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RE-EXAMINING SCIENCE COMMUNICATION:
MODELS, PERSPECTIVES, INSTITUTIONS

Conceptualizing science communication in flux — a framework for analyzing science communication in a digital media environment

Birte Fähnrich

Abstract

The pace and scope of digital transformation has brought about fundamental changes to science communication. These changes have so far hardly been reflected in the underlying concepts of science communication as field of research and practice. Against this backdrop, this paper asks how science communication can be conceptualized in response to fundamental societal changes brought about by digital transformation. In response to this question, this paper builds on the results of a Delphi study with 31 outstanding international science communication scholars. It presents a shared approach that conceptualizes online science communication broadly and tackles different points of view by identifying specific characteristics that enable the distinction of different settings of science communication. It is argued that such an approach should be more appropriate for a contemporary analysis of science communication and also helpful for professional communicators and policymakers to understand the interactions of science and society in the context of the digital media landscape.

Keywords Public perception of science and technology; Scholarly communication; Science communication: theory and models

DOI https://doi.org/10.22323/2.20030402

Submitted: 16th November 2020
Accepted: 19th March 2021
Published: 10th May 2021

Introduction: science communication in flux

In their calls for an exploration of the ongoing changes of the science-society nexus, the guest editors of this special issue refer to the tremendous impact that digital transformation has on science communication. This process has fundamentally influenced and changed the ways in which science and society interact [Davies and Hara, 2017; Nisbet and Scheufele, 2009]. Digital media not only provide new channels for discussion and public engagement but also give increasingly open access to scientific sources, different ways to communicate, changing spaces of interaction, and a diversification of actors who engage in science communication. In recent years, Reddit, Twitter, and YouTube, to name but a few platforms, have become established as forums where scientists, journalists, and other professional gatekeepers, as well as a wide range of societal actors, can engage in conversations about science [Schäfer, Kessler and Fähnrich, 2020] but also, through communicating science, can pursue their strategic interests. Moreover, platforms themselves have become influential players [van Dijck, Poell and de Waal, 2018]. Their use of algorithms to automatically curate information and offer a personalized diet of news has become a driving force of public communication, though they have so far hardly been considered in the context of science communication research [Kaiser, Rauchfleisch and Córdova, 2021]. Due to the pace and scope of this digital transformation, changes in science communication and the functional and dysfunctional effects that these have for science, society, and their interactions can only be analyzed as snapshots and are difficult to predict [Collins, 2014]. This also poses challenges for science communication research as a field of inquiry [Trench and Bucchi, 2010; Rauchfleisch and Schäfer, 2018] and — as called for by guest editors — the development of models and perspectives to describe and analyze science communication against a backdrop of ongoing media change. This essay aims to contribute to the guest editors' call and is dedicated to the fundamental question: how can science communication be conceptualized during this period of digital transformation?

The approach presented here calls on a Delphi study with 31 outstanding international science communication scholars that was conducted in the context of the Horizon 2020-funded RETHINK project. Results of this study showed a great variety (or even disunity) of understandings of science communication. The study eventually pointed to a shared approach towards broadly conceptualizing science communication online and to tackling its multiple facets by defining a range of characteristics and thus developing a more concise framework. This paper begins with a reflection of the concepts of science communication, presents the results of the Delphi study, and concludes with a discussion of the future directions of science communication research and practice.

Common denominators and blind spots: concepts of science communication

In recent decades, science communication has grown and developed tremendously as a field of study. Its research is influenced today by a broad range of disciplinary perspectives that in turn have built upon a huge variety of definitions and apply very different theoretical and methodological approaches to its study [Rauchfleisch and Schäfer, 2018; Trench and Bucchi, 2010; Leßmöllmann, Dascal and Gloning, 2020]. Despite this diversity of "epistemic cultures" [Knorr Cetina, 1999], the field's development has been influenced by common underlying concepts of science communication that have been shaped by the interplay of science, politics, and society [Bauer, 2017]. These different concepts have been described as paradigms and include the so-called "deficit", "public understanding of science", and "public engagement with science" models that have been extensively discussed in previous research [Schäfer, Kessler and Fähnrich, 2020; Chilvers and Kearnes, 2015]. What these have in common is that science communication is perceived as being communication from institutionalized science that is directed at society at large. Their differences refer to the underlying ideas of the relationship of science and society and the related modes of communication. Overall, actual definitions of the concepts at stake have been quite different and oftentimes vague [Jünger and Fähnrich, 2020; Bucchi and Trench, 2016]. It is argued, however, that these concepts have been influential in science communication research as they have shaped the perspectives, or "mental models", of how science communication has been perceived and analyzed as an object of study. This has become especially visible with regard to "the preference for [. . .] normative overanalytical approaches" [Trench and Bucchi, 2010]; e.g., in the attribution of dialogic science communication as a "gold standard" or the often uncritical adoption of the public engagement dogma [Felt and Fochler, 2008; Chilvers and Kearnes, 2015] in recent years.

Although the different paradigms and related shifts in the perception of science communication are often read as repercussions of societal developments [Bauer, 2017], it is striking that the fundamental changes brought about in the context of digital transformation have not yet led to a broader rethinking of the concept of science communication [Akin and Scheufele, 2017; Schäfer, Kessler and Fähnrich, 2020]. It is common sense that developments in digital media have fundamentally changed all public communication, including science communication. With advancements in digital media, the roles of communicators and audiences have dispersed [Bruns, 2008]. As a consequence, we have witnessed a tremendous increase and diversification of individual actors and organizations that have become publicly visible via online channels and thus affect public discourse and opinion [Schäfer, Kessler and Fähnrich, 2020]. Moreover, this has established new forms of collaboration and interaction, with information now produced and consumed in different ways [Neuberger, 2014]. Changes in the media have also contributed to shifts in the traditional institutional order of society. For instance, journalism may have long since lost its role as society's main source of information, but it has turned into a single voice among many others in the networked public sphere [Newman et al., 2020]. Within this sphere, science communication is part of a patchwork of content whose sources are sometimes unrecognizable and whose credibility is often difficult to assess. These developments can thus go along with a fundamental de- or recontextualization of science communication, which is applied in various contexts and across a broad range of purposes [Akin and Scheufele, 2017]. Moreover, digital transformation has brought new players into the game. For instance, recent debates about fake news have emphasized the roles of platforms or social media and have shown how these corporations — by applying technical features such as algorithmic drivers — influence social communication in a so called "platform society" [van Dijck, Poell and de Waal, 2018].

So what does all that mean for science communication? Readers may argue that there has been plenty of research dealing with online science communication in recent years. This is true. But it is argued that a broad range of this research has been framed and influenced by established science communication paradigms. Accordingly, a large proportion of the research has analyzed online communication as a further arena of science communication, for instance on climate change [e.g., Lörcher and Taddicken, 2017]. Other research has dealt with online channels such as Twitter, blogs, and websites and their ability to increase dialogue and the effectiveness of communication, thus perpetuating the concepts of the public understanding of science and public engagement paradigms [e.g., Metag and Schäfer, 2017; Jünger and Fähnrich, 2020; Su et al., 2017; Fischhoff and Scheufele, 2013]. The relevance of this research is beyond question. Nevertheless, it is argued that research in the context of existing paradigms inevitably has a number of blind spots that potentially impede a comprehensive understanding of science communication.

This can be briefly illustrated by looking at research in the field of technology assessment (TA), which deals with how developments in technology can potentially have an effect on society by enabling collective decision-making and political regulation. TA shares some commonalities with science communication as it acts as an interface between science and technology on the one hand and political and societal demands on the other. TA research is strongly based on indicators that constitute the definition of what counts as a problem, to understand its scope and urgency, and to assess strategies for its solution [Boavida and Böschen, 2015]. Indicators — often politically predefined — are thus not "normatively neutral", although they are both preconditions for, and outcomes of, techno-scientific realities. Against this backdrop, the choice for or against certain indicators can lead to fallacies and deficient descriptions which deepen "the difference between map and territory" [Böschen, Sotoudeh and Stelzer, 2019, p. 47, own translation]. Moreover, the use of the same indicators for different problem settings can neglect differences in contextual factors and thus lead to biased assumptions. Böschen, Sotoudeh and Stelzer [2019] argue that the application of indicators — from a political or governance perspective — suggests the ability to control and govern. With regard to science communication, for instance, its common conceptualization as communication from institutionalized science that derives from the existing science communication paradigms and assumption that fostering public engagement with science would lead to increasing public awareness or trust fails to observe that a great share of contemporary science is not communicated by scientific actors and institutions. Instead, with the digital transformation of public communication, a great variety of actors contribute to the science communication reality in all its facets [e.g., Fähnrich, 2018; Thaker, 2020; Mede and Schäfer, 2020]. By using digital media, not only do universities and researchers but also activist groups, corporations, political actors, bloggers, vloggers, science enthusiasts, science sceptics, and many more communicate about science-related content, and thus they contribute to the overall public perception of science. Considering these changing realities might lead to different indicators, problem definitions, and approaches to governance. This, it is assumed, requires a rethinking of the underlying conceptions of science communication against the backdrop of digital transformation.

Conceptualizing science communication in the digital media environment

The Delphi study was an attempt to contribute to a more appropriate concept of science communication against a backdrop of digital transformation. It approached this aim in two ways: from a processual perspective, it provided a constructive approach to dealing with the understanding of science communication through a profound and discursive process of mutual reflection [Linstone and Turoff, 1975, p. 3; Niederberger and Renn, 2019]; and from a content perspective, the collective wisdom gathered in the Delphi study [Steinmüller, 2019, p. 34] led to the development of a situational conception of online science communication that might not only work as a useful and integrating framework for science communication research but could also be applied to inform science communication practice and politics in the future.

The Delphi study was conducted with the participation of science communication scholars who were invited to reflect on ideas of science communication in a digital media environment. It consisted of two waves of semi-structured online surveys that were conducted from November 2019 to January 2020 (wave 1) and from April to June 2020 (wave 2). Experts were selected for their outstanding experience in science communication research. It set out to contact scholars from all parts of the world, from different disciplines (especially in communication sciences, sociology/science and technology studies (STS), and psychology), and included different genders and status groups (from postdoctoral level to full professorship). From 70 potential panelists invited, 31 accepted our invitation (completed questionnaires in wave 1: $n = 26$, response rate: 83,8; completed questionnaires in wave 2: $n = 19$, response rate: 61,2%). The participants represented 17 different national perspectives. Scholars were full or associate professors (63% for wave 2) and had a background in communication science, STS, media studies, political science, psychology, and other fields. The final panel was approximately two-thirds male and one-third female. We refrained from collecting more detailed sociodemographic data to facilitate the anonymity of the experts.

The first wave aimed to explore understandings of participants, who were openly asked for their definitions of science communication. This led to a variety of responses that showed commonalities and also entailed different concepts regarding aspects such as communicators and recipients, objectives, means, and effects. Different participants emphasized the diversification of science communicators, channels, forms, and contexts in the digital environment. These perspectives looked to broader or narrower approaches of science communication and to more analytical viewpoints and more normative ones. Moreover, some of the respondents indicated that the digital context would not necessarily influence the overall concept of science communication, whereas others argued that the tremendous changes afforded by digital tools would require "a new — and presumably ongoing — conceptual understanding". The variety of concepts — despite their overlaps — confirms the heterogeneous perspectives of science communication prevalent in the science communication research community [Trench and Bucchi, 2010].

To analyze the wave 1 responses, these were summarized, ordered, and interpreted using a situational analysis approach. Situational analysis is a method developed in STS [Clarke, 2003; Clarke, Friese and Washburn, 2018] that allows the analysis of elements and the complex social constellations they are embedded into through the use of visual maps. In the context of the Delphi study, this approach was not only useful to analyze the data but also to develop a basis for reflection in wave 2. To this end, key terms in the responses were noted and clustered using situational maps which "display major elements in the situation of inquiry and provoke analysis of relations among them" [Clarke, Friese and Washburn, 2018, p. xxiv]. As the overall idea was to contribute to a more coherent concept of science communication in the digital media environment, searching for common patterns in the responses was at the core of the analysis. Whereas aspects such as relevant communicators or objectives differed, most agreement was expressed towards the subject of science communication in digital contexts. As one Delphi participant argued: "The definition of science communication comes down to the content being communicated (or not)"; therefore, science as the focal topic of science communication was central to many respondents. Accordingly, another participant warned that science communication should not be conceptualized "too narrowly" and its definition not limited to specific actors, objectives, or outcomes.

Agreeing with these perspectives, a broad conceptual approach was proposed:

> *Science communication in digital contexts encompasses all forms of communication about science-related topics via digital media.*

This understanding was considered sufficiently descriptive, broad, and compatible to tackle both the phenomena of the digital science communication environment and integrate different epistemic cultures within the science communication field. A range of participants argued that this conception would help to cover the entire digital science communication landscape from professional science journalism or university communication on websites, blogs and public engagement by scholars via Twitter to diverse forms of science-related communication by corporate actors or NGOs in the context of strategic communication campaigns or applied by science enthusiasts or deniers on YouTube, Reddit, and other platforms, and thus to link different fields of inquiry. However, it was acknowledged that such a broad concept is hardly useful as a basis for (empirical) research. Moreover, and with regard to the vagueness of existing concepts, it was considered necessary to draw "fuzzy boundaries" around them, as proposed by another Delphi participant. It was thus aimed at systemizing science communication online in more detail while still conforming to the required openness that the ongoing digital transformation is bringing about [Storksdieck, Stylinski and Bailey, 2016]. To this end, the responses of wave 1 were analyzed by focusing on key aspects relevant to describe science communication online. These aspects were summarized into categories that included a broad range of context factors such as the actors involved, underlying intentions, aspects of content and framing, level of controversy, and media-specific aspects such as directions of communication, modes of presentation, and types of effects.

These categories were presented to the Delphi participants in wave 2. Experts commented on them and added further categories and examples in the course of the second survey. On this basis, the following (open-ended) list of categories was developed (cf. Table 1) to display the diversity of science communication in the online environment. Focussing on these aspects and applying them, either individually or in combination, in research can help to open up research and overcome the established mental models and blind spots persistent in science communication research.

Table 1. Categories applicable for research of science communication in digital contexts.

Category	*Explanation*	*Examples*
Actors involved	Refers to actors involved in science communication itself; following the concept of "produsage" [cf. Bruns, 2008], there is no clear distinction of communicators and consumers as both roles can change constantly. In this context, the diversity of actors is expanding.	Scientists and science organizations, journalists, politicians, engineers, industry, citizens, PR agencies, science centers/museums, NGOs, media companies, government organizations, think tanks, churches.

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Table 1. *Continued from the previous page.*

Category	*Explanation*	*Examples*
Roles taken by these actors	Refers to different roles of the actors involved. Overall, self- and external perception of these roles do not necessarily coincide [cf. Jünger and Fähnrich, 2020].	Knowledgeables, peers, lay, professionals, non-professionals, authorities, communicators, multipliers, recipients.
Intentions/objectives of the actors involved	Refers to the conscious (strategic) or unconscious objectives of actors to take part in the interaction [cf. Dudo and Besley, 2016; Maier and Taddicken, 2013].	Knowledge creation and exchange, education/information, change of opinions, attitudes, or behavior, gratification (fun/entertainment/pleasure), reputational goals, legitimation of interests, strategic interests/activism, political action.
Initiators	Refers to actors behind the initiatives at a higher level than is usually seen by the public. An indicator for potential power dynamics behind science communication [cf. Kaiser, Rauchfleisch and Córdova, 2021].	Media companies, governments, research funders, lobby groups, NGOs.
Level of formality of communication	Refers to the level of planning and preparedness, potentially linked to objectives and an indicator for the level of professionalization [cf. Nisbet and Markowitz, 2016].	Organized actions such as campaigns and spontaneous communication.
Content	Refers to the broad range of science-related topics that are communicated.	Findings, practices and processes, methods, actors, science policy in fields such as climate change research, medicine, environmental studies, astrophysics, nanotechnology, media psychology.
Framing	Refers to the topics in which science communication is embedded [cf. Nisbet, 2009].	Scientific, economic, political, social, health.
Level of competition	Refers to diversity of public voices on the topic in focus.	Many different voices (e.g., climate change) vs. few expert voices (e.g., quantum computing).
Level of controversy	Refers to perceived political and social relevance towards certain issues, including ethical perspectives [cf. e.g., König and Jucks, 2019].	High level of controversy (e.g., GMO) vs. low level of controversy (e.g., cancer research).
Channels used and level of convergence	Refers to the channels applied and their respective features, as well as the hybridity of communication [cf. Chadwick, 2017; Jones-Jang et al., 2020].	Websites, (micro) blogs, social media, video/streaming platforms, news aggregators and the links between them.
Mode and tone of communication	Refers to the specific way in which content is presented and/or perceived [cf. Taddicken and Reif, 2020].	Informational, controversial, discursive, referring to opinions, ideas and/or facts, emotional, polemic, aggressive, instructive, humorous.

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Table 1. *Continued from the previous page.*

Category	*Explanation*	*Examples*
Directions of communication	Refers to the directions of communication, including unidirectional, dialogic, interactive.	Online press releases, social media campaigns, hackathons.
Types of presentation	Refers to the different forms in which science communication is presented including text, visual, audio, video [cf. Welbourne and Grant, 2016].	Tweets, podcasts, YouTube videos.
Types of public	Indicates how openly accessible content is; distinction between closed groups, clearly defined public, diverse public.	Expert webinars with closed access, reddit posts, Twitter threads.
Level of personalization	Indicates the level of algorithmic curation based on personal preferences, social networks, etc. [cf. Hwong et al., 2017].	Low in pull-media; e.g., when audiences visit sites, use news aggregators, vs. high in push-media, such as social media whereby audiences get news alerts, reading suggestions, customized ads.
Types of effects	Refers to the effects that the communication has, reaching from indicated to non-indicated, specific types of effects, questions of measurability, short- or long-term effects [cf. e.g., Chinn, Lane and Hart, 2018].	Increase in information, confirmation of values, pleasure/fun, change of opinion and behavior.

Conclusion and future directions

More than ten years ago, Trench and Bucchi [2010, p. 2] emphasized the need for conceptual work in science communication "to give researchers, students and professional practitioners better tools to describe and classify what they observe, to explain why things happen as they do, to understand relations and processes, to assess effects and outcomes, and to consider the likely consequences of an initiative of this kind or of that kind". With regard to the fundamental changes that the digital transformation brings about for societal interaction in general, and for science communication in particular, this conceptual work has perhaps become even more relevant today.

The objective of this paper is to draw attention to the blind spots of existing conceptions and, at the same time, propose an attempt for a more appropriate framework for analyzing science communication in the digital world. The aim is to broaden the focus and think beyond the perspective of established mental models and the oftentimes normative perspective of science communication research that "has stunted the development of theoretical perspectives in science communication" [Trench and Bucchi, 2010]. Another concern was to contribute to a more realistic and concise framework of science communication online and to overcome the vagueness of existing concepts. Finally, this framework should be developed on an empirical basis, for which the Delphi study with science communication scholars proved fruitful.

So, how can science communication research profit from the concept developed in this paper?

First, it is argued that the framework is useful as it changes perspective of what counts as science communication in digital contexts. For instance, previous concepts of science communication have focused especially on scientists and professional science communicators or the settings in which they are involved. The broad conception of science communication proposed in this paper widens the focus and includes other actors from diverse societal fields, not only as audiences of science communication but as communicators. Against this backdrop, for instance, analyzing an NGO that applies science to mobilize online engagement for its respective ideological purposes becomes relevant for science communication. The same applies to collaborations of government organizations and platforms such as Google to provide information on a privileged basis. Considering the broad range of attributes outlined above (cf. Table 1), it is important to understand how public perception of science is actually shaped. In addition, it is valuable for a more realistic assessment of the role that science is actually able to play in this competition for public attention. Against this backdrop, the approach presented here is meant to offer both orientation and inspiration for future research. Considering the abovementioned understanding and taking up the range of attributes derived from the Delphi study can thus help researchers contribute to a more realistic and coherent picture of the interactions of science and society in the online environment.

Second, the Delphi participants stressed the importance of context factors to analyze science communication and argued that these have become even more important in the digital media environment. In doing so, underlying motives and intentions of science communication come into the spotlight. This relates not only to the objectives of visible actors who engage in online and social media platforms but also to those pulling the strings in the background. In this regard, players such as Google or YouTube, with their respective business strategies, can also become a concern for science communication research [Kaiser, Rauchfleisch and Córdova, 2021]. This perspective is important as it shifts the normatively shaped focus on the societal function of science communication that still dominates a great share of science communication research towards the strategic function of science communication, thus calling for very different questions and perspectives.

Third, against this backdrop, rethinking science communication is also an important basis for actors involved in science communication practice such as scientists, professional science communicators and policymakers. The perceptions of these stakeholders, as well as their decision-making, are also influenced by the conceptions of science communication research promoted for instance in the context of applied research or policy advice [Bucchi and Trench, 2016]. The U.S. community and its attempt to promote the science of science communication is probably a good example of the (potential) impact of the field [Fischhoff and Scheufele, 2013; Hall Jamieson, Kahan and Scheufele, 2017]. In their commentary on the state of science communication as a discipline, Trench and Bucchi [2010, p. 4] propose that we should think about the "communicative authority of science" and analyze how it is won, exercised, and lost. It could be argued that this should also entail a reflection on how the field of science communication research contributes to its social responsibility as it is shaping the way in which science communication is perceived by its stakeholders (e.g., funding bodies, politics, science communication practice). The proposed conception thus may work as a starting point for future analysis, reflection, and reconsideration of science communication in flux.

Acknowledgments

This research was conducted in the context of the project RETHINK which is funded by the European Commission in the Horizon 2020 framework (SwafS-19-2018-2019). The authors would Iike to thank the participants in the Delphi study for their valuable contributions and for investing their time.

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Author

Birte Fähnrich is Senior Researcher for science communication at the Berlin-Brandenburg Academy of Sciences and Humanities (Berlin, Germany) and Principle Investigator in the Horizon 2020-project RETHINK for Zeppelin University. Her research interests encompass strategic science communication, public engagement, science communication in organizational contexts and communication at the intersection of science and politics.
E-mail: birte.faehnrich@bbaw.de.

How to cite

Fähnrich, B. (2021). 'Conceptualizing science communication in flux — a framework for analyzing science communication in a digital media environment'. *JCOM* 20 (03), Y02. https://doi.org/10.22323/2.20030402.

ISSN 1824-2049. Published by SISSA Medialab. jcom.sissa.it