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RE-EXAMINING SCIENCE COMMUNICATION:
MODELS, PERSPECTIVES, INSTITUTIONS

Quality indicators for science communication: results from a collaborative concept mapping exercise

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Abstract

Although the need to improve quality of science communication is often mentioned in public discussions, the science communication literature offers few conceptualizations of quality. We used a concept mapping approach, involving representatives of various science communication stakeholder groups working collaboratively, to propose a framework of quality. The framework organizes individual elements of quality into twelve indicators arranged into three dimensions: trustworthiness and scientific rigour, presentation and style, and connection with society. The framework supports science communicators in reflecting on their current practices and designing new activities, potentially improving communication effectiveness.

Keywords Science communication: theory and models

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Introduction

Whenever quality is discussed in the context of science communication, it seems to be perceived as something that is lacking or needs to be improved. The discourse has been especially prominent during discussions on topics with high societal impact, such as climate change, vaccination hesitancy or the ongoing COVID-19 pandemic. These are characteristic examples where science communication is seen of paramount importance, yet lacking of quality or necessary impact. The rise of social media on the one hand and the dwindling resources in science journalism on the other are some of the developments that further challenge the quality and reliability of science communication [European Commission, 2020].

In academic research, quality is surprisingly rarely defined in terms that enable to analyse science communication activities. Also, the existing approaches tend to have a narrow focus on certain fields of science communication (e.g. journalism) or a certain aspect of it (e.g. accuracy). Recommendations to improve quality tend to be contested when these are not taking into account the perspectives of all stakeholders. For example, Dornan [1990] has pointed out how journalists reject normative expectations of science communication that are defined by researchers who are unhappy about how the media covers science.

Science communication scholars Brian Trench and Massimiano Bucchi have concluded that the traditional means of guaranteeing quality have eroded and a new framework is needed: "Professional mediators used to guarantee quality through brands and the reputation of their medium. . . . But contemporary information overload requires the user to be more competent, and it demands new definitions of quality" [Bucchi and Trench, 2014, p. 10].

This paper is a response to this call for a new definition of quality, also taking into account what Bucchi and Trench say next: "Public communication of science should now be mature enough to pass . . . to a phase in which quality criteria are central for all parties involved. This implies developing indicators and standards of performance" [Bucchi and Trench, 2014, p. 10].

We find that to be useful for and accepted by the whole science communication community, this new framework of quality should be guided by two principles. First, it should aggregate the understandings of quality that exist within the science communication community, and, second, it should be designed as a helpful tool to support quality in science communicators' work, rather than to be used as a normative framework.

Within the Horizon 2020-funded QUEST project (see https://questproject.eu/), we aimed to provide such a framework of quality foremostly for the QUEST focus strands — journalism, social media and museums — but with the ambition that the result would be universally applicable across the whole landscape of science communication. This paper presents the results of a mapping exercise that brought together science communication stakeholders — researchers, journalists, science communication professionals, science decision makers and members of the public — and asked them to collaboratively conceptualize quality. The outcomes of the exercise are collected into a framework of 12 quality indicators, organized into three quality dimensions.

Approaches to quality in science communication

A prominent and persisting discourse expects science communication to adhere to similar principles that determine quality in science. Central to the discourse are keywords such as accuracy, objectivity, facts and quality of sources and evidence [e.g. Hall Jamieson and Hardy, 2014; Singer, 1990; van der Bles et al., 2019]. Contention around how these are or should be expressed in the media or how they relate to the traditional values of journalism has formed a large part of the tensions between scientists and journalists [Hansen, 1994; Reed, 2001; Secko, Amend and Friday, 2013].

Hansen [2016] has shown that debates around accuracy in scholarly literature have declined since the mid-1980s, mostly because the focus on accuracy was being associated with the 'deficit model' which saw misrepresentation or lack of facts as the source of public ignorance about science. However, Hansen also notes that concerns about accuracy are returning to scholarly literature, now re-formulated in the language of the closely associated journalistic values of balance, objectivity and impartiality [Hansen, 2016] and also associated with the recent phenomenon of mis- and disinformation and the ease of spreading these in social media [Scheufele and Krause, 2019]. Peters [2013] demonstrate that researchers still tend to evaluate the quality of science coverage as low based on the criteria of accuracy and selection of sources, even if their personal experiences with media have been positive.

The value placed on quality of sources is also evident in some of the tools that have been developed to support quality of science media. For example, Šuljok and Brajdić Vuković [2013] propose a Trustworthiness Index, a simple scale of four variables: whether the primary source of information is given in the article, whether an additional source of information is given, whether the opinion of an expert as a "trustworthy" source is cited, and how the article is presented, i.e. superficially or in-depth.

In 2019, the Danish science news website videnskab.dk launched the Science Evidence Indicator to assess the scientific sources behind medical stories [Løvlie, Waagstein and Hyldgård, 2019]. The assessment is based on four separate quality indicators: quality of the scientific publication, position of the used method on evidence hierarchy for medical research, researcher's experience (as determined by the h-index) and other important characteristics of a study [Løvlie, Waagstein and Hyldgård, 2019]. The variables are filled in manually by the journalist and the resulting Scientific Evidence Level (low, medium or high) is shown next to the news article, with relevant comments.

Massimiano Bucchi, however, has called for a "broader notion of quality, encompassing not only accuracy" [Bucchi, 2019, p. 5]. He sees that openness to scrutiny, dialogue, independence and fairness should also be considered. The relevance of "critical and dialogic approaches to science communication" are also emphasized by Davies, Franks et al. [2021].

Rögener and Wormer [2017] set out to develop criteria for good environmental reporting. They collected input from journalists and students and defined 10 criteria for environmental journalism, supported by three general criteria for journalism. When applying these indicators to a set of news articles, they found that greatest weaknesses were not related to accuracy but rather with putting scientific results into context, providing information about the evidence and considering controversial points of view [Rögener and Wormer, 2017]. Their results also show the value of involving stakeholders to the design of the indicators.

The limitations of many of the presented examples lie in the fact that they are media-centred and often also news-centred, therefore covering only a specific section of science communication. At the same time, 'quality' is also a recurring keyword in studies representing a more audience-centred approach, that is, consider the properties of communication that support engagement of the public and effectiveness of transmitting the message. Again, the use of 'quality' in these articles tends to be vague but we find it being associated with characteristics of communication in two main (partially overlapping) contexts: the skills of communicators to engage the audience and the style of communication.

Style, understood broadly by Bucchi [2013] as aesthetic and humanistic qualities of science communication, or as a reference to more specific features such as story-telling or accessibility of text is considered an essential component for building the bridge to the audience. A recurring feature associated with quality is story-telling or narrative approach [Dahlstrom, 2014; Davies, Halpern et al., 2019; Downs, 2014; Morris et al., 2019]. The need to provide understandable materials is also emphasized [Bruine de Bruin and Bostrom, 2013; Cordner, 2015] and tools for measuring the writing skills and use of jargon by scientists have been developed [Baram-Tsabari and Lewenstein, 2013; Sharon and Baram-Tsabari, 2014].

Communication training for researchers "represents an important tool in improving the quality of interactions between scientists and the public", Besley et al. argue [2015]. Articles that discuss training programmes to develop the communication skills of scientists agree that modern science communication needs much more than ability to explain science in an understandable way. Researchers need to be able to approach communication in a more strategic way and skills for that include, in addition to media skills, also framing and various engagement activities such as leading public deliberations, building community partnerships and initiating dialogue [Baram-Tsabari and Lewenstein, 2017; Besley, Dudo, Yuan et al., 2016; Besley, Dudo and Storksdieck, 2015; Illingworth and Roop, 2015; Rodgers et al., 2018; Yuan et al., 2017].

The aspiration for identifying relevant skills to be taught to researchers has led two papers to use a co-design approach and produce a list of competencies or key elements for science communication. In Seethaler et al. [2019] a group of scholars produced a set of ethics and values for effective science communication. The 10 competencies focus on acknowledging values, understanding complexities of decision making, strategies to deal with uncertainty, and diversifying expertise and authority.

In the quest for an evidence-based teaching resource, Mercer-Mapstone and Kuchel [2017] used expert collaboration to produce and validate 12 core skills for effective science communication:

- Identify and understand a suitable target audience;
- Consider the levels of prior knowledge in the target audience;
- Promote audience engagement with the science;
- Encourage a two-way dialogue with the audience;
- Use language that is appropriate for your target audience;
- Use a suitable mode and platform to communicate with the target audience
- Use the tools of storytelling and narrative;
- Separate essential from non-essential factual content in a context that is relevant to the target audience;
- Use/consider style elements appropriate for the mode of communication [such as humour, anecdotes, analogy, metaphors, rhetoric, images, body language, eye contact, and diagrams];
- Identify the purpose and intended outcome of the communication;

– Consider the social, political, and cultural context of the scientific information;
– Understand the underlying theories leading to the development of science communication and why it is important [Mercer-Mapstone and Kuchel, 2017].

Finally, the literature about evaluation of science communication [e.g. Jensen, 2015; Spicer, 2017] considers quality from the perspective of the audience: as quality of engagement or quality of experience. While a necessary component in the overall understanding of quality in science communication, it is rarely connected with evaluation of content.

Method

We approached our aims with the collaborative group concept mapping method. The method allows constructing a conceptual model or framework from the participants' specific perspectives to the issue at hand [Kane and Trochim, 2009]. According to Kane and Trochim, "concept mapping facilitates the identification of common themes to enable theory development, decision making, action, or assessment". Crucially, the approach encourages considering the participants' context [Kane and Trochim, 2009].

To develop the quality framework for science communication, six collaborative workshops were held as part of the QUEST project. The workshops took place between July 2019 and January 2020: in Venice (Italy), Trondheim (Norway), Tallinn (Estonia), Tartu (Estonia), London (United Kingdom) and Dublin (Ireland).

In total, 62 stakeholders participated in the workshops. They represented the main stakeholder groups as identified within the project:

– Scientists (from a variety of disciplines);
– Journalists (incl. general and specialized journalists);
– (Science) communication specialists (incl. social media managers, university or research institution communication specialists, museum and science centre professionals);
– Science decision-makers (incl. decision-makers in universities and research institutions, e.g., heads of faculty or representatives of research funding organizations);
– Members of the public (i.e., people whose daily professional work does not include research or communication).

Participants were recruited via convenience sampling or using the snowball sampling method, following the principles of gender equality and balance between the stakeholder groups. Several participants identified themselves as representing more than one group (e.g. journalist/science communication specialist or scientist/science decision-maker).

During workshops, the participants were arranged into groups of 3–5, making sure each group consisted of representatives of the different stakeholder groups.

Table 1. Data gathering process.

Stage	Pre-workshop	Workshop, part I	Workshop, part II	Workshop, part III
Activity	Participants fill an individual survey sheet with examples that they consider quality science communication.	Participants individually list elements of quality; work in groups to arrange these elements to quality maps.	Each group gets a specific format and is asked to expand on the previously defined quality criteria to meet the needs of the assigned format.	Each group is presented with one example of science communication and is asked to evaluate the examples (first individually, then in the group).
Question	Q: *Please provide specific examples that you consider to represent high quality science communication. For each example, list the criteria according to which you regard this particular example to stand out as high-quality science communication.*	Q: *In your personal view, what comes to mind as elements of quality in science communication?*	Q: *How can the previously defined quality elements be adapted to specific science communication formats?*	Q: *how do you evaluate the example in terms of quality? What could be improved in the example to increase its quality and how could this be achieved?*
Data collection	Individual response sheets	Maps, audio or video recordings of group presentations	Maps, audio or video recordings of group presentations	Individual response sheets, group response sheets

Participants' understanding of quality was explored in several stages, including both individual and collective activities, as described in Table 1.

The workshop format used the Manual Thinking tool [Huber and Veldman, 2015, see also https://manualthinking.com/], designed for hands-on teamwork and co-creation activities. Besides the possibility to represent individual elements with markings of different colours or shapes and arrange them spatially, the tool also enables to represent relationships between elements (e.g. by clustering elements or placing lines between them). The length of each workshop part was up to 60 minutes, including presentation by the groups. The workshops produced 15 quality maps. An example of a map produced as part of the workshops is seen on Figure 1.

For data analysis, the outputs of the workshops that were not held in English (i.e., in Italy and Estonia) were translated into English. Quality-related elements (individual words and phrases) from all stages were collected and analysed manually, using the thematic analysis as a sensemaking approach [Mills, Durepos and Wiebe, 2010]. The analysis process included inductively organizing the elements into thematic groups, taking into account the suggestions made by the participants in the explanatory group presentations and the relationships displayed on the maps. Theoretical literature was consulted to further understand the conceptual background of individual elements. Following initial creation of the thematic groups, the conceptual similarity of the groups was evaluated to further develop the framework. The process was repeated until the final framework

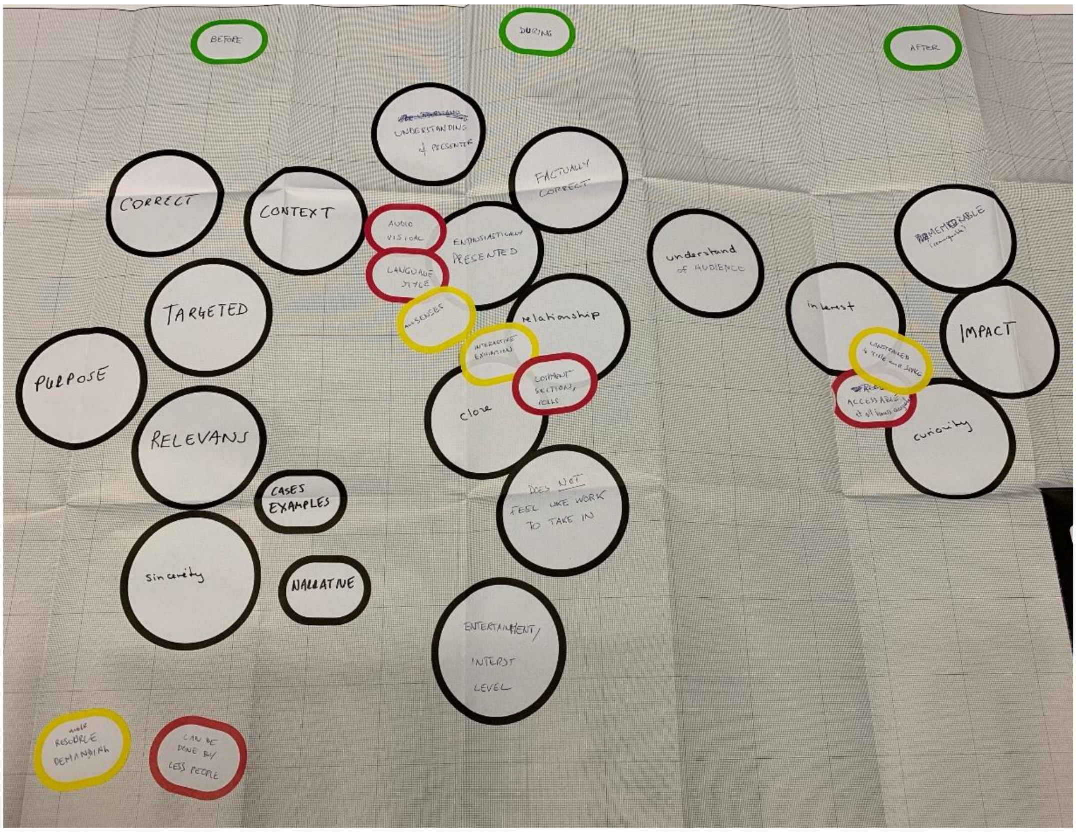

Figure 1. Example of a quality map produced in workshops. Credit: Sarah Davies.

consisted of conceptually distinct categories. Validity of the framework has been informally tested at QUEST events by introducing the results to stakeholder groups and gathering their feedback.

Results

The process of organizing individual elements and the proposed relationships between them that were displayed on the collaboratively produced quality maps resulted in the framework of 12 quality indicators, arranged into three quality dimensions (see Table 2).

Table 2. 12 quality indicators, arranged into three quality dimensions.

Trustworthiness and scientific rigour	*Presentation and style*	*Connection with society*
Scientific	Clear	Purposeful and targeted
Factual	Coherent and contextual	Impactful
Balanced	Spellbinding	Relatable
Transparent	Interacting with the audience	Responsible

Trustworthiness and scientific rigour

The elements of quality in this dimension all revolve around the concept of trust. As Weingart and Guenther [2016] have noted, science communication depends on trust, both in the source and in the medium of communication. These indicators express the view of the stakeholders that the quality of communication is determined by its efforts to create and support trust not only by providing reliable information but also by enlightening the mechanisms behind knowledge creation and dissemination so that the audience is able to make informed decisions about the trustworthiness of information and sources.

The specific elements of this dimension are:

Scientific: this indicator represents the sound scientific foundation of the communication. In this respect, communication has quality if the information presented is derived via scientific method or reasoning. A gold standard for such information are articles published in peer-reviewed journals, but reliable and scientific information can also come from other sources such as textbooks, reports or expert opinions (if the opinion follows scientific reasoning). The audience can be supported in evaluation of the quality of the information by adding relevant signals, e.g. article reference or expert credentials.

Factual: this indicator reflects how scientific information is presented in communication. The hallmark of quality for this indicator is a truthful and objective presentation of scientific facts or knowledge, so that the conclusions or interpretations are in line with the (scientific) evidence. This includes, for example, avoiding 'mixed messages', exaggerated claims of benefits and threats, oversimplifications, cherry picking or faulty generalizations.

Balanced: this indicator illustrates the position of experts and stakeholders in science communication content. Science communication is balanced when the selection of actors and their input to the content allow the audience to learn about all major aspects of the issue and foster a meaningful discussion. Balance can be achieved by presenting comments from independent experts (e.g. a scientist working in the same field but not involved in the study) and from key stakeholders (e.g. medical decision-makers and patients in case of a medical story). Regarding the selection of voices, balance also refers to the aspiration to reflect the diversity in the society.

Transparent: this indicator combines various aspects of transparency, concerning both the communicated science and the communication process. Transparency of the communicated science can be provided by describing the used research method along with its limitations, as well as by providing information about the funding of the research, the affiliations or potential conflict of interest of the researchers when these aspects are relevant for understanding the results or claims. Similar transparency should apply to the communication process: it should reveal any information (author's background, institutional support, funding, etc.) that makes the process transparent.

Presentation and style

The elements in this dimension all focus on how the scientific content is presented and how the audience is engaged with it. The quality of communication is determined by its success in making itself visible, appealing and understood in the challenging landscape of "attention economy" while sustaining a meaningful interaction with the public. The particular challenge lies in balancing the efforts to increase the attractiveness of science communication for the public without compromising the other core values of science communication, such as being trustworthy, objective and transparent.

The specific elements of this dimension are:

Clear: this indicator represents aspects that help the audience to understand complex topics. This includes providing scientific information in an accessible and straightforward language (or using helpful visualizations) while avoiding trivialization and unduly simplifications, and also explaining key concepts and supporting understanding with the structure of the communication such as a clear focus and outlining key messages.

Coherent and contextual: this indicator includes measures taken to improve the audience's understanding of communicated science. Here, the focus is on providing sufficient context so that the audience is able to grasp the role and relevance of the scientific fact or discovery. Context can be provided by explaining the scientific and social history of the topic, by discussing its limitations of the research and by investigating the societal implications of potential applications and the wider context of public concerns, interests and motivations. Coherence contributes to better understanding also when applied to the style and structure of communication. A coherent communication guides the audience through the topic on a logical path and uses a style to match the audience and the purpose of communication.

Spellbinding: this indicator reflects the ability of communication to attract and captivate the audience, with the purpose of using emotional engagement as a tool to bring science closer to the audience and help the audience to engage with complex topics. This can be achieved by using features that are entertaining, create excitement or elicit other kinds of supportive emotional responses. Using narrative and storytelling is another effective approach. The spellbinding effect can be supported by exploitation of the possibilities of the specific format and finding innovative ways to present science. For example, using visual or multisensory experiences, borrowing elements from popular culture (such as memes) or experimenting with the format.

Interacting with the audience: this indicator includes the ways in which communication with the audience is initiated and maintained. Given the possibilities of the format, the level of engagement might include deep engagement with the scientific process, active seeking of public feedback or facilitation of a dialogue with communicators or experts.

Connection with the society

The elements in this dimension are concerned with how communication serves its audience's needs and also the societal mission of science communication. The quality of communication is determined by the ability of science communication to act as the responsible intermediary between science and society and contribute to positive changes in both.

The specific elements of this dimension are:

Purposeful and targeted: this indicator considers the design of communication with respect to its audience. It expects that communication is coherent in its objective, audience and style, i.e. it has a clear idea to whom and what it wants to communicate and has chosen suitable formats, style and tone to reach the target group(s) and make them appreciate and understand the topic. Also, communication is timely: it aims to bring scientific information to its audience as soon as possible (in case of news) or when it is most relevant.

Impactful: this indicator reflects the aspiration of communication to bring forth societal and individual change. The vehicle for this can be introducing new and impactful knowledge and ideas to the public, initiating debates or challenging existing biases. The communication can also be more explicitly oriented towards behavioural change, for example by supporting vaccinations or giving advice about sustainable lifestyle.

Relatable: this indicator represents the connections that communication is making between scientific results or concepts and the familiar elements that people can relate to. This can mean providing a scientific background to everyday phenomena or current events, explaining scientific results or concepts with commonly familiar metaphors or comparisons, or bringing out how a new scientific result can impact our lives.

Responsible: responsibility, on the one hand, is understood as the readiness of science communication to address controversial topics or wrongdoings (both within science and in society more generally), counter mis- and disinformation with evidence-based information and bring out the ethical implications of research. On the other hand, responsibility also means that communication itself adheres to ethical standards, including considering the consequences of communication and avoiding doing harm.

Summary of mapping exercise results

The 12 indicators (or quality elements) are arranged into three dimensions following the typical clustering strategy displayed by the participants on quality maps. While the specific focuses of the clusters on the maps varied, a set-up of several clusters around a central theme was common to all the produced maps, demonstrating that the stakeholders perceive quality as a multi-dimensional feature. Moreover, the relationship between the clusters, as expressed on the maps and in the accompanying comments, is non-hierarchical, that is, all of them are considered necessary to produce quality.

No significant adjustments were made to the maps during part II of the workshops, i.e. when participants were asked to adjust the framework to specific formats (e.g. social media post, exhibition, TV news item). However, the discussions highlighted how the meaning of one or another quality element can be different, depending on the format.

Discussion

From the standpoint of science communication theory, our work responds to the call for "new definitions of quality" [Bucchi and Trench, 2014, p. 10]. The new definition (or definitions) needs to take into account the natural and desired diversity within the science communication ecosystem (as described by, among others, Davies and Horst [2016]) and, at the same time, not be misled "to expect a single, straightforward response to contemporary challenges of science communication ... or to fulfil the expectation of eventually finding the best and most appropriate, one-size-fits-all model of science/public interaction" [Bucchi and Trench, 2014, p. 11].

We have approached the task by mapping the understanding of quality among science communication stakeholders. The collaborative exercise which core feature was to make science communication stakeholder groups work together in proposing quality elements and the relationships between them, resulted in a quality framework summarized in this article.

The three quality dimensions of the framework reflect the main contexts in which science communication quality is discussed in the academic literature: in relation to scientific quality, in relation to style of science communication, and in relation to requirements that support quality engagement. The 12 quality indicators that we propose are also individually well known and discussed in the science communication literature. This paper, however, contributes with arranging them into a coherent framework of quality and suggesting principles that should be considered when discussing quality of science communication.

The discussions during the mapping exercise and the subsequent analysis of the produced quality maps have defined the following principles:

Quality is multi-dimensional, meaning that it is not defined by a single characteristic or element. Rather, all identified dimensions, preferably even all presented indicators need to be present simultaneously. Hence, quality can be understood as a property reflecting the integrity of the framework, that is, the presence of all quality elements in communication. Although not expressed explicitly, a similar outcome emerged from other studies that used a co-design approach [Mercer-Mapstone and Kuchel, 2017; Rögener and Wormer, 2017; Seethaler et al., 2019]. From this also concludes that quality elements and dimensions are non-hierarchical, meaning that none has prevalence in determining quality of communication. This indicates that the lack of one quality element cannot be compensated by a strong presence of another.

The proposed quality framework covers the needs of various science communication formats. It is similarly useful for discussing the quality of science communication in media, social media or in engagement or educational settings, meaning that very different kinds of science communication can now be compared using the same quality criteria. This does not mean, however, that the specifics of each format are not taken into account. There is flexibility within the indicators to define the best ways in which each indicator works within the format. For example, balance can have different meanings in journalism, social media or science education but is still an important indicator of quality in all of them. We present some of the specifics for journalism, social media and museums in Olesk et al. [n.d.].

The presented framework as the outcome of stakeholders' common understanding of quality has both theoretical and practical relevance for science communication. Theory-wise, it furthers the discussion on quality in science communication, opens possibilities to integrate the notion of quality to the models of science communication models and relate these to the various objectives of science communication. Science communication practitioners can use the framework as a tool in their daily work (for one example, see Maiden et al. [2020]) supporting the professionals in reflecting on their current practices and in designing new activities. In this context, we recommend to use the framework mainly as a self-evaluation tool rather than a normative instrument. The quality framework can also be useful for designing science communication training courses.

A definition of quality may also provide a further avenue to investigate the effectiveness of science communication. Quality, as considered in this approach, is foremost a property of science communication content, i.e. describing the input by the communicator. Effectiveness describes the impact of communication, i.e. whether and what kind of response does the communication elicit in the public. Having a framework of quality indicators enables us to identify quality content and test whether such communication is also more effective, leading us towards more evidence-based communication practices.

Our initial, informal validation of the quality framework at QUEST events has provided the feedback that the different stakeholder groups perceive the framework to adequately reflect their experiences and is useful for them. This shows the value of the collaborative mapping method. However, the framework needs further validation as our study has been limited in terms of the number of stakeholder representatives and the balance within the stakeholder groups. For example, in the selection of science communication professionals we were biased towards the QUEST focus strands: media, social media and museums. Further validation of the framework requires inclusion of a greater range of science communication professionals and a stronger representation of members of the public. The current study was also limited to five countries. Although these represent diverse corners of Europe (Italy, Estonia, U.K., Ireland and Norway), input from additional countries could make the indicators more robust. Further lines of research might include testing whether and how the use of the framework as a self-evaluation tool can improve quality, and an exploration of whether and how quality content supports effective science communication.

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