpretation of some scientists that audiences are not responsive to facts and organizational guidelines that are not focused on informing, which can demotivate the scientists to engage in science communication.
- Scientists experience bad and non-constructive interactions online causing them to stop engaging in conversation.
- Scientists experience a lack of time, organizational support and professional incentives for engaging in science communication.

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3.9 The status quo and demands for science communication training (D3.1)

On top of mapping the science communication ecosystem and describing the science-society interfaces and the dynamics that play out here, RETHINK has looked at how professional science communicators are trained at universities to deal with this ecosystem and its interrelations. Science communication actors like journalists, scientists and other experts also to some degree participate in training activities, like short term courses, but the academic degree programs can provide a "bigger picture" of science communication where theory in communication studies is combined with practical skills. Consequently, academic educations in science communication have been considered to be an important prerequisite for the further development and professionalization of science communication (Baram-Tsabari & Lewenstein, 2017).

Given the large number of science communication academic programs and trainings and the background of professionalization in science communication, RETHINK has investigated science communication education by analyzing how academic science communication programs offered by universities (undergraduate and graduate level) equip their students with knowledge and skills to cope with digital information environments and modes of societal communication. It is based on a survey sent to 43 and completed by 13 program managers and lecturers of relevant graduate programs across Europe (UK, the Netherlands, Italy, Russia and Portugal) in order to assess the knowledge and competences that they provide the student with.

The analysis of the survey and how programs cope with changes in the science communication landscape builds on three theoretical categories based on Baram-Tsabari Lewenstein (2017) and Pieczka (2002):

1. Picture of the world, which refers to the perception of the changing societal context in which science communication takes place and how it affects the conditions for science communication. This includes addressing perceptions of the science communication landscape, mediatization, the science-society relation, new orders of knowledge, political demands, risks and opportunities.

2. Conceptual framework, which refers to the extent to which science communication programs address reflections on the communicators' role and praxis in a changing landscape. This includes addressing relevance of digital media, roles concepts, assessment of science communication effectiveness and quality.

3. Professional knowledge, which refers to the extent to which science communication programs equip communicators with the competences and skills that are required in a digitalized world. This includes addressing problem recognition and content knowledge, assessment of risks and opportunities of digital media, applications of digital media, practical knowledge and experience, openness and motivation.

The analysis shows that the overall orientation of programs can be described as either practical skills oriented or equally theoretical and skills oriented. The respondents consider digitalization as important to the programs but integrate it in different ways in lectures, modules, and the program as such. Moreover, the program lecturers and managers would like their students to be aware of both the risks and opportunities of digital media. Likewise, both science communication knowledge such as knowing the public sphere and the media system and competences to build a trustful relationship with audiences are seen as highly relevant for graduates in the field.

In terms of **picture of the world**, there are programs that convey a perception of science communication as conditioned by the emergent developments of mediatization and as an interaction between science

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and society that includes co-production. On the other hand, there are also programs that convey a more traditional perception of science communication as a one-way process, in which the public is informed. However, all programs include a variety of perspectives on science communication.

In terms of **conceptual framework**, the features of mediatization are considered in the programs in order to teach how to be a communicator within this landscape. This includes the importance of having an eye for both the opportunities and risks of digital media, like diversity of content or misuse of communication. Moreover, most of the programs are developed to educate their students for communicator roles that foster interaction between science communicators and the public, rather than serving as a traditional gatekeeper; however traditional journalistic role perceptions like agenda setting or gatekeeping/-watching still remain important for some settings. This reflects openness to taking on different roles in different contexts, rather than serving as a traditional gatekeeper on the one hand, and a one-way notion of communication, on the other hand.

In terms of **professional knowledge**, program managers and lecturers address risks and opportunities of science communication by engaging students in critical thinking and evaluation of information reliability. Furthermore, they teach knowledge such as understanding the public and the media system, competences that build trust and relationship with audiences, and affective elements such as interest in and motivation for communication.

Despite the small number of programs surveyed, the study shows a great variety in notions of science communication, attitudes toward the risks and opportunities of digital media, the role of science communicators, and the knowledge and skills taught. Thus, it might be assumed that professional science communicators are equipped with the sufficient competences to cope with the changing conditions of science communication to a varying degree. That is, the competences to navigate the risks and opportunities of the complex digital ecosystem, connecting and interacting with audiences, building trust and contextualizing communication. Some are mostly equipped with more traditional competences of gatekeepers whereas others are better equipped with dialogical competences of mediators.

At the same time, the results show that both science communication knowledge such as understanding the public sphere and competences to build a trustful relationship with audiences are seen as highly relevant for graduates in the field. This mean that the graduates must be prepared both for one way information needs, for example to spread scientific content through (digital) media, but also to interact with audiences, for example on science events or digital platforms.

3.10 Experts' views on current science communication quality and demands (D3.2)

As we have seen so far, science communication has become more complex both in term of the number of actors and the platforms and formats used due to the growth in online communication. In a more diverse ecosystem, the maintenance of quality has become of central concern and reflecting upon quality is crucial. Therefore, RETHINK has studied criteria and indicators to measure science communication quality that address the specific needs and features of the digital media landscape in order to provide a starting point for sound reflection on science communication quality in a digital environment. It is based on a delphi study consisting of two waves of online surveys with 26 science communication scholars across the globe in the first wave and 19 in the second, representing 17 different national perspectives. The answers are analyzed through a situational analysis approach developed by Adele Clarke (Clarke, 2003; Clarke et al., 2018).

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The study was conducted only with science communication researchers in order to ensure a certain degree of comparability within the panel. Scholars are also considered to be experts on the topic and given the highly normative and complex framework of science communication quality, it thus seems appropriate to focus on this group.

By asking the participants for criteria that they associated with science communication quality in a digital media environment, the first wave identified five categories of criteria:

- **Content** criteria referring to the characteristics of information, i.e. whether it is objective, relevant, accurate, evidence based etc.
- **Presentation** criteria referring to the exchange of information, i.e. whether it is appealing, engaging, transparent, accessible, comprehensible etc.
- **Procedural** criteria referring to goals and audiences, i.e. whether it is effective, clearly motivated, has a clear purpose etc.
- **Technical** criteria referring to the technical aspects of online platforms, i.e. lengths and tone of posts/content, opportunities for dialogue and feedback etc.
- **Context** criteria referring to the institutional and moral framework of science communication, like reliability of evidence and moral intent of communication.

By asking the participants whether they would add categories to the above and to indicate which criteria they considered as the most important to evaluate the quality of online science communication in general, the second wave identified 12 salient categories (i.e. categories chosen by 10 or more participants):

1. Reliability of evidence
2. Clear motivation or purpose
3. Accessible language and style
4. Transparent context
5. Engaging
6. Technically accessible
7. Comprehensible
8. Relevant
9. Opportunities for dialogue & feedback
10. Expertise of sources
11. Accurate
12. Relatable

Moreover, the participants were asked to assess the relevance of the 12 criteria across two of the following settings: News on a university webpage, Twitter threads, a governmental campaign, a blog of environmental activists, posts on Instagram by an influencer and a podcast by a newspaper. Even though some participants were willing to point out generalizable criteria and some were not, the answers indicate that the importance of the different criteria is different in different online settings or contexts.

However, it is notable that the participants mainly compared the criteria across traditional settings such as university webpages, governmental campaigns and newspaper podcasts that they were familiar with, which leaves a vaguer indication of what criteria are relevant to settings such as Twitter threads and Instagram posts that are new to the science communication landscape.

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Besides the criteria and their importance, the study also investigates whether and how the identified criteria could be transformed into quality *standards*. The participants were asked how they would convey, promote or secure the quality criteria that they considered important.

The responses were analyzed by using a positional map with two axes: On one axis, the participants' answers vary in level of formality going from informal to formal approaches. On the other axis, the participants' answers vary by going from direct intervention to self-regulation. The answers distribute evenly all over the map, showing that there are currently many ways of promoting and securing quality standards taking place, but to different degrees. It also shows that experts hold very diverse and even contradictory positions on how to promote, convey or secure quality standards. Many experts emphasized differences in national and political contexts in how to regulate science communication, thus stressing the societal and political embedding of this issue.

Lastly, the participants were asked which approaches had the potential to facilitate the implementation of quality standards and what role science communication professionals and science communication scholars should play in ensuring that quality standards are met.

The participants suggest different approaches, mapped to a macro, meso and micro-perspective:

On a macro level, they locate the responsibility to promote science communication quality at a societal level, including government, society and social media companies. The participants stress the need to start to engage in social discourses and build digital competency and literacy.

On a meso level, the participants refer to professional bodies, science communication societies and associations, and also scientific institutions and their role in quality assurance. These institutions should provide background knowledge and establish standards and education.

On a micro level, the participants address the responsibilities of science communication professionals, science communication scholars, scientists and other actors who communicate science via digital means. Science journalists and PR experts, for example, are supposed to align with the standards and demands defined by their professional communities, and science communication scholars should strengthen their collaboration with practitioners, providing empirical evidence and solving practical problems. It is also argued that 'consumers' have their own responsibility when taking part in or consuming science communication.

In sum, the study shows that it is very challenging to define quality criteria for science communication that address the needs and features of a digital media landscape. Even when consulting a restricted group of communication scholars, the perspectives on what constitutes good science communication, whether it can be determined at all and how it should be implemented are manifold and contestable. Some scholars even argue that communication is so context-dependent that overall science communication quality criteria cannot be defined. Others however are less skeptical and argue that it is important and valuable to develop a framework of such criteria.

Moreover, it is worth noting that the experts focus on contexts of traditional science communication to a large extent, not answering which quality criteria should apply to other communicators such as influencers or activists on social media.

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3.11 Tacking stock of science communication training and quality

Looking at the above studies of science communication training and quality, it is difficult to identify generalizable competences and knowledge that are taught in order to cope with the digital information environment as well as generalizable criteria that should be used to measure the quality of science communication in a digital media landscape. In both instances, the picture is very diverse.

First, there is a great variety in the content and foci of the science communication programs investigated and, hence, in the competences that science communication graduates gain. There are both indications of the presence of traditional notions of science communication as a one-way process as well as indications of programs taking into consideration how different contexts require different approaches, one-way or two-way, and stress the importance of critical thinking.

This variety among programs can partly be explained by the many different communication settings and roles that professional science communicators should fit into in practice. However, it might also be an expression of the difficulty with determining which types of competences, knowledge and skills are important to support good and effective science communication in a digital information environment. Furthermore, the variety contains different potential developments. On the one hand, the science communication programs that emphasize context-dependency, critical thinking and dialogue orientation provide possible pathways for enhancing openness and reflexivity in science communication. On the other hand, the science communication programs that emphasize more traditional skills and competences might train communicators to think through a deficit model.

Second, the delphi study shows that it is difficult for science communication scholars to identify and agree on criteria for measuring the quality of science communication in a digital media landscape, though most of them point to dialogue and two-way communication as important quality criteria. They also stress that the relevance of concrete quality criteria is dependent on the given context.

At the same time, it is striking that the experts largely consider traditional communication settings such as websites, campaigns and podcasts when asked about quality criteria. This is a barrier for improving the quality of interaction between science and society, since it is precisely the 'new' situational settings of science communication that probably pose the greatest challenges for ensuring quality and thus deserve closer attention, analysis and reflection.

When it comes to *how* and *if* we should strengthen quality standards, the experts also draw a multifaceted picture with approaches on societal, institutional and personal levels. Key suggestions are:

1. On a societal level we need to start to engage in social discourses and build digital competency and literacy.
2. Institutions should provide background knowledge and establish standards for and education in science communication.
3. Science communication professionals, scientists, journalists and other actors who communicate science via digital means should take personal responsibility to align with standards for good practice.

The science communication scholars also point to their own responsibility to strengthen their collaboration with practitioners, and at the same time it is argued that 'consumers' have their own responsibility when taking part in or consuming science communication.

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For the scholars asked, the combination of the different interventions listed above seems most appropriate. Overall, experts agree on the need for education but also for reflection and raising awareness within the science communication community. The science communication scholars also argue that the increasing science communication training of scientists and the growing demand for outreach and public engagement activities has led to an overall normative acceptance of quality promotion by professional science communicators.

Comparing the findings of the studies of training programs and quality criteria with the mapping of the science communication ecosystem and studies of the science-society interfaces, there is both convergence and divergence in relation to the status quo of the ecosystem and the science-society relationship, on the one hand, and the foci of the graduate programs and the quality criteria on the other hand.

First, there is convergence in the sense that there are indications of deficit thinking and traditional one-way approaches to science communication in both the working practices and motivations of many science communicators as well as in some science communication programs.

Second, there is divergence in the sense that the programs and the experts also stress the importance of dialogue orientation in and context-dependency of communication and, hence, the need for critical thinking and reflection upon which approaches are adequate in what situations. At the same time, science communication practitioners point out that dialogue and interaction are hard to find, even in online contexts such as social media that would seemingly facilitate it. In other words, there seems to be a gap between what is theoretically considered as desired approaches to and practices of science communication among scholars and the actual practice and/or conditions of science communicators in the field.

Relatedly, it is important to remember that the mapping of the science communication landscape and the study of citizens' sensemaking practices show that there is a large number of non-professional science communicators who play a significant role. This group is not directly influenced by the characteristics of science communication programs, as they do not have a degree in science communication, and they do not necessarily orient themselves toward the ideals or tendencies of the professional community. This poses a challenge as to how to enhance openness and reflexivity outside this community of professional science communicators.

Collecting up on the above, it allows us to add new opportunities and barriers for improving the quality of interaction between science and society to the list in section 3.8.

Opportunities for improving the quality of interaction between science and society:

- Academic science communication programs overall *aim* to provide their graduates with specific knowledge, competences and attitudes that will help them to serve as professional communicators in an increasingly complex science communication environment.
- Some science communication programs also *convey* a perception of science communication as an interaction between science and society including co-production in a complex digital environment.
- Some science communication programs emphasize critical thinking.
- Most science communication scholars point to dialogue and two-way communication as important quality criteria.

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- Science communication scholars point to the quality of communication being dependent of the context in which it takes place.
- Science communication scholars point to many possible ways to strengthen quality standards.
- Increasing science communication training of scientists and the growing demand for outreach and public engagement activities seems to have led to an overall normative acceptance of quality promotion by professional science communicators.

Barriers for improving the quality of interaction between science and society:

- Academic science communication programs differ with regard to the extent to which the programs are aware of and adapt to a changing communication environment characterized by digitalization.
- Some science communication programs convey a more traditional perception of science communication as a one-way process in which the public is informed.
- Science communication scholars do not reflect upon new communication settings to the same degree that they reflect upon more traditional settings.
- Science communication scholars don't agree on how and if we should strengthen quality standards.
- We still know little about training in dialogue-based science communication outside the universities' academic programs. To what extend are science knowledge brokers like journalists, health care professionals, communication officers, staff at museums and NGOs equipped to deal with the complex digital science communication environment?

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4. Conclusion

Taking stock of the current science communication ecosystem and its practices, it is evident that it is complex and diverse. Science journalists are no longer the central gatekeepers of scientific information. Instead, digitalization has enabled multiple actors such as scientists, press-officers, policymakers, businesspeople, bloggers, activists and more to use different platforms and formats to reach and engage with wide audiences on scientific issues. This provides both potentials for opening up science and enhancing reflexivity in communicative interactions but also risks of echo chambers and misinformation, as it becomes difficult to assess the reliability of information.

Considering the working practices and motivations of science communicators, the links to their audiences and whether they take advantage of this potential for opening up science and enhance reflexivity, it shows that it happens to a varying degree. On the one hand, science communicators have a tendency to take on the role of conduits aiming to inform audiences with a pre-existent interest about scientific issues. Furthermore, they experience a sense of disconnect with their audiences and sometimes a lack of interest as well as a lack of time and resources to engage in science communication. On the other hand, science communicators often play the role of convenors as well, facilitating interaction between experts and non-experts and are used to employ mainstream social media that enable interaction and dialogue with a wide audience. Nevertheless, it seems challenging to establish this dialogue and get feedback from the audiences. In relation to this, it should be noted that most of the surveyed respondents were 'traditional' communicators such as journalists, press officers, researchers, and lecturers.

Taking a closer look at the (dis)incentives of scientists to engage in science communication in particular, some of the same patterns seem to repeat themselves. On the one hand, scientists are intrinsically motivated and feel a responsibility to engage in science communication. However, this motivation is to a large extent oriented toward providing facts and co-exists with a desire to maintain a clear distinction between professional and personal roles. Furthermore, the scientists encounter a number of barriers for engaging in science communication such as lack of time and resources, lack of organizational support, lack of incentives for valuing science communication and bad interactions online. These barriers increase the difficulty of connecting with audiences and strengthening the quality of interactions between science and society. This becomes apparent when considering citizens' sensemaking practices in the context of COVID-19, as it shows that these practices are heavily dependent on their personal situation, emotions, a priori beliefs and trust in the source. In other words, making sense of science-related issues such as COVID-19 is not merely a matter of accessing knowledge or getting the facts straight, but is dependent on which personal contexts these facts are put into, how they relate to what people already know and what the relationship between the communicator and the audience is. Consequently, it seems that science communication has to take into account audiences' personal situations and maybe even be personalized in order to connect with them and become effective. Yet, this requires communicators to be alert to their contexts and customize their messages, which takes time and resources.

Moreover, the question of context is important to the quality of communication, which is why it is difficult for science communication scholars to point out generalizable quality criteria for science communication in a digital media environment that are not relative to specific online setting or context. In relation this, however, it interesting to note how the scholars considered which quality criteria should apply to communicators such as influencers or activists on social media to a limited extent. Finally, the difficulty with defining what good science communication is seems to be reflected in the characteristics of the academic science communication programs, as they convey different perceptions of science communication as well as competences and skills. On the one hand, some programs convey a traditional perception of science communication as a one-way process educating students to play the role of

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gatekeepers. On the other hand, some programs convey a perception of science communication as a two-way process educating students to play the role of conveners. In other words, it might be assumed that professional science communicators are equipped with the sufficient competences to cope with the changing conditions of science communication to a varying degree.

All in all, the above analysis of the current science communication practices and ecosystem leaves us with a number of opportunities and barriers for strengthening the quality of interactions between science and society.

Opportunities for improving the quality of interaction between science and society:

- A diversity of science communication actors exist using a variety of platforms and formats that can potentially enrich conversations on science-related topics.
- A majority of science communicators play the role of convenor and aim to create conversations between researchers and the public.
- A majority of science communicators regularly use mainstream social media providing the potential to reach a broader audience in new ways.
- Sensemaking practices are dynamic and continuous, which in principle enable science communication to facilitate openness and reflexivity.
- Many scientists feel an intrinsic motivation and sense of responsibility to engage in science communication and want to democratize science.
- Scientists indicates that the fast-paced nature of online communication can facilitate more conversations.
- Academic science communication programs overall *aim* to provide their graduates with specific knowledge, competences and attitudes that will help them to serve as professional communicators in an increasingly complex science communication environment.
- Some science communication programs also *convey* a perception of science communication as an interaction between science and society including co-production in a complex digital environment.
- Some science communication programs emphasize critical thinking.
- Most science communication scholars point to dialogue and two-way communication as important quality criteria.
- Science communication scholars point to the quality of communication being dependent of the context in which it takes place.
- Science communication scholars point to many possible ways to strengthen quality standards.
- Increasing science communication training of scientists and the growing demand for outreach and public engagement activities seems to have led to an overall normative acceptance of quality promotion by professional science communicators.

Barriers for improving the quality of interaction between science and society:

- The digital communication environment is complex and social media algorithms and APIs limit the sources that one is exposed to online.
- A majority of science communicators play the role of conduit and aim to inform the public about science, which implies deficit thinking.
- Science communicators experience a lack of time and resources for engaging in science communication.

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- A majority of science communicators aim to reach audiences with a pre-existing interest in science and undeserved audiences are seldom the focus of their activities, which reproduces inequalities in access to knowledge.
- Science communicators experience a sense of disconnect with their audiences, which is demotivating.
- Sensemaking practices are heavily dependent on people's personal situation, emotions, a priori beliefs.
- There is a potential mismatch between the desires of some scientists to inform the public, the interpretation of some scientists that audiences are not responsive to facts and organizational guidelines that are not focused on informing, which can demotivate the scientists to engage in science communication.
- Scientists experience bad and non-constructive interactions online causing them to stop engaging in conversation.
- Scientists experience a lack of time, organizational support and professional incentives for engaging in science communication.
- Academic science communication programs differ with regard to the extent to which the programs are aware of and adapt to a changing communication environment characterized by digitalization.
- Some science communication programs convey a more traditional perception of science communication as a one-way process in which the public is informed.
- Science communication scholars do not reflect upon new communication settings to the same degree that they reflect upon more traditional settings.
- Science communication scholars don't agree on how and if we should strengthen quality standards.
- We still know little about training in dialogue-based science communication outside the universities' academic programs. To what extend are science knowledge brokers like journalists, health care professionals, communication officers, staff at museums and NGOs equipped to deal with the complex digital science communication environment?

5. Future Perspectives

The analysis here aims to provide a solid foundation for developing frameworks and strategies within the RETHINK project which can foster a more fruitful interaction between science and society. With this in mind, the next stages of the project will entail:

1. The development of a role topology that can support the breakdown of barriers and engender trust between science and society.
2. The development of strategies for opening up sensemaking practices, among other things, through reflection and conversation tools as well as interaction spaces.
3. The development of training resources for science communicators to cope with the changing conditions within a digital media landscape.
4. The conduction of small-scale experiments in the Rethinkerspaces with professional science communicators to open up sensemaking practices.
5. The development of a framework for how to improve the reliability and quality of science communication.

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However, we would like to point already in this report toward possible actions to undertake in the future in order to take advantage of the opportunities and counter the barriers listed above.

Improvement of policies

- Considering that scientists are intrinsically motivated to engage in science communication but experience a lack of time, resources, appreciation and acknowledgement to do so, it is worth thinking about implementing:
    - The inclusion of science communication in different types of scientific evaluation systems.
    - The inclusion of science communication in job descriptions.
- The European Commission's media literacy policy sees media literacy as a "reply to a changing and increasingly complex media landscape" (Viola, 2016), which is why it should take into account the above insights into the roles and practices of the current science communication ecosystem.

Improvement of public resources

- Given that the digital science communication landscape is so complex and provides access to an abundance of information, it would be beneficial to develop resources that can support the public in assessing the reliability of sources and distinguishing between different types of information e.g. facts, assessments, opinions, misinformation etc. Relatedly, resources to enhance transparency could be developed, both to make the origin of the information clear and to foster comfort with uncertainty related to scientific issues.

Improvement of education / training

- Considering that some scientists are not that familiar with the digital media environment and believe they lack capabilities for and fear to engage in science communication online, it would be beneficial to develop materials for upgrading the online communication skills of scientists. In the Rethinkerspaces, we will refine and test training resources that can be used in academic education contexts to adapt communication of scientific issues to new modes and settings of science communication.
- Given the large diversity in the curricula at the different science communication education programs, it would be beneficial to improve and coordinate science communication curricula and learning goals at universities.
- For science communication students, it is important to engage them more in critical thinking, evaluation of scientific information and its reliability.
- For the vast majority of professional science communicators and knowledge brokers, that do not have a science communication degree, e.g. journalists, health care professionals, communication officers, staff at museums and NGOs, we also need to develop and improve education and training with regards to sensemaking practices.
- An ambition could also be to reach out to informal science communicators with resources or creating a dialogue on openness and reflexivity in their communication on social media.

Improvement of dialogue

- Given that science communicators feel a disconnect with their audience, it would be beneficial to develop new types of feedback mechanism, e.g. on various social media.
- Both science communication professionals and scholars have a tendency to focus on already science interested audiences and traditional communication platforms. It would therefore be

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beneficial if both groups focused more on reaching undeserved audiences and those not interested in science on new digital platforms.

- A separate goal could be to reach out to science deniers and propagandists.
- In light of this, it would also make good sense to foster and strengthen collaboration and interaction between science communication scholars and practitioners to advance conceptual understanding and theory on sensemaking practices and dialogue-based science communication.

Improvement knowledge and standards

- We still need more knowledge about non-professionals digital behavior and views on science communication.
- We also need to improve the research-based knowledge on science communication in the new media landscape and develop quality criteria for science communication on 'new' digital media platforms.
- It could be useful if different professional bodies, science communication societies etc. would discuss and establish standards for quality and good practice for digital science communication.

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