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*Annette Leßmöllmann, Marcelo Dascal,  
Thomas Gloning (Eds.)*

# SCIENCE COMMUNICATION

HANDBOOKS OF  
COMMUNICATION SCIENCE

DE  
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Annette Leßmöllmann, Marcelo Dascal and Thomas Glöning (Eds.)  
**Science Communication**

# **Handbooks of Communication Science**



Edited by  
Peter J. Schulz and Paul Cobley

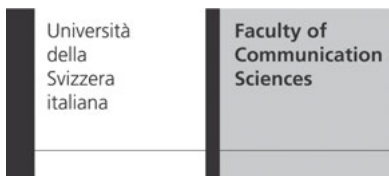
## **Volume 17**

# Science Communication



Edited by  
Annette Leßmöllmann  
Marcelo Dascal  
Thomas Gloning

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# Preface

The handbook that you hold in your hands or that you see on your screen has a long history. Initially, around 2010, Marcelo Dascal was contacted by the series editors (Peter Schulz and Paul Cobley). He was supposed to act as the principal editor of the volume 17 “Science communication” in the series “Handbooks of Communication Science”. Marcelo agreed and asked Thomas Gloning to join the project. Both drafted an initial concept, a thematic outline, they contacted authors for specific topics, they discussed abstracts and concepts with authors, time tables and other things that come with editing a handbook of this type.

Then, in 2013, Marcelo had an accident, from which he never recovered, although we all – a large community of colleagues, students and friends – hoped that he would. However, he did not in the years to come. Other medical problems followed. Varda, his wife, and his family took loving care of him.

When around 2017 it became clear that Marcelo Dascal could not work on this handbook any more, Thomas Gloning asked Annette Leßmöllmann, a specialist in science communication, to join the project. She agreed and provided a broad range of new aspects, new ideas, and new contacts. Without Annette (says Thomas) this handbook would not have seen the light of day.

Marcelo Dascal died early in 2019. Marcelo was a prolific writer, a passionate teacher, a sought-for speaker on workshops and congresses, he was awarded many honors. Numerous colleagues, students and friends all over the world (among them the undersigned) miss this inspiring, magnanimous, hard-working scholar, teacher and friend. His spirit continues to inspire many people. Those, who knew him, will not forget him.

We want to thank several people for their valuable help and support.

The editors of the series “Handbooks of Communication Science” gave inspiration in crafting the conceptual foundations, they were there when difficult decisions had to be taken and they had to have a lot of patience, given the history of this endeavour.

Then there are the wonderful teams in Karlsruhe (Annette) and Giessen (Thomas): Christiane Benetz, Roman Degreif, Sarah Insacco, Dennis Kaltwasser, Stephanie Lomuscio, Heike Müller-Moritz (†), Philipp Niemann, Kristina Pelikan, Andre Pietsch, and Tanja Schmith gave us invaluable support with proof reading, indexing and many other things the edition of an international handbook requires. A big “Thanks” to all of you! Alas, we cannot know, who in the earlier stages gave support to Marcelo in Tel Aviv. At least it was Varda, Marcelo’s wife. Thanks to you, Varda!

Since Marcelo could not write the article on scientific controversies, Gerd Fritz (Giessen) agreed to contribute this important chapter in a handbook of scholarly communication in addition to the chapter on “Reviewing” he had already written. This handbook and one of its editors in particular (Thomas) have benefited in many other ways from his advice and his ongoing support. We are very grateful.

From its beginnings to the final stages of the book, Barbara Karlson at Mouton de Gruyter has been an ideal project editor. It was both a pleasure and a marvelous experience to work with her. If ever we will produce another handbook ... But for now we are happy that *this* one is out. In any case we now know what an ideal project editor looks like. Thanks, Frau Karlson, for everything you have done for the handbook and for its often exhausted editors. We also want to thank the team at Mouton de Gruyter, e. g. Lukas Lehmann of the production team, and Elisabeth Nichols, who worked for this handbook as a native speaking copy editor.

Finally, warm thanks to our authors for their knowledgeable and inspiring contributions, for their timing, and, above all, for their willingness to discuss open points with the editors. They invested a whole lot of patience as this handbook took many years to appear, due to the circumstances sketched above. We also want to thank all the persons who helped our authors with their articles, be it by discussing the content, drafts, specific issues, be it by help with translating or polishing the English text, be it in contributing references etc. Thank you all, authors and supporters of authors.

The surviving editors dedicate this handbook of science communication:

To the memory of Marcelo Dascal

Annette Leßmöllmann and Thomas Gloning  
Karlsruhe and Giessen, September 2019

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## Introduction to the volume

To ask someone what “science communication” might be can bring surprising and very diverging results: some would call the communication of, say, a higher education institution a prototypical representative of this notion, as they conceive of “science communication” as something strategic. Others might say that a paper in *Nature* is an appropriate example, or a blogpost or an article in *Scientific American*, as both are very closely connected to scientific content, even though the communicative intentions are different. Others might name science centers or museums as good examples, as these institutions try to teach their audiences about science. Others might mention a new edition and translation of the work of Copernicus as a significant contribution in the field.

These few examples – there could be many more – show that science communication is a multi-faceted notion. This handbook embraces the multitude of meanings and hence addresses many diverse communicative acts that entail a relationship to scientific knowledge or work, stemming from institutions or individuals, addressing both scientists or the public, intending to inform, influence, enlighten, argue or otherwise negotiate about science. In these and many other aspects, the handbook takes a broad perspective: It looks at communicating individuals and institutions; it starts off from a broad notion of “science” – not excluding any scientific subject –, and it adopts an inter- or multidisciplinary approach to the field. In this introduction we will give the reader some basic guidelines and notions to grapple this multitude and to navigate through the book.

## 1 Internal and external science communication: broad notions

In modern societies a broad range of scientific disciplines produce knowledge, either as a value in itself or for the sake of practical utilization. In this handbook we use the term “science” as an umbrella term not only to refer to the natural sciences but, in its broad sense, to comprise the humanities, research on art, the social sciences, and other scholarly fields of inquiry, that are guided by principles of systematic research.

Given that, we also take communication to be a vital backbone of science: communication contributes in many ways to produce knowledge. It is also crucial in order to publish knowledge, to make scientific results available for scrutiny. In addition, communication is the basic tool to organize the process of scientific research itself. If one looks at science and its disciplines as a more or less closed system, one can term its communicative aspects as “internal science communication” or “internal scientific

communication”. However, science and scientific knowledge are also communicated to a wider public, science can become the topic of communication beyond specialized disciplines. One can dub these aspects and forms of communication as “external science communication”. These two perspectives do not produce clear cut boundaries. There are various relations and there is a specific dynamic in the configuration of internal and external science communication.

Internal science communication has a lot to do with epistemic practices like taking notes, writing a lab journal, summarizing texts, discussing preliminary data, etc. It also deals with relatively formalized sorts of texts, like a paper in *Nature*. External communication flourishes with a wide spectrum of formats, but also of actors and institutions with their respective communication interests, be they strategic, popularizing, enlightening, dialogue-oriented, or else. External, in contrast to internal communication, cannot assume that communicative partners share the same scientific values, accept the same methodological principles or “speak the same language”.

In this handbook, we touch upon both perspectives on science communication, the internal and the external one, fathoming a variety of aspects concerning the different communicative practices. In doing so, the handbook will also include the – presumably expanding – grey zones between internal and external science communication: On the one hand, internal practices like debating truth conditions or the substantiation of a scientific argument enter more and more the public sphere, which can be seen on debates about controversial issues like climate change or homeopathy on Twitter. On the other hand, social software and its instruments for counting and evaluating impact are entering and possibly changing the scientific field, e. g. by scientometric methods like *altmetrics*.

Within the last years, a new field labelled *scholarly communication* has emerged which focusses on open access, strategical planning of communicative infrastructures, the planning of administrative, financial and funding policies, library and digital services management, etc. In this handbook we stick to the term *scholarly communication* in its traditional meaning referring to all aspects and forms of communication within the realm of scholarly activities, without assuming, however, that this usage is exclusive.

In case our authors chose to use notions and definitions, mentioned here, otherwise, they explicitly refer to it.

## 2 Dimensions of science and science communication

The interrelation between science and science communication shows a number of important dimensions which generate perspectives of research on science communication. In this section, we mention some basic assumptions concerning this relationship.

## Epistemic function

The basic function of scientific communication lies in its role for the constitution, the systematic production and the scrutiny of knowledge. In order to fulfill this function, specific communicative tools have evolved over time, e. g. forms of language use, text types, spoken genres, forms of visualization, terminology systems, activity types like quoting or defining, etc. They form organized repertoires that answer discipline-specific needs. Besides, they are the product of historical evolution and in some cases the result of intentional design, and they are closely connected to technological development and media usage.

## Communication and the social organization of science

In science, knowledge in itself is worthless if it isn't communicated to anyone in the field. (If the same statement is also true for the communication to the public is still a matter of debate.) For science, not communicating to the scientific population would mean to not acting scientifically. The other side of this coin is, that no science can be done without taking note of the work of others and referring back to it. The creation – via language and visualization, or, today, all multimodal tools at hand – and dissemination of findings and insights were always part of science, connected with different communicative acts: Certification (of a dissertation, or of an argument), conjecture and refutation (in a scientific dispute), contextualization (within a field), proving or substantiating (of a hypothesis), applying and pledging (for a grant), etc. The connection of scientific work and scientific communication is more than an addition. Communication can help to develop ideas, it can be an epistemic tool in itself or, at least, being supportive to the epistemic work of scientists. In short: for this handbook we assume that communication and science always belong together.

## Science and science communication in society

Science is an integral part of modern societies, it fulfills functions for society and its systems (e. g. economy, culture, sports, architecture, medicine, mobility, or education), scientific institutions are funded in and by societies, scientists are persons that have other social roles as well, and science relies on infrastructure that is publicly funded (e. g. libraries, data licences, research technology). These close relationships are mirrored by multi-faceted communicative ties, e. g. in grant proposals, budget reports or scientific reports, in the products of science journalism, “third mission” activities, knowledge popularization, or the scientific “voices” in public controversies over questions of general interest.

## The individual perspective

As a rule, individuals and institutions are connected within science communication. A prominent figure is the scientist her- or himself: Scientists are not born into this world as scientists. They have to acquire knowledge, research or writing skills, principles of conduct, a certain habitus, etc. Becoming a scientist takes many years and is often an important aspect of the life of an individual. His or her development is closely tied to infrastructure provided by society and by a huge number of acts of communication (e.g. writing papers and reading comments on papers). Being educated at school, studying at a university, starting a career as a researcher, and working as a scientist are in large parts communicative endeavours, that have an individual and a social side. Each aspect of this complex configuration is an object of study, e.g. the question how people acquire individual writing or publishing skills according to the (supra-individual) needs of a specific discipline or a research community.

## Medialization

Connected with questions of societal or technological development and embedded into a highly medialized world, scientific questions, methods and outcomes are more and more debated on a social and political level. Changes in the medial landscapes offer to virtually everyone the possibility to communicate, defend, argue, oppose, or overtly ignore scientific knowledge. How knowledge can be used and what a scientific argumentation is like is more and more not only a scientific matter, but also debated on the tribunes of the medialized world. Communication of and about scientific content with different publics are both politically fostered and on the rise in some countries (whereas in others, media are used to oppress communication on science). The communication types in different fields of external science communication are highly differentiated and medialized: from different styles and types of science journalism to strategic communication, e.g., of scientific institutions; from public talks of scientists to science slams and multi-medialized science centers and museums.

Equally, the medialization of internal science communication has changed during the last decades with a highly differentiated spectrum of new formats, new media and forms of communication and publication (e.g., video abstracts). The use of old and new formats is currently a matter of dynamic development, and publishing practices are constantly evolving. Different disciplines tend to prefer different publication strategies, and sometimes publication trends vary from country to country (like the usage of weblogs, the prevalence of book publishing or the urge to publish in high impact journals). Some fields turn towards open access journals or engage into pre- and post-publication discussions online. Many medialized communicative and epistemic practices emerged, from wikis and weblogs to social networks offering both a repository as well as a communicative function, like ResearchGate.

## Technological change and science communication

Both internal and external communication are often driven by the same type of technological change: both take advantage, e. g., of a broader bandwidth for data exchange, of social software technologies, of algorithms structuring information research, or of mobile media usage. Both struggle with analogous phenomena, e. g., the overflow of information and the fact that, without algorithms, nobody will find anything of relevance any more in the current information tsunami. However, technologies do not determine changes in science communication. They offer possibilities, affordances that human actors have to use in a productive way.

## Historical dynamics

The recent dynamics in digitalization are only one step in a long tradition of technological developments that have significantly changed scientific communication: the printing press, microscopes and telescopes, the x-ray technology, or presentation technologies, to name but a few. In a broader view, *all* aspects of science communication are subject to historical evolution, be it change or continuity: text types, oral forms of communication and presentation, terminology systems, forms of collaboration, types of visualization, the available media, etc. These aspects do not develop individually but as parts of complex configurations that evolve in time.

The dimensions described so far build up a complex architecture of (mutual) relationships, e. g. the intertwining of the individual and the social. In order to organize such a complex topic, different strategies are possible. These following strategies described in the next section form a blueprint for our handbook.

## 3 Perspectives on science communication and the structure of the handbook

For this handbook, we decided to combine a *first strategy* that looks at different research approaches and asks for their specific contribution to the study of science communication. This is the aim of section I. A *second and third strategy* is to describe main topics and central aspects of internal and external science communication. This is the aim of sections II and III, respectively: In section II the authors deal with text types, media, and practices of internal science communication. Section III is devoted to external science communication and the relation between science, scientists, and the public. A *fourth strategy* is based on an evolutionary perspective: How has science communication evolved, what are current trends, and what could or should be future developments? In sections IV and V the authors share an evolutionary perspective:



they deal with the history of science communication and with current and future trends.

Below we will sketch the content of the sections in more detail.

## **Section I: Perspectives of research on scholarly and science communication**

This handbook takes communicative acts, their role and their organization in science communication as a starting point to bring together current research on the topic, giving linguistics, media and communicative sciences a certain priority. But a major purpose of this handbook is to show the disciplinary variety within the field sometimes called “science of science communication”, i. e. we asked not only linguists and media or communication scientists, but also philosophers, mathematicians, psychologists, sociologists, political scientists, information scientists, visual scientists, and scholars of Science and Technology Studies to spell out the theoretical, methodological and empirical approaches to the field of research on science communication. If “the science of science communication” can be considered as an emerging field, we decided to explore this field from many relevant perspectives.

Section I is gathering disciplinary approaches to science communication that seem most relevant to us. It starts with philosophy of science “in twenty-two questions” by Gregor Betz and David Lanius, presenting and discussing notions and questions from epistemology and theory of science, like the role of Popperian falsificationism, and their relevance for science communicators. In Chapter 2, Friederike Hendriks and Dorothe Kienhues open up a rich empirical overview on psychological and pedagogical literature concerning science literacy, the way children deal with science, and bounded rationality. Chapter 3 discusses the notions of medialization in the light of visualization, popularization and digitalization from a media studies perspective (Hans-Jürgen Bucher). Mapping the field of the vast empirical literature in communication science is the task Mike Schäfer, Sabrina Kessler and Birte Fähnrich took over in Chapter 4. In Chapter 5, also rooted within communication science, Hannah Schmid-Petri and Moritz Bürger presents a model to grasp the complexity of science communication via network theory. In Chapter 7, the contributions of Science and Technology Studies is presented by Gábor Zemplén, also including the historical development. Chapters 7, 8, and 9 take up the linguistic perspective: Chapter 7 covers linguistics and semiotics including a historical review (Nina Janich); Chapter 8 examines the sub-discipline of terminology research (Britt Schuster), and Chapter 9 presents empirical research on how students grapple with writing tasks in the academic realm (Thorsten Pohl).

## **Section II: Text types, media, and practices of science communication**

This section is dedicated to internal scholarly communication in the sense discussed above: communicative products of and acts between scientists from the same discipline or from different fields are at stake here. Thomas Gloning (Chapter 10) opens up the section with an overview and a discussion of epistemic genres in science communication. Luc Pauwels presents his approach on visual representations in knowledge production in Chapter 11 and gives an overview of research in the field. Henning Lobin (Chapter 12) points out the fruitful links between presentation and rhetorics in the context of presentation technology. Sylvia Jaworska (Chapter 13) offers a rich overview on empirical work on spoken language, which she characterizes as a late-blooming field. In Chapters 14 and 15, Gerd Fritz is investigating two important forms of communication in science: reviewing, as a discipline specific way of commenting and quality checking in science, and scientific controversies, both from the point of view of linguistic pragmatics and action theory. Chapters 16 and 17 are closely linked, as Thomas Gloning gives an introduction into symbolic notations in several fields, also including historical perspectives, and Michel Serfati specialized on the rise of symbolic notation in mathematics. Finally, Benedetto Lepori and Sara Greco present their approach to grant writing in Chapter 18.

## **Section III: Science, scientists, and the public**

The authors of this section deal with prominent, disputed, and sometimes neglected aspects of science communication in the public sphere. Wolf-Andreas Liebert (Chapter 19) starts out from traditional popularization strategies from a linguistic point of view, describing basic prototypes of popularization in different settings. Sharon Dunwoody (Chapter 20) traces the development of science journalism and its challenges globally and especially in the digital age. Holger Wormer (Chapter 21) makes a strong argument for independent and sceptical science journalism and the conditions for academic teaching of this subject, which could be a model for journalism teaching in general, also in the field of data journalism. Charlotte Autzen's and Emma Weitkamp's contribution (Chapter 22) can be read partly as a counterpoint to Wormer's, as they focus on the blurring boundaries between journalism, PR and science communication in general – boundaries he considers essential. Philipp Schrögel und Christian Humm (Chapter 23) offer definitions and clarifications in the sphere of advocacy and advising and discuss the question if scientists should, or should not, try to speak truth to power. Philipp Niemann and his colleagues (Chapter 24) present empirical findings relating to newer formats like scientific web videos and science slams and the question how they are perceived and understood by the viewer.

## Sections IV and V: evolutionary aspects of science communication

As mentioned above, sections IV and V share an evolutionary perspective: the authors deal with the history of science communication (Chapters 25–27) and with current and future trends (28–31).

Section IV is dedicated to the historical perspective of science communication. Thomas Gloning gives an overview on historical developments of internal scientific communication in Chapter 25. The contribution of Monika Hanauska (Chapter 27) focuses on developments in external science communication, as far as they can be separated from internal ones. Michael Prinz (Chapter 26) elaborates on three prominent scholarly communication activities in history: lecture, disputation, and dissertation.

In section V we are completing the picture with four views on current trends and the future of science communication. Martina Franzen (Chapter 28) considers science communication as a subject for the sociological study of societal change and discusses in depth how new media usage will revolutionize scientific publication. Mareike König's contribution (Chapter 29) is linked to the argumentation in Chapter 28 and discusses in detail how new media usages have the power to merge internal and external ways of communication. Peter Reuter and Andreas Brandtner (Chapter 30) show how libraries are changing from a knowledge reservoir to a knowledge facilitator in the digital age (Chapter 30). Annette Leßmöllmann wraps up the volume in Chapter 31 by discussing current trends and future visions for both research on science communication and science communication practice presented in this volume and elsewhere.

## Other reading perspectives

Apart from the sections and its topic structure, the volume offers possibilities to pursue different interests and thus cherry-pick across sections. We mention some of these reading perspectives here, cautioning the reader that this is by no means a complete list:

- For philosophical advice for practitioners in science communication, we recommend Chapter 1.
- Vocational fields are the main topics of Chapters 20, 21, and 22. Chapters 25 and 27 touch this topic from a historical perspective, Chapter 31 from the perspective of future developments.
- Empirical findings are focused on in Chapter 4 with the communication science perspective, Chapter 5 with the psychological and pedagogical angle, Chapter 8 on terminological research, and Chapter 13 on spoken language.
- New frameworks for future research are advocated in Chapter 5 (network theory), Chapter 11 (visualization), Chapter 28 (science communication and social change),

Chapter 18 (grant proposal writing), Chapter 23 (advocacy and advice), Chapter 24 (new formats and their reception), and Chapter 31 (future trends in general).

- Many chapters touch the question of new media usage, but some of them focus on it: Chapters 28, 30 and 31, and in part Chapters 14 and 15.
- Chapters 16 and 17 concentrate on the aspect of formalization.
- Chapters 6, 7, 14, 15, and 20 touch historical aspects of their topics, respectively. They complement the three historical Chapters of section IV.
- Those interested in a linguistic perspective will not only benefit from Chapters 7, 8, and 9, but also from 10, 12, 13, and 19, and with a perspective of pragmatics and action theory, especially from Chapters 14 and 15.

## 4 Conclusion

The aim of the multidisciplinary and multi-faceted strategy for this handbook is to open up the view on a field with multiple perspectives on scientific communication. This handbook should be seen as a navigational device through these multi-perspectives. With many cross references, we tried to assist the reader to find possible touch points and pointers to future work. The common theme of this book is thus not to set basic notions, theories and methods into stone, but to thoroughly pin down approaches and the state of the art in order to open up future developments and perspectives on science communication as a research field with a lot of basic and applied research done – and still to be done.



---

## **I Perspectives of research on scholarly and science communication**



Gregor Betz and David Lanius

# 1 Philosophy of science for science communication in twenty-two questions

**Abstract:** Philosophy of science attempts to reconstruct science as a rational cognitive enterprise. In doing so, it depicts a normative ideal of knowledge acquisition and does not primarily seek to describe actual scientific practice in an empirically adequate way. A comprehensive picture of what good science consists in may serve as a standard against which we evaluate and criticize actual scientific practices. Such a normative picture may also explain why it is reasonable for us to trust scientists – to the extent that they live up to the ideal – and to rely on their findings in decision-making. Likewise, a sound normative understanding of science exposes the limits of scientific understanding and prevents us from placing blind faith in scientists and experts. For these reasons, philosophy of science represents a useful resource and background theory for the practice and study of science communication. In this handbook article, we provide an opinionated introduction to philosophy of science by flashing a light on 22 central issues, which (we think) are of special interest to scholars and practitioners of science communication – and, in particular, to scholars and practitioners of external science communication.

**Keywords:** philosophy of science – scientific explanation – scientific justification – reliability – evidence – scientific progress – scientific controversy – scientific confirmation – science and democracy – science and values – scientific expertise – scientific policy advice – trustworthiness

Philosophy of science attempts to reconstruct science as a rational cognitive enterprise. In doing so, it depicts a normative ideal of knowledge acquisition and does not primarily seek to describe actual scientific practice in an empirically adequate way.

A comprehensive picture of what good science consists in may serve as a standard against which we evaluate and criticize actual scientific practices. Such a normative picture may also explain why it is reasonable for us to trust scientists – to the extent that they live up to the ideal – and to rely on their findings in decision-making. Likewise, a sound normative understanding of science exposes the limits of scientific understanding and prevents us from placing blind faith in scientists and experts. For these reasons, philosophy of science represents a useful resource and background theory for the practice and study of science communication.

This handbook article provides an opinionated introduction to philosophy of science – with a focus on the empirical sciences – by flashing a light on 22 central issues (referred to as Q1 to Q22), which (we think) are of special interest to scholars and practitioners of (external) science communication. The anthology by Curd and Cover



(2012) as well as the *Stanford Encyclopedia of Philosophy* (Zalta 2018) provide excellent starting points for further reading.

## Questions

1. Why does scientific knowledge come in degrees?
2. How reliable is scientific observation?
3. What does “scientifically proven” really mean?
4. Can science falsify a hypothesis?
5. Is Karl Popper rightly the philosophical hero of practicing scientists?
6. Which evidence do we need to consider when assessing a scientific hypothesis?
7. Why do we need to know the alternatives in order to understand how strongly a scientific hypothesis is justified?
8. What is the difference between justification and explanation?
9. Has Paul Feyerabend shown that anything – really: anything! – goes?
10. Do controversies in science undermine its trustworthiness?
11. Is science’s success a reason to trust or rather distrust it?
12. What is a scientific paradigm?
13. Has Thomas Kuhn shown that there is neither scientific progress nor scientific objectivity?
14. Do we promote blind faith in science by defending its rationality?
15. What is the difference between science and pseudoscience?
16. What is the meaning of probability?
17. Can, or should, science be value-free?
18. What is worth being scientifically investigated?
19. Can empirical findings ever necessitate a policy decision?
20. Is the influential role of scientific experts in policy making a threat to our democracy?
21. Does science tell us what is really real – and what not?
22. Are we slaves of science?

## 1 Why does scientific knowledge come in degrees?

In a deductive argument, the truth of the premises guarantees the truth of the conclusion. This is not the case in non-deductive, or so-called inductive, reasoning. In inductive arguments, premises render a conclusion only plausible or more likely (Skyrms 2000).

The results and findings in the empirical sciences are justified in inductive ways (Q3). Unlike deductive (e.g. mathematical proofs) inductive justification is gradual

(Q6, Q7): A hypothesis can be better justified than a rival one; the degree by which a theory is confirmed might increase – or decrease – as more and more evidence is accumulated (Hempel 1966; Glymour 1980; Howsen and Urbach 1989; Earman 1992).

The extent to which a finding (e. g. a theory, hypothesis or prediction) may count as well-confirmed, or scientifically established, depends on different factors (see Sutherland, Spiegelhalter, and Burgman 2013), especially

1. on the ability of the hypothesis to account for and to systematically explain given observations (Q8);
2. on the breadth and diversity of the total evidence against which the hypothesis is assessed (Q6);
3. on the degree of confirmation of the background assumptions which are relied upon in scientific inference and evidence acquisition (Q2);
4. on the extent to which alternatives to the hypothesis-to-be-established have been comprehensively spelled out and thoroughly explored (Q7).

If neither a hypothesis nor its negation is well confirmed, there is scientific uncertainty. The degree to which scientific knowledge is limited determines and characterizes the existing uncertainty. Scientific uncertainty can accordingly stem from different sources and can be articulated in different ways (Hansson and Hirsch Hadorn 2016b; Hansson 2016). Sometimes, uncertainty may be quantified in a probabilistic way (Q16), for example, “The probability of the hypothesis to be correct is 70 %.” Sometimes, uncertainty is so “deep” that one can only enumerate alternative possibilities, for example, “It is possible that there is extra-terrestrial life and it is possible that there is no extra-terrestrial life. Either claim could be true.”

It is erroneous to equate deep, possibly irreducible, uncertainty about a domain X with the denial that there are objective facts about X at all. For instance, the irreducible uncertainty about the Ilias’ author’s date of birth doesn’t mean that there is no matter of fact about the Ilias’ author’s date of birth. Also, scientific knowledge coming in degrees does not imply that every scientific finding is uncertain. Many scientific findings, like many everyday convictions, can be considered as virtually certain (Q3).

Scientific knowledge must thus be conceptualized in a nuanced way. And the communication of scientific findings should indicate – where possible – the firmness of our current understanding and the extent of existing uncertainties.

## 2 How reliable is scientific observation?

One thing that seems special about the empirical sciences (and a reason for their epistemic authority) is that they are – *empirical*, which has been understood as: purely based on observed facts about the world. But, how pure and firm is this observational basis of the empirical sciences?

Theory-ladenness of observation refers to the phenomenon that knowledge acquisition through observation (like observing an eclipse, measuring global mean temperature or weighing a child) depends on assumptions that cannot be directly verified through observation. The claim that observation is always and inevitably theory-laden is today a consensus-position in philosophy of science (Bogen 2017). The main arguments for this claim are, in a nutshell:

- Knowledge acquisition through observation always relies on the assumption that one's sense organs operate in a reliable way.
- Knowledge acquisition through observation relies on the assumption that circumstances under which the observation is made are normal.
- Knowledge acquisition through measurement relies on a general theory about the measurement apparatus and the specific assumption that it is working correctly (Duhem 1998).
- The choice of language, which involves metaphysical assumptions, determines which observational statements can be articulated and verified in the first place. And the meaning of an observational statement depends on the meaning of many other, non-observational, statements (Kuhn 1962).

Thus, the objectivity of scientific observation does not consist in its purity or indisputability. Scientific observations can be disputed – and actually are frequently contested in controversies among scientists (Q10) (see Chapter 15, this volume). Instead, it has been suggested to construe the objectivity and reliability of scientific observation in methodological, or procedural, terms: scientific observation follows highly standardized routines and protocols in order to guarantee a maximum level of reproducibility (see Chalmers 1984).

In summary, there is no indisputable empirical grounding of science. It is thus important to be aware of theoretical assumptions that enter observation or measurement when investigating or practicing the communication of scientific findings.

### 3 What does “scientifically proven” really mean?

Fallible knowledge is knowledge that might turn out to be wrong in the future. Infallible knowledge is safe and maximally certain. Mathematical theorems, once proven, are the paradigm case of infallibility. The empirical sciences don't yield infallible knowledge. Whatever we currently know about the world can possibly, and in principle, be revised. Fallibilism has different reasons:

- Inductive rather than deductive justification of scientific hypotheses by empirical evidence (Q1);
- Theory ladenness of observation (Q2);

- Reliance of scientific arguments on further background assumptions (Q4);
- Finiteness of the empirical basis despite the fact that scientific theories typically imply infinitely many observational statements (Q6);
- Inability to enumerate all conceptually possible rival theories or hypotheses (Stanford 2006).

So, “scientifically proven” cannot mean “established as infallible”, lest no result whatsoever be scientifically proven.

While fallibilism is uncontroversial, the diagnosis of underdetermination is not. An argumentative situation is underdetermined if contrary conclusions are equally well justified. Regarding scientific reasoning and theory choice, it is common to distinguish transient and global underdetermination (Godfrey-Smith 2008).

Transient underdetermination means that, in the course of an ongoing research program or scientific controversy, there may exist equally well justified rival hypotheses. Transient underdetermination is, however, consistent with the view that such epistemic stalemates can be resolved in the future.

Not so global underdetermination! It means that whatever the circumstances, there will always be rival hypotheses and theories that are equally well justified. This latter, stronger, claim is a matter of dispute in philosophy of science. While there are good arguments to the effect that there always exist rival theories that are logically consistent with the available evidence, this is short from establishing that these rival theories are equally well justified in non-deductive terms (Laudan 1990).

This being said, what does “scientifically proven” mean? A charitable interpretation, which takes fallibilism for granted and accounts for transient underdetermination, is that a finding has been “proven” just in case transient underdetermination has been resolved and the finding has turned out to be (part of) the unique best-justified theory in a critical research program.

In the context of the study and practice of science communication it might be recommendable to refrain from using the term “scientifically proven” altogether and to rather describe the status of a finding in more specific terms, e. g. by characterizing a theory as “by far the best confirmed one”, as “predictively extremely successful”, as “consensus view the community settled upon after fierce controversy”, or “fruitful theoretical basis for technological innovation”.

## 4 Can science falsify a hypothesis?

Scientific hypotheses and theories sometimes conflict with observation. That is what makes a theory empirical in the first place (Q2). But doesn’t this imply that, even if scientific theories cannot be proven to be true, they can at least be falsified, i. e., deductively shown to be wrong, on purely empirical grounds? The idea is: If the theory says

that all swans are white and this particular swan is black, then, inevitably, the theory is wrong.

It has long been understood (at least since Pierre Duhem's work on theory choice; see Duhem 1998) that this is too simplistic a picture of scientific reasoning. In this context, "holism" is the view that theories and hypotheses never entail, on their own, observationally verifiable statements. So, in the swan example, we at most verify that a particular animal is black; we have to add the additional premise that this animal is a swan in order to refute the theory. Willard Van Orman Quine famously summarized holism as the view that one can hold on to any hypothesis, come what may, as long as one is prepared to make the required adjustments in other parts of one's net of beliefs (Quine 1951).

In philosophy of science, holism is considered to be – from a purely logical perspective – a viable view (Curd and Cover 2012). However, it has been stressed that, in many scientific contexts, the auxiliary assumptions and background theories that are used to establish inferential connections between theories and observation are held fix and are not up for revision (Q12). Moreover, Quine's dictum ignores further epistemic standards (such as explanatory power) beyond logical consistency; inductive arguments do sometimes indeed compel one to give up on a certain view. Finally, Karl Popper (2002b) even went so far as to say that giving up a hypothesis that faces recalcitrant evidence – without being logically forced to do so – is precisely what sets science apart from pseudoscience (Q15).

The upshot for the study and practice of science communication is that science cannot infallibly, once and for all, falsify a given hypothesis. However, science can and does often provide very strong inductive reasons against a given claim, which make it highly irrational to stick to it.

## 5 Is Karl Popper rightly the philosophical hero of practicing scientists?

Popper has shaped the explicit methodological views of scientists – if not necessarily their practice – for generations. This being so, it seems noteworthy that (a) no philosopher of science subscribes to Popper's falsificationism today and (b) Popper himself has retreated from his original position in his later work (see also Lakatos 1999).

But what exactly was Popper's original position? Popper struggled with the fact that logic alone cannot force one to give up a hypothesis that faces conflicting evidence (Q4). It is not a logical, but, at best, a methodological maxim to refute such hypotheses. Now, Popper postulated that this methodological maxim is the heart of good science. It is simply unscientific, he claimed, to hold on to a hypothesis, come what may. That is, in a nutshell, Popper's falsificationism (Popper 2002b).

This philosophical position has come under severe attack. The major objection, which made Popper change his mind, is that many episodes in the history of science that count as hallmarks of good science would turn out as unscientific under this account (see Lakatos 1999). For example, the discovery of Uranus is considered as a major success for Newtonian mechanics and gravitation theory. Yet, it was only achieved by violating Popper's maxim (predicting another planet was a way of rescuing the theory given recalcitrant evidence).

Popper's falsificationism is thus falsified by a normative reconstruction of the history of science. In his later work, Popper retreated from the strict falsificationist maxim, and rather emphasized, less categorically, the importance of a critical, open-minded, stance of testing one's theories and of theory corroboration by means of passing critical tests (see Popper 2002a).

The upshot for the study and practice of science communication is that methodological views that champion Popper should not be uncritically replicated. Science proceeds in a much more complex and differentiated way than the early Popper envisioned.

## 6 Which evidence do we need to consider when assessing a scientific hypothesis?

When assessing how strongly a scientific hypothesis is confirmed all in all, one has to take into consideration all the empirical evidence that bears on the hypothesis in one way or another. This is the essence of the so-called total evidence principle (see Carnap 1950: 211).

At first glance, this principle might seem obvious. For why should it be O.K. to omit relevant evidence? Things aren't that trivial at closer inspection, however. First of all, consider mathematics: It suffices to know one proof of a theorem to see that it holds; it is by no means required to take all the alternative proofs into account. The reasons that speak in favor of a theorem, provided by mathematical proofs, don't accumulate.

In contrast, the reasons for a scientific hypothesis provided by empirical evidence do. The various evidence items pile up and do only collectively determine the justificatory status of the hypothesis. Additional evidence can increase or decrease the overall degree of confirmation (Q1, Q7).

Sometimes, the accumulation of individual reasons is described in terms of weighing confirming and disconfirming evidence (Spohn 2012). This metaphor can be misleading, however. Positive and negative evidence does not simply sum up. That is because of a peculiar property of inductive inference (which logicians call "non-monotonicity"): As novel evidence is added, not only might the overall "balance of reasons" for or against a hypothesis be reversed, but an old evidence item that

previously confirmed the hypothesis might now clearly speak against it (see Ginsberg 1987; Pfeifer and Kleiter 2005; Strasser 2016).

Science communication sometimes proceeds in a piecemeal way. When it popularizes the results of a recently published paper, describes a ground-breaking experiment, which is underway, or features the work of a scientist who has been rewarded for her achievements, etc., such a narrow focus might sometimes be legitimate. However, a limited perspective, which excludes most of the evidence that is also relevant for a given question, doesn't allow for assessing a scientific hypothesis in terms of its belief-worthiness. For example, the fact that a spectacular experiment recently produced confirming evidence for some theory doesn't mean that the total evidence also speaks in favor of it.

If science communication seeks to support decision makers and the public in general in forming beliefs about scientific matters, it has to provide the big picture. In doing so, it may rely on review articles, meta studies and assessment reports, which reflect the state of research in a given field.

## 7 Why do we need to know the alternatives in order to understand how strongly a scientific hypothesis is justified?

Before I order a particular meal, it ordinarily makes sense to find out what the alternatives on the menu are. In this regard, scientific inference resembles practical reasoning and contrasts with mathematical one. The belief-worthiness of a theory depends on what the alternatives are and on how strongly they are justified. Yet consider mathematics: One doesn't have to consider any alternative to the Pythagorean theorem (which relates the squares of the sides in a right-angled triangle) in order to see that it holds (Q6).

The sensitivity to the alternatives derives from the special features of scientific inference. We can distinguish three types of confirmation (Crupi 2013):

1. *Incremental confirmation.* Some evidence confirms or disconfirms a hypothesis (to some degree).
2. *Comparative confirmation.* Given the evidence, one hypothesis is better confirmed than another one.
3. *Overall confirmation.* Given the evidence, a hypothesis is confirmed or disconfirmed (strongly, to a certain degree).

Whether a scientific hypothesis is belief-worthy or should be adopted for policy-making purposes, depends on its overall confirmation. And its overall confirmation is a function of its comparative confirmation relative to all the alternatives.

In conclusion, an assessment and communication of scientific theories that aims to support rational belief formation or decision-making has to provide the big picture, which puts individual scientific findings in perspective to the state of the art in a field (Q6).

## 8 What is the difference between justification and explanation?

To *justify* a claim is to establish the truth of the claim (the conclusion) with reference to other true claims (the premises). To *explain* why the claim holds is to give an account (called “explanans”) that renders the corresponding fact (the “explanandum”) comprehensible. Consider the claim that young spiders consume their mother. A justification of this claim is: Many scientific experts, independently of each other, have made the observation that young spiders eat their mother; thus, young spiders eat their mother. This argument from expert testimony warrants the conclusion. However, the reasoning doesn’t tell us *why* spiders behave accordingly. A potential explanation goes: Consuming their mother in the weeks after being born drastically increases the offsprings’ chance to survive. Yet, note that such an evolutionary explanation doesn’t justify the claim.

The purpose of science is not simply to discover (ever more) significant truths, but to increase our understanding of the world (Friedman 1974; Van Fraassen 1980; Kitcher 1993). That is one reason why explanations are so prominent in science. Another reason is that explanations can themselves be deployed in scientific inference.

First, explanations are sometimes also good justifications for a claim; this is, for example, the case with causal explanations: Citing causes that bring about an effect renders the effect comprehensible and, at the same time, can be construed as a causal argument in favor of the corresponding claim.

Second, explanations allow one to infer, under certain conditions, the truth of the explanans from the truth of the explanandum. Assume that geologists discover a layer of basaltic rock in a profile of strata, which leads them to infer the conclusion that there was volcanic activity at this place at the corresponding geological period. In this argument, the explanandum of a causal explanation serves as premise (observation of basaltic stratum) and the explanans (ancient volcanic activity) represents its conclusion. Arguments of this type are called inference to the best explanation (Harman 1965; Lipton 2004).

Non-deductive, holistic scientific reasoning (Q6, Q7) can frequently be construed as inference to the best explanation. Scientists consider rival hypotheses that yield, given background theories and auxiliary assumptions, alternative explanations of the empirical observations. These alternative explanations of the observed facts will



differ in terms of unifactory strength (i. e., their ability to explain heterogeneous evidence), scope or simplicity, all of which determine the overall quality of an explanation (Woodward 2017). The hypothesis that yields, compared to all rivals, the best explanation of the observed facts is inferred as correct.

In summary, justification and explanation are, albeit related, two different kinds of reasoning, which serve different epistemic functions and should be kept apart when communicating science. Moreover, inference to the best explanation might be a handy scheme for presenting complex non-deductive scientific reasoning to a broader public.

## 9 Has Paul Feyerabend shown that anything – really: anything! – goes?

“Anything goes” – that sounds like a slogan of a radical relativist, of someone who thinks that one statement is as belief-worthy as any other. Believe whatever you want! For a radical relativist, “justification”, “knowledge” and “truth” are void concepts; and science is, for lack of epistemic authority, nothing but an oppressive regime constructed by an elite to exercise illegitimate power.

In *Against Method*, Paul Feyerabend famously presented his position under the slogan “Anything goes”. So, has Feyerabend argued for a radical skepticism and relativism? That’s far from being the case (see also Hacking’s introduction in Feyerabend 2010).

Feyerabend actually opposes the following view: There exist strict methodological rules that scientists qua scientists should follow; where “strict” means that the rules don’t allow for any exception (Feyerabend 2010). Popper’s falsificationism (Q5) is a case in point – and was not coincidentally the prime opponent Feyerabend had in mind. Now, Feyerabend argued, by citing episodes from the history of science, that there are always situations where it can be reasonable *not* to follow a given methodological rule. It might, for instance, even be rational to hold on to an inconsistent theory (temporarily and for lack of better alternatives).

To say that the scientific method doesn’t consist in strict rules doesn’t imply that scientific reasoning is erratic and arbitrary. Thomas Kuhn, for example, maintained that scientific inference is guided by different universal scientific criteria (such as empirical adequacy, theoretical simplicity, or scope), which have to be balanced by each other from case to case (Kuhn 1977). Such a picture is entirely consistent with Feyerabend’s point.

Likewise, it is a misinterpretation to say that, according to Feyerabend, science is no better than any other cognitive enterprise (as religion or myth) in providing reliable and useful insights about the world. On the contrary, the ability of scientists to adapt their methodology in context-sensitive ways might actually be the cause of science’s epistemic success.

## 10 Do controversies in science undermine its trustworthiness?

Science seems controversial by its very nature (Machamer, Pera, and Baltas 2000): Many scientific hypotheses are disputed (see Chapter 15, this volume). Scientists make a living of showing what their colleagues got wrong. And for any public expert testimony, there appears to be an expert with a contrary opinion. But how can we reasonably trust science when scientists do not even agree among themselves (see also Coady 2012: 27–58)?

Note, first of all, that many scientific insights are, as a matter of fact, not seriously contested. While uncontroversial “textbook knowledge” is typically not the focus of science journalism, it is probably the bulk of our scientific understanding (Q12). On many issues, scientists do agree and have agreed for decades now.

Moreover, such consensus views do not emerge at random. Rather, they are the results of scientific debates. Widely agreed-upon scientific hypotheses have survived severe criticism and outperformed a variety of rival theories. It is precisely this fact that makes science trustworthy and its findings reliable (Kitcher 1993; Mayo 1996; Carrier 2010).

Rather than undermining the trustworthiness of science, pluralism, critique and controversy are thus essential for our trust in science. It is precisely because (and inasmuch as) no scientific hypothesis is consensually accepted before it has been intensely scrutinized that we rightly accept and rely on scientific consensus positions.

Scientific controversies can be faked (see Oreskes and Conway 2010). Simulating scientific debate – essentially by advocating a pre-determined view and mimicking scientific discourse – appears to be an effective way of spreading doubt and preventing that scientific insights inform policy-making. Fake controversies are a special, and especially harmful, case of pseudoscience (Q15).

Scientific controversies should thus be conceptualized and described in science reporting in a twofold way: on the one hand, controversies indicate limits of current understanding and prevailing scientific uncertainty; on the other hand, controversies are the mechanism through which reliable results are generated in the first place.

## 11 Is science’s success a reason to trust or rather distrust it?

Many philosophers of science construe the epistemic authority of science in comparative and ultimately pragmatic terms. The collective practice subsumed under the term “modern science” – which has been modified and refined in the last four centuries – is typically considered to be the predictively and explanatorily most successful form

of knowledge acquisition ever practiced by humans (see Goldman 1999: 247–254). According to a saying (commonly attributed to Winston Churchill) the merit of democracy is that all alternative forms of government are worse. Likewise, it seems that all alternative forms of knowledge acquisition that have been tried by humankind are far less successful than modern science.

On the one hand, the astonishing success of modern science in predicting and explaining the world seems to justify relying on it and bestowing extraordinary power to scientific institutions (especially in the form of public funding). On the other hand, the dominant societal position of science risks to marginalize alternative forms of knowledge acquisition. It's not clear that there still is a fair competition between science and its alternatives; and it's not straightforward that science has to prove its epistemic superiority in the 21st century in a way comparable to the period of the scientific revolution (16th–18th centuries). This is Paul Feyerabend's major argument in *Science for a Free Society*, which he casts as: "today science prevails not because of its comparative merits, but because the show has been rigged in its favour" (Feyerabend 1978: 102). So, Feyerabend insists, the fact that science has been the most appropriate means for addressing problems in the past doesn't warrant that it's also the most reliable form of knowledge acquisition for our current and future problems.

In principle, unfair competition is a problem when evaluating different practices of knowledge acquisition. Yet, it is an open empirical question to which extent modern science has actually "rigged the show in its favour". It is another open empirical question whether our current problems aren't sufficiently similar to past questions (which have been successfully addressed by science) in order to infer, by analogy, future epistemic superiority of science from its past one. Finally, it could be argued that science has substituted external competition with systematic internal critique: Accordingly, its methodological plurality, which may also concern fundamental methodological questions, and the criticism from within rather than from outside science give us reason to trust it (Q10).

The upshot here is that science's epistemic authority should be described and construed in comparative terms by pointing out its predictive and explanatory success. It would be misleading to say that science is *a priori* the most appropriate form of knowledge acquisition.

## 12 What is a scientific paradigm?

Scientific inference relies on a broad range of so-called background assumptions. To begin with, auxiliary assumptions inferentially connect hypotheses and observational statements. Measurement theories describe scientific instruments and are taken for granted when acquiring empirical evidence. Categorical assumptions that concern one's conceptual framework – which can be construed as metaphysical assump-

tions – determine which sorts of things a scientific hypothesis may refer to (Q2). Methodological assumptions specify what counts as reason for a hypothesis or what counts as a good explanation for a phenomenon (Q8).

A scientific paradigm is, roughly, what binds background assumptions of this sort together. Scientists who work within the same paradigm agree in terms of methodological, metaphysical and auxiliary background assumptions.

It was Thomas Kuhn who stressed the import of shared background assumptions for understanding the history of science and who introduced the concept of a scientific paradigm – or, “disciplinary matrix” (Kuhn 1962). Subsequently, Larry Laudan and Philip Kitcher have extended Kuhn’s original account and suggested to refer to clusters of background assumptions as “research traditions” (Laudan 1977) and “practice” (Kitcher 1993).

The concept of a paradigm, however, does not only allow one to make sense of historic episodes of science. It can also be motivated from a systematic perspective of the philosophy of science. If scientists didn’t agree on background assumptions, which underlie scientific inference, no scientific conclusion would ever be agreed upon, scientific debates would be chaotic and scientific progress would be impossible. This is because any scientific argument can be challenged by denying its background assumptions (Q4). Holding such background assumptions fixed within a certain context (a scientific paradigm) is thus an efficient way of organizing scientific debate and managing the fact that scientific reasoning relies sensitively on multiple background assumptions.

Hence, two sorts of agreement or dissent should be distinguished when practicing or studying science communication. On the one hand, scientists might disagree with respect to rival theories about a certain domain and answers to a given research question. On the other hand, dissent may be more profound, and the underlying background assumptions might not be agreed upon. In the latter case, the scientists work within different paradigms.

## **13 Has Thomas Kuhn shown that there is neither scientific progress nor scientific objectivity?**

Kuhn (1962) distinguished normal science from scientific revolutions. In phases of normal science, scientists work within and spell out a shared paradigm (Q12). Scientific revolutions are characterized by a competition of rival paradigms and by paradigm change.

Regarding scientific revolutions, Kuhn argued for two prominent – and, today, largely agreed upon – normative theses. First, paradigm change isn’t governed by strict rules which can be fully made explicit. In other words, there is no algorithm that tells scientists when to give up an old paradigm (Q9). Second, reasonable paradigm

change – and hence scientific progress – is not necessarily cumulative; i. e., scientists can legitimately give up an old paradigm in exchange of a new, yet (momentarily) predictively and explanatorily less successful one.

Kuhn's views on scientific progress have frequently been misconstrued. In particular, two claims wrongly attributed to Kuhn are: incommensurability of rival paradigms and scientific relativism (see also Laudan 1977). According to incommensurability, it's impossible to say which of two paradigms is epistemically better, which implies scientific relativism, i. e. the view that all scientific findings hold only relative to the paradigm one has chosen for non-epistemic reasons.

Yet, Kuhn maintained that scientific revolutions are triggered and resolved by inter-paradigmatic exchange of arguments – a view which is incompatible with incommensurability. Proponents of rival paradigms do rationally argue with one another (see also Hoyningen-Huene 1993). However, Kuhn insisted, these arguments will never force a scientist to give up a paradigm (Q4). Inter-paradigmatic argumentation resembles more balancing pro and con reasons than mathematical proof (Q1).

The upshot for the practice and study of science communication is not to be led astray by simplistic relativism or social constructivism. Although scientific reasoning is frequently complex and difficult to grasp, the view that scientific results are no better justified than any other claims, because they hold at best only relative to arbitrarily chosen paradigms, is simply not backed by arguments – and certainly not by Kuhnian ones.

## 14 Do we promote blind faith in science by defending its rationality?

Two claims about science need to be distinguished, a normative and a factual one:

- (a) There is a normative ideal of science according to which scientific findings are empirically well-justified and trustworthy.
- (b) Actual scientific practice conforms to this ideal.

General philosophy of science is a critical exploration and – all in all – a defense of claim (a). This claim entails that a given scientific practice can be rational or irrational. And it implies that there are standards according to which we can judge whether a given scientific practice proceeds in a right or in a wrong way. Moreover, a rational reconstruction of science informs us about fundamental limitations of scientific understanding, such as the fallibility of scientific results or the non-deductive nature of scientific reasoning. So, rather than promoting blind faith in science, understanding the rationality standards of science and of its different disciplinary zones puts us in a position to critically assess a given scientific episode in the first place (Cartwright 1983, 1999). Such critical analyses are, for example, carried out in those

branches of philosophy of science that are concerned with specific disciplines, such as the philosophy of economics (e.g. Sugden 2009) or the philosophy of the Earth sciences (e.g. Frigg, Thompson, and Werndl 2015).

Without philosophy of science – i.e., without an understanding of what science’s rationality consists in – we would face a choice between blind faith and blind mistrust in science. Philosophy of science is not the ideology of ruling technocrats and the scientific elite; it is, on the contrary, an emancipatory project which puts us in a position to critically assess science in the first place.

## 15 What is the difference between science and pseudoscience?

Classically, Karl Popper maintained that science is characterized by its hypotheses being falsifiable, i.e. scientists try to *refute* their hypotheses and give them up if contrary observations are made (Q4). Accordingly, Albert Einstein’s theory of relativity is scientific to the extent that its proponents are willing to drop the theory in case of empirical refutation. In contrast, pseudoscience either proposes non-refutable, empty hypotheses from the outset or employs logical maneuvers to immunize its hypotheses against criticism. Accordingly, Sigmund Freud’s psychoanalysis represents pseudoscience to the extent that its proponents hold on to the theory come what may. Yet, Popper’s demarcation criterion seems untenable because many instances of presumably good science actually turn out to be unscientific according to the proposed criterion (Q5).

While Popper’s classical picture is certainly too simplistic, we can identify and actually do agree upon many examples of pseudoscience such as homeopathy, ufology, ancient astronaut theory, Holocaust denialism, Intelligent Design, Neuro-Linguistic Programming or climate change denialism. All these theories are unscientific in some sense.

But what does “unscientific” mean here? Many philosophers of science have proposed lists of criteria for pseudoscience, which include, for instance, an imperturbable belief in authority, unrepeatable experiments, handpicked examples, disregard of refuting information and built-in subterfuges. Such traits of pseudoscience violate the established standards for science such as systematicity or replicability (Q4, Q5, Q9, Q12). In general, we might say that pseudoscience is in conflict to acknowledged scientific methods, while it presents itself to adhere to them.

This characterization of pseudoscience works well for the clear and already agreed upon instances of pseudoscience above. However, as there are various standards of good science, which can be satisfied by different degrees, scientific practices can always be more or less scientific. The following three examples may help to illustrate this problem.

Let's start with an article submitted by Alan Sokal to *Social Text*, an academic journal of postmodern cultural studies (Sokal 1996). According to him, the submission was an experiment to test the journal's scientific standards. Shortly after its publication, Sokal revealed that the article was actually a hoax. Despite being published, the paper did not adhere to scientific methods. It is unclear, however, whether its publication undermined the whole journal as unscientific, whether it was a demonstration of problematic publishing practices in cultural studies or whether it showed that even in reputable journals there may be problems of quality control.

What about normative theories and practices such as ethics or religion? Both ethics and religion have arguably different methodologies from science and also differ in their goal from empirical science – they do not aim to explain or predict anything. The case is different, however, for some religiously motivated enterprises like creationism or Dianetics, as their goals and apparent methods do pretend to be scientific.

Finally, let's look at Traditional Chinese Medicine (TCM). It may be considered pseudoscience due to its lack of confirming evidence. However, TCM abides by other methods than science and does so openly. It is even possible that practices such as TCM are useful to science, since they may uncover methods that could improve science by igniting fruitful controversy (Q10).

As a consequence for science communication, rather than discrediting a practice as outright unscientific, it might be more helpful to point out, in more detail, in which ways (aims, methods/standards, predictive success) a given practice deviates from the ideal of good science and paradigmatic cases thereof.

## 16 What is the meaning of probability?

Probabilities pervade many branches of science and are ubiquitous in the communication of scientific results. It has been argued that whatever uncertainty we face, it can be adequately expressed as probability statements (probabilism) (e.g. O'Hagan and Oakley 2004). Some philosophers claim that we should give up our binary notion of belief altogether – i.e., to consider a statement to be either true or false – in favor of a purely probabilistic conception of belief (see Huber and Schmidt-Petri 2009).

Despite their widespread use, it's far from clear what exactly probability statements mean (see Stegmüller 1969; Gillies 2000). One way of classifying alternative interpretations of probability consists in distinguishing (i) subjective probability, (ii) objective probability and (iii) logical probability.

A subjective probability characterizes how strongly a person believes in a given proposition. Subjective probability statements hold relative to a given person; and different persons can reasonably disagree in terms of their degrees of belief.

An objective probability characterizes a real system and expresses the objective chance that a given event occurs in that domain. Such objective probability statements

can be conceived as dispositions of a system to bring about certain events (propensity interpretation) or as the relative frequency of such events in the long run (frequentism).

A logical probability characterizes how statements hang together logically or semantically and expresses to which degree a given statement follows inductively from other statements. Logical probabilities describe a language and not a person's beliefs or an event's objective chance.

The upshot for the study and practice of science communication is not to take the meaning of probabilities for granted. Probability statements are ambiguous. Whenever possible, one should ask what a probability statement is supposed to express. And one should try to be as clear as possible in one's own use of probability statements, for instance, by using more specific phrases like "Experts believe very strongly that the hypothesis is correct", "According to model simulations, the objective chance of this event is  $x$ ", or "The degree of confirmation of this hypothesis, given the observations, is  $x$ ."

## 17 Can, or should, science be value-free?

The role that values can legitimately play in scientific reasoning is still controversially discussed in philosophy of science (see Elliott and Steel 2017). What is this debate about – and what not?

First, it is uncontroversial that scientific reasoning relies on so-called epistemic values (such as consistency or explanatory scope), against which the merits of rival theories are judged (McMullin 1983). The key issue of the controversy, in contrast, is whether science can and should be carried out without commitments to *moral* or *political* value judgments.

Second, it is also undisputed that there exist many decisions in scientific contexts that should be made with resort to non-epistemic values. These decisions concern, for example, which research questions to pursue, how to fund research and whether to make use of scientific results in one or another way (see Chapter 18, this volume). What is debated is what the proper role of non-epistemic values is in the so-called *context of justification*; i. e.: Is it legitimate to rely on non-epistemic values in the justification of a scientific result?

Third, it is equally uncontroversial that, very frequently, science is actually not value-free. Scientific results are often based on and motivated by non-epistemic value commitments (Shrader-Frechette 2014). In contrast, what is hotly discussed in philosophy of science is whether such use of non-epistemic values may sometimes be *legitimate*.

On the one hand, there are three arguments to the effect that scientific results should be justified without commitments to non-epistemic values (see Weber 1922;



Betz 2013; Schurz 2013). The *argument from autonomy* points out that scientific findings are the basis of practical reasoning and decision-making. If scientific results were infected by moral and political value judgments, this would undermine the personal autonomy of the decision maker. In a similar vein, the *argument from democracy* reasons that democratic self-determination would be severely affected if scientists, as policy advisers, did base their results on political or moral considerations; not only personal, but also collective autonomy would be undermined by value-laden expert advice. Finally, the *argument from veracity* points out the epistemic consequences of relying on non-epistemic values in scientific reasoning; such reliance on poorly justified normative assumptions, it is argued, undermines the overall reliability and accuracy of scientific findings.

On the other hand, various objections have been raised to the value-free ideal. The *argument from inductive risks* maintains that scientists, when carrying out an inference, should be aware of the possibility to err and should therefore assess their inference in view of the morally relevant societal consequences such errors would have (Rudner 1953; Douglas 2000). The *semantic argument* contends that many terms science makes use of – specifically when articulating findings – have both normative and descriptive content (e. g. *famine*, *rape* or *intelligence*) (Putnam 2002; Dupré 2007). Getting rid of these terms is supposedly not a viable option, as this would make science societally irrelevant. A third line of argumentation points to the actual, virtually insurmountable, difficulties in realizing the value-free ideal: cognitive limitations, the complexity of scientific reasoning, the variety of uncertainties, and time-constraints all seem to render the value-free ideal unrealizable and maybe even useless as an ideal (see Betz 2017).

While this is not the place to decide the controversy, it can be argued that there is agreement on the following three points (see Douglas 2009; Kitcher 2011). First, scientific reasoning is inevitably based on some kinds of value judgments. Second, where possible and ethically legitimate, non-epistemic value judgments should be avoided. Third, at the minimum, non-epistemic value judgments should be made transparent.

It is thus necessary to conceptualize scientific reasoning in a differentiated way – taking the distinctions into account between context of discovery, context of justification and context of application; between normative and descriptive claims; between practical and scientific reasoning; and between epistemic and non-epistemic values. As scientists are not necessarily familiar with these distinctions themselves, scholars and practitioners of science communication need a sound understanding of these notions, for example when communicating scientific findings to the public in a policy-relevant way.

## 18 What is worth being scientifically investigated?

It's one thing to say that a hypothesis is sufficiently well justified in order to provisionally accept it (e.g. for policy making purposes), and it is another thing to consider a hypothesis as promising and as being worthy of further pursuit (see Laudan 1977).

What is pursuit-worthy – for example, which research questions one should try to answer, which kind of research should be publicly funded, whether and to what extent science should be advanced at all – is of course a genuinely normative question, which touches upon political, economic and moral considerations (Q17).

How should we reason about such questions? How do we recognize a pursuit-worthy – “significant” – research project? Here, three types of considerations seem to be pertinent: (i) scientific reasons for/against its significance; (ii) extra-scientific reasons for/against its significance; (iii) pragmatic or feasibility considerations (see Chapter 18, this volume).

Scientific or epistemic reasons for carrying out a specific research project derive from fundamental epistemic goals – such as the aims to discover more truths and to understand why they hold – and are motivated by pure curiosity.

Extra-scientific reasons for (not) carrying out a specific research project are diverse and derive from the benefits and harms of such research. So, for example, potential applications of the research findings might be predicted to be highly beneficial in economic terms. Or, it is stressed that the research findings might pave the way for novel military technology. Or, it is argued that the research will allow for better-informed policy decisions.

Both scientific and extra-scientific reasons for/against the significance of a research project rely on an assessment of its feasibility and success likelihood. This is because a research project is not worth being financed unless it is assumed that the project will at least partially succeed in answering its central question. Thus, judgments of pursuit-worthiness always involve a prognosis of how the research to-be-funded will unfold.

Research questions and potential research projects are related in various ways. For instance, a project might deliver findings that are needed to construct the measurement apparatus that is required for another project. Or, a project might check the background assumptions that are assumed in another project. Or, a project might provide the empirical observations that, in another project, are used to evaluate a hypothesis by computer simulation. Because research projects and their intended findings are interwoven, reasons that pertain to the significance of one research question will typically affect the significance of many other questions (Q4). Assessing the significance of research projects is hence a holistic task. Philip Kitcher has suggested to conceptualize holistic pursuit-worthiness in terms of significance nets, in which significance can “flow” from one inter-connected node to another (Kitcher 2001; see also Lepori and Greco in this volume).

It is thus not only important not to mix up questions of pursuit-worthiness with questions of belief-worthiness, but also to construe controversies of pursuit-worthiness (e. g. about research funding or a research moratorium) as genuinely normative debates.

## 19 Can empirical findings ever necessitate a policy decision?

Policies are frequently justified by citing scientific findings. “Why do we phase out CFCs? – Because it’s scientifically established that they cause the depletion of the ozone layer.” Sometimes, it’s even suggested that scientifically established facts render a policy inevitable: “There was no alternative. We had to bail out the bank in view of a predicted melt-down of the global financial order.” Or: “Climate science’s findings make drastic cuts in carbon emissions inevitable.”

Still, do scientific findings really necessitate policy decisions, as the fictitious quotations seem to pretend? And if not, what is the precise relation between scientific findings and policy decisions?

Scientific findings are descriptive statements. They describe what has been, what is, or what will be the case. Sometimes, they are conditionalized on certain assumptions (i. e., they have the form “if these assumptions hold, it will be the case that x”). Sometimes, they are hedged in view of the prevailing uncertainty (e. g. rather than saying that x will be the case, it is maintained that it’s *likely* that x will be the case) (Q1). However, conditionalization and hedging don’t affect the descriptive character of scientific results.

Policy recommendations, which express what *should* be done, in contrast, are normative, or more precisely, prescriptive statements. (Roughly speaking, prescriptive statements say what ought to, may or must not be done; evaluative statements characterize or compare states of affairs in terms of some standard; normative statements are either evaluative or prescriptive.)

Now, descriptive statements, on their own, never entail a normative (and, in particular, prescriptive) statement. Inferring a prescriptive conclusion from descriptive premises is to commit the famous is-ought fallacy or naturalistic fallacy (Hume 2007). So, from an argumentative point of view, scientific findings, on their own, never necessitate a specific policy decision.

Of course, this doesn’t mean that scientific findings have no proper role to play in policy justifications. On the contrary, policy deliberation and the justifications of policy measures typically proceed from both normative and descriptive premises (Lempert, Popper, and Bankes 2003; Hansson and Hirsch Hadorn 2016a). We can distinguish three situations:

First – and this can be considered best practice – both normative assumptions as well as scientific findings are explicitly stated in the justification of policy recommendations.

Second, the normative premises remain implicit because they are assumed to be uncontroversial in the given context. For example, a minister of finance, speaking to colleagues, may rightly assume that her audience agrees that a collapse of the financial system should be avoided whatever the economic costs. Yet, in these cases, making the normative assumptions explicit wouldn't hurt, either.

Third, the normative premises remain implicit despite being controversial. This is potentially misleading. To justify a policy with reference to scientific findings while hiding the controversial normative premises of the argument prevents rather than promotes rational democratic deliberation.

The upshot for the study and practice of science communication is that the justification of policy measures has its own logic, which deviates from the logic of scientific inference. Policy deliberation involves both descriptive and normative input; policy recommendations never follow from scientific findings on their own. Clear science communication that pays tribute to these distinctions could make an important contribution to increase the argumentative quality of our societal debates.

## **20 Is the influential role of scientific experts in policy making a threat to our democracy?**

Through permanent advisory bodies and agencies that support the executive branch of government, through parliamentary ad hoc commissions, through the courts' reliance on expert testimony, through national academies, through its near monopoly in tertiary education, and through an endless stream of commissioned and noncommissioned studies on policy issues, science is profoundly shaping policy-making in our societies. Isn't this a danger to democracy?

Policy decisions cannot be justified with resort to scientific findings alone (Q19). So, in a democracy, policies should not be determined by scientists alone.

Yet, factual expertise is needed in decision-making – no matter whether individual or collective – in order to maximize the chance that the option decided upon will eventually bring about the intended consequences. A collective's ability to rule itself, i.e., to achieve jointly agreed upon goals through collective decision-making, is limited by the comprehension and accuracy of its foreknowledge concerning the policy options. A society that is consistently mistaken about the outcomes of policies will simply not realize its aims. That's why democracy, understood as the ideal of collective self-determination, calls for the involvement of experts in decision-making. More precisely, relying on the best available source for assessing consequences of policy options is a precondition of effective democratic government.

As long as scientific experts stick to their role and inform democratic deliberation by improving policy-relevant foreknowledge, their enormous influence in policy making is no threat to democracy (Q17). Of course, such a prominent role in decision procedures potentially allows experts to shape policies in view of idiosyncratic policy aims, hence undermining democratic decision-making. Yet, such a potential for misuse has to be anticipated and dealt with regarding all key positions in a political system (e. g. officials working in ministries, heads of government agencies or justices).

As a result, science journalism might have the important function to identify episodes where scientific policy advice has failed (for overstepping its mandate in a democracy) and to bring these cases to the attention of the broader public (see Chapters 22 and 23, this volume). In order to do so, it's pivotal that normative and descriptive questions are clearly distinguished in science communication.

## **21 Does science tell us what is really real – and what not?**

The empirical sciences spell out an ever more detailed, denser and predictively more and more successful, unified – essentially materialistic – description of the world, which may be called “the scientific worldview”. According to the scientific worldview, all objects, including animals and humans, are ultimately more or less complex constellations of elementary particles, whose dynamics are controlled by a handful of fundamental forces. All empirical phenomena can (in principle) be explained in causal or evolutionary terms. The universe is an absurdly sized spatio-temporal structure, expanding at mad pace. Life has emerged on Earth, a planet at the margins of the cosmos, for purely contingent reasons and out of pure luck. Mankind will inhabit the cosmos only for a comparatively small period of time compared to the universe's lifespan. In the long run, the cosmos will either consist only of gigantic spheres of lead, or collapse into a single, infinitely dense, point. And that's it.

Is the scientific worldview the only reasonable outlook on the world as a whole?

The first – and maybe most important – point is: This is not an empirical question. The metaphysical status of science cannot be settled by empirical science itself. What is at stake is the status of the results arrived at through scientific reasoning, and piling up ever more results fails to address the question how to interpret them in the first place.

The philosophical thesis that the empirical sciences do not only provide a metaphysically adequate, but also in principle complete description of the world as a whole is called “naturalism”. “Scientific realism” refers to the somewhat weaker claim according to which the metaphysical assumptions of our best theories are approximately true and need to be incorporated in any metaphysically adequate worldview (Putnam 1982; Chakravartty 2017). Both philosophical theses are controversial.

The most important argument for scientific realism (which can be extended into an argument for naturalism, we submit) is the so-called no-miracle argument. It argues that the colossal explanatory and predictive success of the empirical sciences were incomprehensible – a sheer miracle – if the theories, on which these explanations and predictions are based, did not truly reflect what is actually the case. The no-miracle argument is probably the most prominent inference to the best explanation in philosophy (Q8).

Against the no-miracle argument, it is maintained that the history of science provides numerous examples of predictively and explanatorily successful theories, which are, strictly speaking and especially in regard of their metaphysical assumptions, false. This “pessimistic meta-induction” points to examples such as the caloric theory of heat or the phlogiston theory of combustion.

The upshot for the study and practice of science communication is to distinguish (i) the belief-worthiness of scientific findings and (ii) the metaphysical status of the scientific worldview. Accepting the empirically justified results of science does not *ipso* commit one to metaphysical naturalism.

## 22 Are we slaves of science?

While scientific results are fallible and cannot be established with mathematical certainty (Q3), science – as far as we know – represents the most successful and most reliable resource for acquiring significant knowledge and understanding of worldly phenomena (Q10, Q11). Any agent who shares these goals is well advised – for instrumental reasons – to stick with science. Does science thus dictate what we ought to believe?

It is indeed *prima facie* irrational to deny well-justified scientific results (e. g. that CO<sub>2</sub> is a greenhouse gas or that copper is a good conductor). Yet, despite this being so, it seems an exaggeration to say that we are slaves of science.

The following points leave room for cognitive autonomy and indeed call for a critical assessment of actual scientific practice:

- Many empirical questions will never be answered by science for contingent reasons.
- Science doesn’t dictate answers to normative questions (Q19).
- Science doesn’t dictate answers to metaphysical questions (Q21).
- Evidence that a given scientific study doesn’t live up to the standards of good science provides a strong reason for refusing to accept its results (Q14).

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## 2 Science understanding between scientific literacy and trust: contributions from psychological and educational research

**Abstract:** In this article, we describe how laypeople are able to engage with science and scientific issues in spite of their bounded understanding (limited relevant background knowledge about science and about how science works). Drawing on psychological and related research, we describe that laypeople engage with science and scientific issues, either by aiming to gain available skills and knowledge to understand scientific information (scientific literacy), or by selectively and considerably placing trust in science or scientific experts. While we argue that most of such reasoning about scientific evidence and arguments can be called reasonable and expedient, we also identify some reasons why understanding might fail, for example because certain pitfalls of science communication might foster misinformation. In our conclusion, we briefly provide some ways in which science communication might protect against fostering laypeople's flawed reasoning.

**Keywords:** science communication – psychological research – public understanding of science – scientific literacy – science education – epistemic trust – trust in science

## 1 Understanding science – a challenging endeavor?

Science is fundamental to our knowledge society. That is, science is no longer just a theoretical and isolated approach to understanding the natural and social world; nowadays, science affects people's everyday lives in many different ways. Corner and Hahn (2009) synopsise that “many of the most important decisions we make (as individuals or as a society) are rooted in our understanding and evaluation of scientific evidence, arguments and claims” (Corner and Hahn 2009: 199). For example, decisions about whether to reduce or to abstain from eating red meat or about whether or not to buy a diesel car, can and should be informed by science. However, most often science cannot provide a simple answer to everyday questions. This is not only because those questions also involve other dimensions (e. g. ethical, economical), but also because science often cannot provide sound and orientational knowledge (Niaz 2010).

Due to the rapid advancement of technology and scientific progress in our societies, especially important issues of our time like climate change or advancements in treating illnesses rest on scientific knowledge that is new, evolving, and continuously being tested. According to Cole (1995), this type of evolving knowledge, also called “research frontier”, is different from “core” knowledge: “Core” refers to a set of theo-

ries, methods, and facts that are the results of extensive research and practice and are generally agreed upon to be the present state of certain and important knowledge in a given discipline. “Research frontier” might eventually be transferred into core knowledge, once it is considered by the scientific community to be both true and important. In fact, scientific work does not only entail truth-seeking only by means of a set of reliable methods; one of its most potent methods for establishing truths is by forming consensus within the scientific community (Oreskes 2007).

In consequence, scientific research conducted at a given time should be considered as part of the research frontier. That is, science is characterized by uncertainty and provisionality. Scientists continuously debate what might be considered true – these debates are implied in the way they are conducting studies, but they are also directly addressed in papers, at conferences, and during informal conversations. Both inherent uncertainty and continuous debate within the scientific community are partly accessible to the general public via science communication (Peters and Dunwoody 2016). Here lies the first challenge for laypeople’s understanding and evaluation of scientific evidence: While many claims remain uncertain, people need to be able to select the best arguments and evidence.

In most parts of the world, the Internet is on the rise as a source of scientific information, and it is a first choice when one wants to look up information about one’s specific issues of interest (see, for example, National Science Board 2016). Online, people are confronted with a variety of information of ever-expanding quantity and divergent quality; social media platforms offer a continuously changing information landscape that enters people’s feeds without much (individual) preselection or editorial control. Further, the information people receive varies in credibility. Here lies a second challenge for laypeople’s understanding and evaluation of scientific evidence: information one has received or selected must be evaluated for credibility.

These two challenges – making judgments about scientific issues on the basis of (1) intrinsically uncertain and (2) possibly inaccurate information – lie at the core of laypeople’s understanding of scientific communication. By using the term “laypeople” for members of the public, we address a qualitative difference in origin and systematicity between knowledge possessed by domain experts and knowledge possessed by laypeople (Bromme, Rambow, and Nückles 2001). Achieving expertise is grounded on training and experience over many years. Due to the complexity of science, the variety of methods, and the rapid specialization of scientific knowledge disciplines, one person can master expertise only in a very limited number of fields. In consequence, scientific knowledge is subject to a division of cognitive labor (Keil et al. 2008). Thus, laypeople are characterized by limited factual knowledge about most science-related topics, and they also have a limited understanding of how knowledge is established in most sciences; both of these limitations underlie laypeople’s bounded understanding of science (Bromme and Goldman 2014).

In this article, we describe, largely relying on psychological research (1.1), how laypeople reason with science-based information, in spite of their bounded under-

standing of science. In part 2, we lay out what contributes to “sound” science understanding, where we cover how children learn about science (2.1), and how an elaborate science understanding can be conceptualized (2.2). In section 2.3 we will then focus on normative approaches to science education in schools, leading to forms of knowledge that constitute scientific literacy (2.4). In section 2.5 we summarize further competencies associated with scientific literacy that have been identified in educational and psychological research and that contribute to everyday reasoning about science.

In part 3, we then address how trust in science and sources of scientific information might inform laypeople’s everyday reasoning about science. Again, starting with the notion that even young children are able to make adequate trust judgments (3.1), we show the degree to which laypeople are equipped for judging about the source of scientific communication, for example scientists or journalists (3.2). We will thereby also consider research showing that laypeople rest their trust on cues related to the source of scientific communication and the message (content and form of communication). Taken together, we conclude (part 4) that being able to both adequately deal with scientific content and choose trustworthy sources of knowledge makes up laypeople’s understanding of scientific communication.

## 1.1 Why psychology? Research topics and methods

Psychology aims to investigate people’s cognitions, emotions, and behaviour, and other phenomena linked to the human mind. Psychology, as an empirical science, relies on scientific methods to gather data to test and develop the theoretical concepts of interest; the most prevalent methodology in psychology is the experiment. Here, a variable of interest is experimentally changed to find out how this alteration will affect a certain outcome variable. There are many ways to measure these outcome variables: While attitudes and deliberate decisions are often measured with self-report items or interview questions, cognitive processes are often measured using think-aloud protocols (asking participants to speak out loud their thoughts and deliberations while doing a task), neuropsychological methodology (e.g. EEG, EMG, fMRI), or eye tracking. Behaviour (for example that of small children) is often measured by observation.

What takes place in the human mind when dealing with scientific communication is (more or less directly) investigated by several research areas of psychology (Bromme and Kienhues 2017). Developmental psychology investigates children’s early understanding of the (natural) world and causal and statistical thinking, both important for later science understanding. Educational psychology (in close alignment with educational sciences) considers the cognitive processes involved in learning (about) science, addressing the acquisition and structure of scientific literacy. Differential psychology investigates people’s more trait-like motivations, values, and different modes

of reasoning that are employed in the understanding of scientific communication. Social psychologists are interested in group interactions, e. g. how people are swayed by the majority opinion, how they might learn from others, and even be persuaded by charismatic sources of information. In this article, we will address laypeople's understanding of science communication from a variety of these research areas and related areas of research, especially educational research.

## 2 Understanding scientific information

### 2.1 Early development of science understanding and scientific thinking

From birth, humans try to make sense of the world. As such, in the first years of life, children use their observations and experiences to develop intuitive theories about the natural world, such as objects (intuitive physics), plants and animals (intuitive biology), and other people's minds (intuitive psychology). Also, young children develop their skills in mathematical, statistical, and causal reasoning. Children's intuitive theories might consist of some unchanging core beliefs and some more specific beliefs that are up for change (Wellman and Gelman 1992). While early theories are usually not entirely consistent and persistent, and much more superficial and general than scientific theories, they provide a referential structure for the understanding of science and science-based knowledge (Gelman and Noles 2011). As such, children's early intuitive theories could be conceived to be building blocks to learning about science in school and later in life (National Research Council 2007). We will provide a short overview of the relevant research; however, more detailed and comprehensive reviews can be found elsewhere (e. g. classically, Wellman and Gelman 1992).

Intuitive theories about physics entail learning about the properties of objects, starting at the realization that objects that cannot be seen do not vanish but continue to exist (object permanence), which develops at five months of age (Baillargeon, Spelke, and Wasserman 1985). Children at six months of age show some understanding of causal relations between objects, for example that one object can set another object in motion upon collision (Leslie and Keeble 1987).

Intuitive biology concerns reasoning about properties of living beings, most importantly, telling apart living beings from inanimate objects, for example by considering self-generated movement (Wellman and Gelman 1992), growth and healing (realizing that both are not attributable to intent (psychology) or mechanics (physics)), and the need for food and water (Inagaki and Hatano 2006). Children in their preschool years (as well as many adults) construe (essentialist) ideas about distinct categories, based on the ascription of an unchanging underlying essence that makes up biological kinds (Gelman 2004). Such essentialist ideas might lead children to incorrectly attribute

causality to the animal's inner essence, e. g. its essence causing an animal's actions, or even growth (Gelman 2004).

Intuitive psychology entails children's beliefs about other people's and their own desires, intentions, thoughts, and beliefs: children's *theory of mind*. Infants already pay attention to ostensive cues (in Western cultures this might be a mother's pointing or gaze direction), and they infer from this the other's intention to demonstrate or teach (Csibra and Gergely 2009). At the age of three, children know the difference between the mental and the physical world. For example, they realize that physical laws can be broken in the imagined world but not in the physical world (Wellman and Gelman 1992). Around the age of three, a child is able to correctly identify another person's false belief that does not correspond with their own beliefs about a true event (Wellman, Cross, and Watson 2001).

Along with intuitive theories about the (natural) world, children develop causal and statistical reasoning. Even infants are able to map cause and effect by temporal contiguity, spatial contiguity, consistent covariation, and mechanism (National Research Council 2007; Sobel and Legare 2014). Also, children employ statistical reasoning, such as random sampling (Gopnik 2012), they use probabilistic models to test and revise hypotheses when dealing with evidence, and they are resistant to give up strongly confirmed hypotheses until enough counter-evidence mounts up (Meltzoff and Gopnik 2013). As such, a cornerstone of scientific thinking (e. g. hypothesis testing, reliance on evidence, generalization) might already be part of children's early reasoning and knowledge acquisition, but, of course, it lacks the specificity, background knowledge, and rigorous standardization of scientific theory building (Gelman and Noles 2011). Still, this foundation might support learning about science in school (National Research Council 2007), where the early conceptions of the natural and the social world mentioned above are reevaluated and scientific knowledge is taught in a more formal manner.

## 2.2 What should “sound” science understanding and scientific thinking entail?

How do such naïve theories and thinking processes develop into more rational, elaborate reasoning and understanding? The question of rationality and “sound” reasoning has been addressed in various scientific disciplines. In psychological research, the best known works are those of Tversky, Kahneman, and colleagues (for a summary, see Kahneman 2011). They identified two systems of thinking: The first one automatic and intuitive, but prone to a number of thinking fallacies and biases, the other one effortful and deliberate, thus able to execute complex logical thinking and come to reasoned decisions. They also introduced a number of biases and thinking fallacies that may result from heuristic (system 1) thinking, suggesting that system 2 thinking would be the “better” option to achieve “true” results (but also requires both the

ability and motivation to do so, see similar notions in Petty and Cacioppo 1986). Critical thinking partly evolved as an educational program to foster people's "purposeful, reflective thinking" (Facione 2015: 23).

However, Gigerenzer (2015) points out that heuristic thinking can sometimes be advantageous, namely in situations in which there is uncertainty, and ideal solutions to a problem are not known. In fact (as mentioned above), scientific understanding and thinking is constrained by the uncertainty and complexity of scientific knowledge, and thus thinking that usually would be attributed to system 1 thinking (e. g. source judgments) can actually be an effective strategy for reasoning about science (Bromme and Gierth in press). In this section, and in part 3 we argue that reasoning about science can be advantageously done heuristically *and* systematically.

In psychological and educational research, the construct "scientific literacy" has aimed to provide a framework under which reasoning skills, domains of knowledge, but also preconditions that contribute to people's science understanding are summarized. It is based on the assumption that science understanding and effective scientific reasoning can be promoted through education. Below we outline various views on scientific literacy, especially the most recently identified components content knowledge, epistemic knowledge, and procedural knowledge (OECD 2016). We then sketch some further competencies, more or less intertwined with the notion of scientific literacy, that contribute to science understanding. These discussions are influenced by societal, technical, and scientific developments. For example, the easy accessibility of science-based information on the Internet has led researchers to reconsider the skills that are important for engaging with science (Tabak 2015). In the same vein, the recent discussions about fake news and rejection of scientific evidence (Lewandowsky and Oberauer 2016) indicate that understanding what makes science science (e. g. scientific methods) is extremely important, not only for people to value science but also to identify pseudo-science and non-scientific approaches.

## 2.3 Scientific literacy: What should be learned about science in schools?

People need to be scientifically literate to engage with science both on an individual and societal level. That is, scientific literacy can be understood as the normative conception of what people should know about science when leaving school. Nevertheless, the definition of scientific literacy is difficult, varying, and often inconclusive. For example, Bybee (1997) claims that scientific literacy is frequently used as an unclarified slogan by science educators. All in all, there is remarkably little agreement regarding the meaning of scientific literacy and its implementation in the curriculum. In the following, we will present different viewpoints (and their development in the last century) of scientific literacy conceptions, not to provide a comprehensive overview, but to introduce the trends these conceptions have undergone.

Generally, scientific literacy encompasses all people, not just (future) scientists (Trefil and O'Brien-Trefil 2009). It therefore can be traced back to the purposes of science education and the question of what constitutes good (science) education. Such issues have kept educators and researchers busy for decades. For example, in 1935 Davis stated fourteen objectives of science teaching (and thereby laid the groundwork for science as a subject in primary and secondary school). Those objectives included the “ability to distinguish between fact and theory”, the “habit of basing judgment on fact” and the “willingness to change opinion on the basis of new evidence” (Davis 1935: 117). At that time, the term “scientific literacy” was not yet used (as it came up in the late 1950s; De Boer 2000). However, even the very early attempts regarding scientific literacy indicate that scientific literacy is composed of different facets, including for example factual and methodological knowledge but also a specific mindset. Various influential conceptualizations of scientific literacy followed, mostly including multi-dimensional approaches. For example, Miller (1983: 31) summarizes that in most early attempts (from the mid-1960s on) two dimensions constituted scientific literacy, namely “an understanding of the norms of science and knowledge about major scientific constructs”. He adds a third dimension, which is the “awareness of the impact of science and technology on society and the political choices that must inevitably emerge” (Miller 1983: 31). Miller argues that his understanding of public policy issues can be traced back to Shen’s (1975) “civic scientific literacy”. That is, Miller stresses dimensions that are prerequisites for citizens’ active participation in society and democracy. This very idea of scientific literacy is also at the heart of several other definitions (cf. e.g. functional scientific literacy (Ryder 2001; Tabak 2015), or civic scientific literacy (Priest 2013)).

Of recent definitions of scientific literacy, the one provided by the Programme for International Student Assessment (PISA) (OECD 2016) might be the most influential: Here, scientific literacy refers to being a reflective citizen, which includes being able to engage with science-related issues and with the ideas of science. Three forms of knowledge constitute this recent PISA definition (OECD 2016): content knowledge, procedural knowledge, and epistemic knowledge. In the following, we will describe these elements in further detail.

## 2.4 Scientific literacy: content, process, and epistemic knowledge

Content knowledge includes knowledge of theories and facts: this is what is predominately taught in school (Kind and Osborne 2017). However, which topics should be part of the science curriculum has been widely discussed. Trefil (2008) states that people should “know something about all areas of science, rather than a lot about a single area” (Trefil 2008: 9), suggesting that students (at least) should be taught what he calls the “Great Ideas”, that is the general principles that constitute an understand-



ing of a wide range of scientific phenomena (e. g. conservation of energy). Others have argued that educators should consider scientific findings and theories that best foster appreciation of science, scientific knowledge that might guide everyday decisions, or topics that might have impact on *various* aspects of everyday life and related decisions (e. g. Feinstein, Allen, and Jenkins 2013). Such transferable knowledge is probably the most important aim in curriculum development. Health issues and environmental issues are some of the most prominent examples of where science learned in schools could inform everyday decisions and actions. However, knowledge transfer often fails: With regard to environmental conservation actions, Crowell and Schunn (2016) found only a very weak relationship between number of science courses during formal education and scientific literacy and even a negative relationship between educational attainment and scientific literacy.

In line with this, in the ongoing discussions on scientific literacy as outlined above there is a shift from the importance of content knowledge to the importance of process knowledge as well as epistemic knowledge. Process knowledge refers to knowledge of methods and practices in science. Kind and Osborne (2017) outline that such knowledge includes the constructs science uses to establish knowledge (such as knowledge about variables, or replication). Epistemic knowledge refers to an understanding of the process of knowledge building, this includes what classifies a theory or a hypothesis or how arguments are used in science (Kind and Osborne 2017).

Kienhues, Thomm, and Bromme (2018) worked out some structural features of science that help to understand the differences between and similarities of different scientific domains. One of these features, the methods and sources of evidence used within a domain, is closely linked to procedural and epistemic knowledge. They outline that

knowledge construction in natural sciences follows theory-driven models that are examined by experimentation, by systematic data gathering, analyses, and interpretation, while knowledge construction in history, in contrast, follows hypotheses which are yet to be examined based on diverse documents and the systematic gathering, analyses, interpretation, and placement of these documents in historic contexts (Kienhues, Thomm, and Bromme 2018: 255).

Knowing these methods and mechanisms is crucial for understanding a specific scientific domain, and therefore also crucial for understanding and evaluating the knowledge claims a domain produces.

Also Chinn, Buckland, and Samarapungavan (2011) highlight the importance of people's assumptions about the reliability of methods for generating scientific knowledge. In their view, such assumptions entail an understanding of what they call "reliable and unreliable processes of achieving epistemic aims". Duncan and Chinn (2016) argue that an underdeveloped understanding of such processes likely leads to a lack of deference to scientific evidence of high quality.

## 2.5 Further competencies that contribute to science understanding

As already pointed out, scientific literacy is a rather normative and also school-focused attempt towards having people gain the competencies that contribute to science understanding. In the following, we will sketch some further competencies that are discussed either as prerequisites or integral components of scientific literacy in a broader sense, especially with regard to public engagement with science.

Nowadays, being able to handle concurring online information is almost an integral part of dealing with science-based information. Therefore, Tabak (2015) outlines the role of “multiple documents literacy” (e.g. Stadtler and Bromme 2013) for successfully (that is, critically) dealing with scientific evidence. Multiple documents literacy includes being able to evaluate, comprehend, and integrate diverse information sources.

Science understanding in an information society is also intertwined with what is discussed as information literacy. Such literacy includes defining information needs, efficiently searching and accessing information, and evaluating and using this information, and it also includes knowledge about copyright or intellectual property (Çoklar, Yaman, and Yurdakul 2017). Klucevek (2017) argues that discipline-specific information literacy is crucial for achieving higher scientific literacy. Hendriks and Kienhues (forthcoming) summarize that various literacies taking into account information processing, including Internet literacy, information literacy, news media literacy, or multiple documents literacy comprise overlapping components. In consequence, due to the enormous availability of science-related information online and in various media, scientific literacy is likely to be partly intertwined with those literacies related to information processing.

Sinatra, Kienhues, and Hofer (2014) stress that people’s conceptions about knowledge and knowing are crucial in their everyday dealing with science information. Such conceptions are in the focus of research on “epistemic cognition” (e.g. Sinatra and Chinn 2011). Individuals bring these conceptions (or sometimes misconceptions) to their reasoning about evidence, for example in regard to the extent that scientific knowledge is perceived to be tentative or how scientific knowledge claims are justified.

In consequence, fostering adequate, adaptive epistemic cognition can be seen as crucial. Barzilai and Chinn (2018) provide a synthesis on achieving such goal. They identify various key aspects of what they call “apt epistemic performance”, which means that individuals are able to “reliably succeed, through competence, in epistemic activities such as forming accurate judgments or evaluating arguments, across a range of situations, and to appraise accurately through meta-competence when success can be achieved reliably enough” (Barzilai and Chinn 2018: 362). Promoting such apt epistemic performance includes aspects such as disciplinary knowledge, norms, and practices, which nicely connect to the three components of scientific literacy outlined above. However, Barzilai and Chinn (2018) emphasize that apt epistemic

performance should extend beyond the classroom, such that it takes into account people's dealing with science-based knowledge claims in everyday life.

Although the points above by no means represent an inclusive listing of competencies and concepts related to science understanding, they may help to understand the multi-facetedness and different foci that underlie attempts of psychologists and education scholars to grasp science literacy and laypeople's science understanding.

### 3 Trust in science and experts

While the notion of scientific literacy establishes the knowledge and competencies that are needed to appropriately deal with scientific evidence and arguments, laypeople's science understanding will remain bounded to some extent. On the expert level, the division of cognitive labor (Kitcher 1990) has resulted in a large number of highly specialized domain experts. As such, the complexity of scientific knowledge that follows from this division of cognitive labor and the uncertainty that is entailed in science, both exemplify that for laypeople to overcome their bounded understanding of science, they need to trust and defer to domain experts (Bromme and Goldman 2014). When it is not possible to rely on one's own knowledge and understanding to reason with scientific information (first-hand evaluation), it is warranted to trust what others say (second-hand evaluation) (Bromme, Kienhues, and Porsch 2010). Therefore, we argue that trusting others who might know better is not a fallback strategy (as argued elsewhere, e. g. Elaboration Likelihood Model, Petty and Cacioppo 1986), but a mode of reasoning that is sometimes advantageous for rational elaboration and decision making. In fact, in many cases first-hand learning (by sensual experience) is not possible. For example, concepts like genes, oxygen, and historical events like the Salem witch trials must be learnt about by learning from others, that is, by deferring to expert sources of information.

Trust, in psychological terms, is defined by the dependence of a trustor on an action of the trusted person or entity, while being vulnerable to the risk that this action might not be performed as anticipated. Trust then is established by developing a set of positive expectations about the trusted person or entity (Mayer, Davis, and Schoorman 1995; Schäfer 2016). We have previously extended this notion to *epistemic* trust (Hendriks, Kienhues, and Bromme 2016b), building on the works of epistemologists (e. g. Origgi 2014; Sperber et al. 2010): When a science communicator puts forward a scientific claim, the layperson (due to her bounded understanding) will not be able to judge the veracity of this claim first-hand. However, she is subjected to the risk that the claim might not hold true (firstly because of epistemic uncertainty within science, but secondly because of the knowledge and intent of the science communicator). Thus, the layperson will not trust blindly, but will evaluate the science communicator's trustworthiness. A long research tradition (from Aristotle to the works of the Yale group in

the 1950s) has tried to extract the characteristics that make a source most persuasive, and a variety of subscales were constructed (for a review see Metzger et al. 2003). However, in science communication, people might look for very specific characteristics of sources, based on their procedural and epistemic knowledge about science. Specifically, we found that laypeople form expectations about the expertise, integrity, and benevolence of experts (Hendriks, Kienhues, and Bromme 2015). In the following, we explain these dimensions of epistemic trustworthiness further, also referring to research that shows what inferences people make regarding these dimensions.

### 3.1 Learning how to trust

From early on in life, children develop a readiness to defer to others for information, but also to be epistemically vigilant against untrustworthy speakers (Sperber et al. 2010). For example, three-year-olds opt to trust an informant (by continuing to use a new object label introduced by her) who had previously named several objects correctly, over an informant who had made just one mistake (Pasquini et al. 2007). Furthermore, children prefer the accuracy of speakers over other non-epistemic characteristics, like the speaker's familiarity or age (Corriveau and Harris 2009; Jaswal and Hansen 2006). By the age of six, children are capable of identifying a speaker's deceptive motives (Mills 2014). For example, four-year-olds choose not to trust a puppet that has been introduced as a "big liar" for information about the location of hidden candy (Mascaro and Sperber 2009). Five-year-olds trust the advice about finding stickers given by an informant who has previously offered helpful information to others more than when the advice is given by someone who has tricked others before (Vanderbilt, Liu, and Heyman 2011). Starting at the age of seven, children take a liar's intentions into consideration: For example, in one study children had been told stories about a lying or a truth-telling character and the intentions for either lying or telling the truth; while the children did not trust a self-interested liar, they trusted a liar who had given a false statement in order to help another child (Fu et al. 2015). In sum, individuals start being vigilant about the trustworthiness of information sources at a very young age.

However, such early vigilance applies to face to face interactions. In contrast, a lot of science-based information is received via documents, namely text, but also video or images. A critical skill in text comprehension is "Sourcing" (a term established in reading research); this means "identifying and representing source features to predict, interpret, and evaluate documents' content and relevance according to a reading task" (Wennås Brante and Strømsø 2018: 777). Although studies have indicated that students often do not spontaneously pay attention to sources of text documents (Kobayashi 2013; for a review on sourcing skills and behaviour, see Tabak 2015), sourcing abilities – paying attention to sources, as well as identifying relevant source characteristics – may be trained (see Wennås Brante and Strømsø 2017 for a review on interventions for sourcing skills).

Dealing with multiple (mostly text) documents is also a challenge when dealing with scientific information online (Tabak 2015). In online media, such as news sites and social media, gatekeepers are not reliably present. Online, virtually anyone can post information, without necessarily being an expert, having checked the information, or having considered several sources. Specifically, science-related information is communicated both by professional science communicators, and unqualified, even deceitful sources. Also, scientists, perhaps young scientists in particular, might seek out the opportunity to communicate with members of the public without intermediaries (Brossard 2013). Thus, the public needs to gauge the trustworthiness of information providers by making inferences from various indicative cues (Landrum, Eaves, and Shafto 2015). In the following, we present evidence showing that laypeople use a combination of source and message cues to arrive at trustworthiness decisions about science communicators.

### 3.2 Inferring trustworthiness from scientific communication

Laypeople's beliefs about science (as a cognitive, but also as a social endeavor) influence their judgments about scientific communication. Scientific information resembling a scientific discourse style, such as use of citations and references to the methodology, results in people ascribing more credibility to the information and perceiving it as more scientific (Bromme et al. 2015; Thomm and Bromme 2012). In a study by Rabinovich and Morton (2012), participants who understood science to be a debate, in contrast to those who understood science as a search for one simple truth, were more likely to be persuaded by a text containing scientific uncertainties. Acknowledging discourse and uncertainty as an inevitable feature of scientific knowledge is part of sound epistemic cognition, and it might benefit laypeople's ability to deal adequately with scientific arguments and evidence.

Research on laypeople's judgments about different kinds of evidence has shown that they seem to prefer arguments that stem from relevant domain experts (expert evidence) and arguments that are supported by numbers (statistical evidence) to arguments supported only by personal experience (anecdotal evidence) (Hornikx 2008). To find out about the expertise of an information source, individuals might evaluate an expert's pertinence to a knowledge domain. Bromme and Thomm (2016) found that adults were quite well calibrated in their judgments of pertinence to the scientific topics, even if they described their own topic knowledge as low. As such, if online information is enhanced with references to experts, it is perceived to be more scientific and credible (Thiebach, Mayweg-Paus, and Jucks 2015) and will be selected more often for reading (Winter and Krämer 2014).

Even though someone might be a relevant domain expert, her affiliation to a non-reputable institution (perhaps with marketing aims) might make her testimony suspect. In fact, researchers from private research institutions are generally judged

as less trustworthy than university scientists (Cummings 2014). Also, if a scientific project is done in cooperation with an industry stakeholder, this might have detrimental effects on people's trust in these projects (Besley et al. 2017).

Additionally, features of the message ("message" addresses not only the transmitted content, but also discourse style, such as the language used or the overall logic of argumentation) determine how a scientific claim is interpreted, but they might also offer relevant information about its source. For example, the use of technical language might be a cue for readers to make judgments about the trustworthiness of a communicator (Thon and Jucks 2017), while the use of comprehensible language might reduce laypeople's perceived need to consult further experts, which might display an overconfidence in their own judgments' capabilities about scientific claims (easiness effect, e. g. Scharrer et al. 2012). Furthermore, experts who use two-sided argumentation – instead of only pro- or only contra-arguments – are considered more trustworthy and more persuasive (Mayweg-Paus and Jucks 2017).

Often enough, both message and source features are considered in combination. Source information might make laypeople more vigilant when examining the message, while message features might suggest evaluating a source more closely (Tabak 2015). For example, conflicts within scientific claims might be a reason to pay more attention to sources (Thomm and Bromme 2016). Also, conflict explanations rely on source-related strategies, such as differences in expertise or personal interests of the researchers who put out two conflicting claims (Thomm, Hentschke and Bromme 2015). Similarly, laypeople make inferences about a source's intent when they deal with scientific information. To uncover deceptive motives or conflicting interests of a speaker, it is critical to be able to infer intentions that motivate a communicative action (Sperber et al. 2010). Rabinovich, Morton, and Birney (2012) investigated how different communicative intentions in climate scientists' communication affect trust judgments. Participants who were told that climate scientists had the intention to inform reported higher trust in scientists and were more willing to engage in climate-friendly behaviour, in contrast to participants who were told that scientists wanted to persuade the general public of their opinion. Similarly, it seems to matter for laypeople's judgments of a scientist's trustworthiness whether the scientist (for example in her science blog) discloses further information about reported results, such as uncertainty, or contextual ethical arguments (Hendriks, Kienhues, and Bromme 2016a; Jensen 2008).

These results do not imply that scientists should only communicate to inform and should never be associated with an advocacy position – one might argue that scientists should actually be advocates for science, and for the beneficial applications that science develops. In fact, when scientists argue for non-controversial beneficial applications of science (such as severe weather alerts), laypeople might even ascribe higher credibility to advocating scientists (Beall et al. 2017). However, credibility judgments might be made by comparing a scientist's advocacy with their behaviour – a climate scientist who advocates for saving energy might only be found credible as long as she

adheres to her own advice at least to some degree, for example by flying less or saving energy in her own home (Attari, Krantz, and Weber 2016).

In sum, laypeople seem pretty sensitive to features related to the source and message that are indicative of a source's trustworthiness, which might benefit their evaluations of scientific communication.

### 3.3 Why dealing with science-based information is not a sure-fire success

The notion of scientific literacy implies that people should be empowered to deal with science and to be able to weigh evidence. This is similar to the enlightenment idea that science itself played in history (Hendriks, Kienhues, and Bromme 2016b), namely as an endeavor to scrutinize what was told by authorities to find out the "truth". Surely, more modern definitions of scientific literacy, and also the notion of epistemic trust, stress the importance that dealing with science-based information should mainly be functional for solving everyday science-related problems.

However, although many strategies – both related to elaborate, scientifically literate thinking about science and informed trust judgments about experts – will lead to good solutions for the individual dealing with a science-based problem, some issues will arise in laypeople's reasoning. Specifically, laypeople's reasoning might be subject to what we will call *flawed reasoning*, which we assume to be unintentional, or *motivated reasoning*, which is (unconsciously or consciously) influenced by attitudes or moral beliefs (for an extensive review, see Sinatra, Kienhues, and Hofer 2014).

On the one hand, *flawed reasoning* might stem from people's early intuitive theories, such as essentialism (Dar-Nimrod and Heine 2011; Shtulman 2017). There is some evidence that childhood intuitive theories and cultural beliefs are integrated with scientific ideas that are learned in formal education (Evans, Legare, and Rosengren 2011). Also, flawed reasoning might be the result of unintentional cognitive bias, such as assuming causality between factors when they are only correlated (Shah et al. 2017). Furthermore, the way in which (online) conversations go might influence people's attitudes about science-based topics. Anderson et al. (2014) showed that uncivil comments added to online scientific information led to a polarization of participants' attitudes about the topic (nanotechnology). In a study by Winter and Krämer (2016), in one experimental condition several online comments opposed the general claim of a text about a scientific issue (here, dangers of violent video games). In consequence, readers believed the general public opinion to be in line with comments, and readers with low topic involvement (students, as opposed to parents of minors) did even change their attitude toward media violence accordingly.

On the other hand, when employing *motivated reasoning*, people might be closed off to counterarguments and -evidence, for example when they employ the need for closure (Kruglanski et al. 2005) or the myside bias (Macpherson and Stanovich

2007). Furthermore, political and ideological beliefs might influence the processing of information (Kahan 2013), such that violations of people's identity lead to them form opinions about topics that are ideologically laden (Kahan 2013). Similarly, when the social identity of a reader is threatened by scientific evidence, the evidence might be appraised more critically (Nauroth et al. 2016).

These considerations may seem to undermine the notion that laypeople might be able to arrive at an adequate understanding of science and reasonably evaluate scientific evidence, arguments, and claims. However, we argue that flawed and motivated reasoning are not the norm, but rather the exception. In our conclusions below, we not only summarize how “sound” scientific thinking and reasoning could be fostered, but we also address how flawed and motivated reasoning might be addressed.

## 4 Conclusion

In this article we have outlined psychological approaches toward understanding laypeople's understanding of scientific communication. We have focused on laypeople's knowledge and understanding, by introducing the notion of scientific literacy and other frameworks that address laypeople's epistemic cognition. We have also described how their science understanding will necessarily be bounded, but that such bounds can be overcome by using reasoning to assess the trustworthiness, the expertise, integrity, and benevolence of those who put forward scientific information. We have then reasoned that trustworthiness judgments are informed by epistemic and procedural knowledge.

In consequence, science communication could consider and address people's competencies in dealing with science-based information, especially by addressing how people make trustworthiness judgments. That is, science-based information should also be supplemented with information that allows people to reasonably infer the epistemic trustworthiness of the scientific communicator. For example, higher transparency and more detailed information about sources in journalistic articles (e. g. credentials, affiliations) could actually make the claims stated more credible and could provide readers with the opportunity to compare and contrast several claims. It would also allow readers to make judgments about the trustworthiness of how journalists work. In short, disclosing information about sources would mean to empower people's ability to judge the trustworthiness of science communicators and also plausibility of scientific arguments (see also Kienhues, Thomm, and Bromme 2018).

We have outlined how people can make reasoned decisions and either directly or indirectly validate scientific communication. However, to complicate things, we have also mentioned instances in which laypeople's understanding might fall short, either because of the information that was provided or because of the way this information was (un-) intentionally processed. We cannot provide a full solution to this, but we



raise awareness of how the communication of science might avoid feeding misunderstanding.

Important here is the differentiation between motivated reasoning and flawed reasoning. Cook and Lewandowsky (2011) emphasize that “outreaches should be directed towards the undecided majority rather than the unswayable minority” (Cook and Lewandowsky 2011: 4). In our terms, this implies that science communicators as well as educators should facilitate and foster people’s ability to reduce their own flawed reasoning. This includes providing the information needed by readers for avoiding common pitfalls, as well as for promoting their scientific and information literacy. This focus would be a better use of communicative energies than to simply encourage people to abandon motivated reasoning.

Misinformation might be spread accidentally or deliberately, and as a result myths and false beliefs about science (such as the link between vaccination and autism) might persist in people’s minds, being familiar or coherent with their belief systems (Lewandowsky et al. 2012). But also, information might be especially convincing, for example when it is accompanied by neuroscience information, or even just by uninformative brain images (McCabe and Castel 2008; Weisberg et al. 2008). Cook and Lewandowsky (2011) have outlined various approaches for how to reduce the influence of misinformation, such as in an article intended to correct a myth, not beginning the article by stating the incorrect myth but instead stating the correction in its headline. Miton and Mercier (2015) have suggested counter-intuitive ideas (e. g. regarding vaccination) should be communicated in such a way that “people better understand why and when they can trust scientific results” (Miton and Mercier 2015: 636); this could mean referring to scientific methods that ensure the reliability of scientific results. And finally, emphasizing the provisionality of their results, Kahan et al. (2017) showed that science curiosity might reduce biased processing of political information.

Such psychological research – and the broad spectrum of research traditions we briefly sketched in this article – might provide valuable knowledge about laypeople’s science understanding, as well as hold implications for the successful communication of science. Further exploration of key interactions – how people’s scientific literacy interacts with their trust in science and scientists, with their interests and emotions, and with their already existing conceptions and attitudes toward science-based issues – might help shed some light on what is yet unknown about laypeople’s understanding and evaluation of scientific arguments, evidence, and claims.

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Hans-Jürgen Bucher

### 3 The contribution of media studies to the understanding of science communication

**Abstract:** The concept of “medialization” has become a key concept for analyzing the interdependent relations between science, media and the public sphere. The intention of this article is a critical investigation of this concept from a perspective of media studies in order to distinguish its different meanings, thus making the concept applicable for empirical research. The investigation is conducted in two steps: In a first step four main theoretical approaches of medialization are discussed. In a second step the article focuses on three processes which have constituted the medialization of science communication in part since the beginning of its history. These processes are *visualization*, *popularization* and *digitalization*. Each of them has transformed science communication in a specific way and on a special level: *Visualization* enriches science communication with new visual modes of discourse; *popularization* extends the scope of the target audience by addressing persons with a wide range of pre-knowledges and attitudes towards science; *digitalization* adds a new sphere of communication for disseminating scientific knowledge and allows to transform monological one-to-many communication into dialogical many-to-many interaction. Analyzing these three processes can help to gain a deeper insight into the medialization of science communication as all exhibit the double-structure of medialization: they stand for an extension of media-based science communication as well as for repercussions of these innovations to science itself.

**Keywords:** medialization (mediation) – multimodality – visualization – popularization – digitalization – easiness effect – online communication

## 1 Introduction

Although science does not belong to the main media topics compared to politics, economy or sports there have been increases in science media coverage during the last decades which are “historically unique and point to a qualitative change in the system” (Bauer 2012: 43). Even though other authors assume stagnation during the last years (Schäfer 2017), the term medialization might be justified to characterize the relation between media and science. There is evidence that the mutual dependence between science and media has become stronger during this process (Weingart 2012) pushing science communication more than ever on the agenda of media studies. The intention of the following article is to systematize the contributions of media studies to the understanding of science communication by analyzing some of the main tendencies which determine its recent developments and thus to contribute to an expla-



nation of the meta-process called medialization. The central argument of the article is that the medialization of science and science communication can be explained by the processes of visualization, popularization and digitalization. In contrast to macro-structural approaches from mass communication studies or sociology, the article focuses on the logic of the different media and its impact on the different dimensions of media communication like the dimension of signs and modes, the dimension of interaction and dynamics of communication or the dimension of topics and content.

## 2 “Medialization” as a key-concept for analyzing science communication

One of the key concepts for analyzing science communication is the term “medialization” or “mediatization”.<sup>1</sup> The term, coined for mass media research in general, was applied prominently by Weingart (2006) to analyze the relation between science, media and society. “Medialization of science” comprises two different, but complementary tendencies which could be observed since the 19th century, but have been intensified by the emergence of a media society during the last decades. The first tendency refers to an increasing media attention for scientific issues, mirrored in a quantitative extension of media coverage of science, in the qualitative unfolding of special formats in all media and the occurrence of new actors like public relation professionals or YouTubers (“public of science”) (Rödder 2009; Lehmkuhl et al. 2010; Bauer 2012). The second tendency refers to the repercussion of media to science, for example the adaptation and anticipation in science communication to principles, standards or criteria of media (“science of public”) (Weingart 2012; Schäfer, Kristiansen, and Bonfadelli 2015; Bonfadelli et al. 2017). The first tendency can be explained with reference to the increasing relevance of scientific knowledge in modern life, for example for health care, digitalization, nutrition or engagements in environment protection. The orientation of science towards the media is a result of the public’s pressure on scientists to legitimate their funding and their research activities in the face of decreasing trust of laypersons and politicians in unaccountable professional elites.

In science communication studies it is common ground that the relationship between media and science is problematic in several respects, because the two spheres are ruled by different principles, functions or “logics” (Weingart and Schulz 2014; Weingart 2012; Schäfer 2012). From a sceptical perspective representations of science in media outlets lack accuracy and correctness, are sensationalistic, simplified, unjust-

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<sup>1</sup> Although there are several proposals to differentiate between “medialization”, “mediatization” or “mediation”, in this article only the term “medialization” is used because it is well established in science communication research. Besides, the different definitions are overlapping and not necessary for the approach of this article.

tifiably alarming and neglect scientific uncertainty (Ankney, Heilman, and Kolff 1996; Knudsen 2005; Rödder and Schäfer 2010; Jensen 2008). On the other hand, it is suspected that science's orientation towards media logic impacts science's self-direction and independence and replaces orientation towards truth by orientation to public attention (Weingart 2006, 2012). In a more neutral sense medialization of science communication can be considered as an expansion of potentials to communicate with the public as well as with the scientific community. This multi-layered process introduces new media technologies, establishes a more interactive relationship with the public, modifies well-established routines of communication by new formats, genres and channels and brings about new actors, institutions of science communication and management (Peters 2012; Schäfer 2014).

The concepts of medialization are as manifold as are the concepts of media. In order for them to be fruitful for the analysis of science communication, a differentiation between some typical approaches is required. With respect to the implied concept of media and the range and direction of effects of medialization one can distinguish between four main approaches: A “*hegemonial*” *concept* (Jensen 2013) which defines medialization as a process of colonialization in which the media as an independent institution with its own logic drives other institutions like politics, sports or science to accommodate, because they depend on the media as a link into the public sphere (Kepplinger 2002; Couldry 2008). When it comes to the level of abstraction a *macro-structural* or *system-theoretical approach* is equivalent to the hegemonial approach but does not share its pejorative implications. Media are perceived as an independent subsystem of society (Weingart 2006) or as a cultural and social power (Couldry 2008). This family of theories defines medialization as a “meta-process” in history, comparable to industrialization or globalization (Krotz 2007), “in which institutionalized media of communication [...] are involved in the general circulation of symbols in social life” (Silverstone 2002: 762) and which encompasses all social institutions (Hjarvard 2008: 113). While this approach is media-centered and the hegemonial approach is society-centered, there is a third family of theories which can be labeled as *institution-centered*. Based on Anthony Giddens theory of social structuration medialization is conceptualized as “a constitutive component and a necessary condition of social structuration throughout the history of human communication and media technologies” (Jensen 2013: 214). Medialization is considered to be a process in which structural conditions like media logic or technical infrastructure influence the actions of the actors, but at the same time they are the result of these actions. As a counterpart to the three mentioned approaches a fourth *medium-centered approach* conceptualizes medialization on a *micro-structural level of discourse* as the impact of media formats and genres on production and reception (Livingstone 2009). Originally this concept of medialization goes back to the classical definition of Altheide and Snow: “Mediation refers to the impact of the logic and form of any medium involved in the communication process” (1988: 195). This approach, which in contrast to macro-structural ones is labeled “mediation” by some authors, “posits the primacy of form over content” (Alt-

heide and Snow 1988: 206) to explain “how media direct social interaction” (Altheide and Snow 1988: 195). Therefore this approach focuses on the reconstruction of media logics and the semiotic dimension of media (Schulz 2004).

For investigating science communication all four approaches of medialization can be applied since each of them sheds light on specific aspects of the relations between media, public sphere and science. In contrast to macro-structural approaches which usually have been in the focus this article puts the institutional and the micro-structural, discourse-oriented approach in the center. As medialization is a dynamic and process-based concept implicating a transformation of social and cultural relations and of practices of communication this article focuses on three processes which have constituted the medialization of science communication in part since the beginning of its history. These processes are *visualization*, *popularization* and *digitalization*. Each of them has transformed science communication in a specific way and on a special level: *Visualization* enriches science communication with new visual modes of discourse; *popularization* extends the scope of the target audience by addressing persons with a wide range of pre-knowledges and attitudes towards science. *Digitalization* adds a new sphere of communication for disseminating scientific knowledge and allows the transformation of monological one-to-many communication into dialogical many-to-many interaction. Analyzing these three processes can help to gain a deeper insight into the medialization of science communication as all exhibit the double-structure of medialization: they stand for an extension of media-based science communication as well as for repercussions of these innovations to science itself.

### 3 Visualization of science communication: extending modes of discourse

Science communication was one of the first domains of public discourse to benefit from “the mass visual culture of the nineteenth century” (Crary 1990: 16; Lenman 1995; Ruchatz 2003: 209–243; Barrow 2008). Laterna magica, woodcarving or etchings and their graphic reproduction, photography and film were picked up in art history (Dilly 1994; Ratzeburg 2002; Reichle 2005), geography (Brogiato, Fritscher, and Wardenga 2005), medicine (Rowley-Jolivet 2010), astronomy or physics (Rowley-Jolivet 2010) to make objects observable and intelligible (for early modern science between 1500 and 1800 see: Lefèvre, Renn, and Schoepflin 2003). The new potentials of visualization had great impact not only on the research process itself, but also on knowledge transfer within the scientific communities as well as to the public (Ruchatz 2003; Trumbo 2000). Several studies have demonstrated that visualizations are not merely re-presentations of scientific objects or illustrations of theories, but are means of the research process itself as they serve as “visual arguments” or figurations which “concretize notions and proposals by impressing a graphic form” (Cambrosio, Jacobi, and

Keating 2005: 124). In the digital age the relevance and diffusion of visuals in all areas of science communication have even increased (Bucchi and Saracino 2016; Pauwels 2006) and generated new branches of research like computational social science or network visualization (Foucault Welles and Meirelles 2014) and also accelerated the exchange of scientific knowledge (Estrada and Davis 2015).

Typical for science communication is the variety of visuals which comes from different referents of visual representations (Pauwels 2006; Hüppauf and Weingart 2008). The first type can be labeled as *documentary visuals* and may refer to material or physical objects which are observable to the human eye like experiments, animals, human encounters or talking scientists. Second, there are *technical visuals* which refer to objects and their aspects that only become visible with special representational means and devices like microscopes, telescopes, eye tracking devices, computer tomography, X-ray apparatus or sonography. A third type of scientific visuals are *data visualizations* like charts, infographics, heat maps or simulation models. These different imaging methods have changed science communication in several ways: they afford new research strategies and diagnostics, accelerate and globalize science communication because they need not be translated into other languages. They also have the potential to optimize the comprehensibility of science which leads to new communication genres that integrate visual and textual modes in different ways like scientific films (Landecker 2006; Gouyon 2015), presentations with visuals (Rowley-Jolivet 2004; Bucher and Niemann 2012), science comics (Jüngst 2010; Bucher and Boy 2018), web videos (Morcillo, Czurda, and Robertson-von Trotha 2016) or science slams (Carlsson 2018).

Although the benefits of visualizations for science communication are obvious, scepticism about their epistemic nature and even the rejection of them are common up until today. One objection which was articulated even in the beginning of modern history of visual media in the middle of the 19th century criticizes an “over-illustration” and its underlying “fallacy of supposing that the eye could be made to do the work of the mind” (Congdon 1884: 483). The assumption that visuals belong to the realm of emotions and entertainment and are therefore a counterpart to rationality and objectivity has been part of an iconophobia in European culture over centuries. This scepticism has affected the discourse on visualization in science communication in several respects. TV science documentaries have been criticized because their “aesthetic strategies and high-tech visual spectacle tend to overwhelm scientific content” (Van Dijck 2006: 19) and favor spectacle and entertainment over factual representation and realism (Darley 2003). The latest debate on the epistemological potentials of visualization was raised by the advent of digital slide-based presentations, whose “cognitive style” in the eyes of its critics “routinely disrupts, dominates, and trivializes content” and “elevates format over content, betraying an attitude of commercialism that turns everything into a sales pitch” (Tufte 2003, unpag.). Therefore it is suspected that PowerPoint turns scientific argumentation into persuasion, violating the principles of rational discourse (Turkle 2003; Peters 2007; Schnettler and Knoblauch 2007).

Overall, the sceptical party suspects that visualizations imply a victory of form over content or aesthetics over science. In contrast, the optimistic position emphasizes that visualization increases the potentials of science communication, as images improve comprehension, support the remembrance of information and approach the addressees emotionally as well as cognitively (Trumbo 1999; O'Neill and Smith 2014) by promoting public engagement and self-efficacy (O'Neill and Nicholson-Cole 2009; Metag et al. 2016). Another advantage of visualizations is their cross-cultural applicability and their independence from language competence, although some authors underline the necessity of a visual literacy especially for science communication (Trumbo 1999; Bucchi and Saracino 2016).

The controversy about the epistemic potentials of visualizations in science communication is a typical discourse of medialization which unfolds regularly when new media show up (Bucher 2016). In case of scientific images one can trace back this controversy to some typical aspects of visual communication which constitute its specific modal logic and of which all are relevant for science communication.

The first reason for a sceptical attitude towards visualizations in science communication is based on the fact that each visualization is never a mere (mechanical) reproduction of its referent, but involves a conversion or transformation from an object of reference into a representation. In this process, which can be called “a mode of brokered research communication” with journalists, think tanks, PR agencies and corporate communication as intermediaries (Allen 2018), the visualized referent “is captured, transformed, or even (re-)created through a chain of decisions [...] that involves several actors, technological devices, and normative settings” (Pauwels 2006: 5). Therefore the epistemological value of visualizations depends on the quality of this transformation process, which hence has to be one of the main objects of visual communication research. An approach to scientific visualization which treats representations in isolation from its production and discourse context is therefore inadequate, because it misses the process of their formation and the context in which they are used intentionally (Pauwels 2006: 21–22). Since scientific visualizations are more and more the results of digital image processing, especially in biochemistry, molecular biology, nanotechnology or astrophysics and astronomy, adequate interpretations of these images require knowledge about these processes and the operating algorithms (Norris 1994; Hassan and Fluke 2011). To preclude a crisis of trust in scientific images some journals are already applying guidelines for digital image processing “to draw a line for the scientific community regarding acceptable and unacceptable practices in image production” (Frow 2012: 370).

The process of transformation from an issue to a visual and the resulting images are not only responsible for the quality of information transfer but also have an ideological impact. Research on the visualization of issues like climate change (Metag et al. 2016; O'Neill and Nicholson-Cole 2009) migration (Allen 2018), nanotechnology (Landau et al. 2008) in media outlets have demonstrated that the selection of visual representation influences the recipient's attitude towards these issues and plays a

pivotal role in building public engagement (O'Neill et al. 2013). In the case of climate change, for example, images related to climate disasters like floods, droughts, polar bears and melting ice are associated with respondents' feeling that climate change is an important and salient issue whereas images of politicians or information graphics do not have a comparable attitudinal or mobilizing impact (O'Neill and Hulme 2009; Metag et al. 2016). It characterizes science communication to a lay audience that the transformation of scientific issues like climate change, genetics or nanotechnology into visualizations requires a kind of translation, which is submitted not only to scientific and technical criteria but also to aesthetical, attentional and entertaining criteria (Allen 2018). These criteria of popularizing scientific images may have the effect that complex scientific issues become simplified because images that support public expectations or fit into a popular frame may get spread more easily (Foucault Welles and Mereilles 2014). As a result of the process of transformation scientific visualizations can be located both in communication *within* science and in public communication *about* science. At the same time scientific images can be documentations of research and cultural icons of the time like the helix image of DNA or the "Blue Planet". Therefore they are objects and results of medialization and should be regarded "as specific forms of representation and production, which fluctuate between the scientific and the public sphere" (Nikolow and Bluma 2008: 35).

A second reason fueling the controversy about the role of visualizations in science communication is rooted in the modal logic of images itself. It characterizes the different modes of communication that each implies a specific epistemological commitment (Kress 2010: 16–17). When applying visuals one has to consider representational commitments in a spatial or relational respect: text-based information, for example that A is "beside", "under", "over", or "inside of", B allows some vagueness, whereas an image of these relations between A and B requires the exact positioning of A and B. Besides the spatial and relational commitment of images picture theory has emphasized some more typical features of this mode of communication which have to be considered if images are used in science communication. Images lack an alphabet or syntax and are therefore *ambiguous in their structure* (Scholz 1993; O'Neill and Smith 2014). Images cannot be structured wrongly like words or sentences and there are no rules for identifying elements on a picture or their arrangement because the picture itself does not give any criteria which elements or parts are relevant and which are not (Sachs-Hombach and Schirra 2007). "Pictorial systems differ from other symbol systems foremost through their syntactical density and relative syntactical repleteness" (Scholz 2000: 207).

Charts, maps or information graphics are different in some respect as for these types of visualization some rules and spatial principles have developed, for example the arrangement of the x- and y-axes or the codification of colors. Because of such standardization, charts or information graphics exhibit a lower syntactical density and repleteness than for example photographs. Whereas in a photograph of the surface of the moon every feature or nuance could be relevant, in case of a chart explaining

the phases of the moon conventional elements like arrows or colors limit the aspects which are relevant for its symbolic function as an explanation.

Pictures are also *semantically ambiguous* because they are – in contrast to symbols like words – icons whose meaning cannot be inferred via conventions or rules but only via associative conclusions (Mitchell 1986; 2008). Because of this semantic repleteness very different features and aspects of a picture can become cues to trigger associations, with the result that a picture allows different readings and can be subject to different or even conflicting understandings. The classical eye tracking study of Yarbush from 1967 had already demonstrated empirically that the meaning-making of a picture is not determined by its features but depends on the particular intentions of the recipient: “In any picture, the observer can obtain essential and useful information by glancing at some details, while others tell him nothing new or useful” (Yarbush 1967: 182). A striking example of conflicting understandings of the same picture is the famous space photograph shot from the astronauts of Apollo 17 on their flight to the moon which for the first time in the history of mankind shows the whole earth and which was published in a “Preliminary Science Report” of the space mission. In a geopolitical One-World reading the Apollo image “signifies secular mastery of the world through spatial control” as a metaphor of US political hegemony. In contrast a Whole-Earth reading, disseminated by environmental and ecological organizations “signifies the necessity of planetary stewardship” and interprets the image as “representing a quasi-spiritual interconnectedness and the vulnerability of terrestrial life” (Cosgrove 1994: 287). Both interpretations are ideological and socially constructed and transcend the geographical and cartographical features of the image (O’Neill and Smith 2014).

The *modal logic of images* – their transformational character, their specific epistemological commitments and their syntactic and semantic ambiguity – has some crucial implications for visualizations in science communication. First, they are open to interpretation by their recipients in different respects:

*Propositional ambiguity:* The same image can be used to express different propositions (the chart indicates that the summer 2018 was extremely hot or it indicates that global warming has accelerated).

*Illocutionary ambiguity:* The same image can be used for different illocutionary acts (to document, criticize or insist that the mean temperature has increased during the last century).

*Intentional ambiguity:* The same picture can be used to pursue different communicative goals (to document the development of mean temperature, to warn about global warming, to criticize politicians’ inactivity, to mobilize the addressees).

The second consequence results from the first one: because of their modal logic and the inherent ambiguity pictures should not be used as well as interpreted in isolation from other modes but as part of a *multimodal orchestration* in which they are pragmatically and semantically supported by additional attendant modes like text or spoken words. In a certain way the concept of visual communication is somehow

misleading because there are no purely visual media, but only mixed or multimodal media (Mitchell 2005; Kress and van Leeuwen 2001) which is why Mitchell proposes to put the phrase “visual communication” “into quotation marks for a while [...] in order to open it up to fresh investigation” (Mitchell 2005: 264). Empirical reception studies including eye tracking research verify that understanding and interpreting visuals is based on cross-modal meaning-making in which the recipients integrate all different modal resources they can rely on (Bucher and Niemann 2012; Bucher 2017). From the modal logic of visuals it follows: In order for pictures to do their jobs in science communication – to inform, to prove, to convey, to illustrate – they should be well integrated into multimodal orchestrations in which different modes support one another in the meaning-making process.

## 4 Popularization: extending the target audience

Popularization of science can be explained as a strategy which is applied when experts communicate with a broad audience which can either be laypersons or experts from another scientific discipline. Therefore the concept of popularization implies different arenas of communication whose actors differ in knowledge and competences as well as the existence of a certain pressure to bridge these differences by communication. In science communication this type of constellation starts to emerge during the 19th century when science became an autonomous social system which has to communicate with the public to win its attention and legitimization (Weingart 2006; for a historical overview see Cooter and Pumfrey 1994; Bauer 2012). In the course of this development social institutions like science clubs, science magazines, public science lectures, exhibitions and museums came into being to organize the transfer of knowledge from science to public (Schwarz 1999). Even the terms “popularize”, “popularization” or “popular science” appeared in ordinary language use for the first time during this process and got their semantic meaning in the sense of “general understandability” (Allgemeinverständlichkeit) (Daum 1998: 33–41). Examples of popularization comprise a wide range of scientific depictions like newspaper reports, TV documentaries and series, public presentations or lectures, science slams, press releases, YouTube videos, science comics or motion pictures like *Jurassic Park* or *The Day After Tomorrow*.

One of the main problems one is confronted with when analyzing popularization is the vagueness of the concept itself. There is no clear-cut boundary for distinguishing specialist discourse from popular discourse, real science from popular science or appropriate simplification from distortion (Hilgartner 1990). Do grant proposals, abstracts of science articles, advanced textbooks, medical or economic articles for practitioners, visualizations of results or information graphics belong to a specialist discourse or to a popularized discourse (Myers 2003: 267–271)? Finally the increas-



ing relevance of popularization has to be seen in the context of an intensified competition for public funding (Grundmann and Cavallé 2000), the impeding loss of trust in expert knowledge (Achterberg, De Koster, and Van Der Waal 2015) and the increasing potential to commercialize scientific knowledge (Gunnarsson and Elam 2012).

There are two different approaches to analyzing popularization as a communicative strategy: the first approach rests on the so-called *deficit model* (Hilgartner 1990; Bauer, Allum, and Miller 2007) and conceptualizes popularization as the translation of a highly specialized discourse of experts into a simplified and dumbed down discourse of laypersons, who are from a scientific perspective “a blank slate of ignorance on which scientists write knowledge” (Myers 2003: 266). The second approach rests on a different picture of the relation between science and the public: it neither assumes a clear cut between scientific and popular discourse nor between scientific and everyday knowledge and therefore rejects the view of popularization as a translation of a specialized discourse of experts into a simplified discourse of laypersons. Instead, this second approach views popularization as *recontextualization* of scientific discourse into another communication arena, be it media discourse, science museums or science comics (Luzón 2013; Estrada and Davis 2015). This perspective opens the way for analyzing *popularization as a phenomenon of discourse* which can be characterized on the level of rhetorical and stylistic measures, genres, formats, multimodal extension, or specific goals and purposes.

In the case of verbal communication addressing non-experts, two main measures have been identified as strategies of popularization (Gülich 2003; Ciapuscio 2003): first reformulations, which explain a reference expression with a treating expression which is mostly linguistically marked – for example with the phrase “for example” or “what this means is ...”. A second measure is the application of verbal illustrations like metaphors, concretization or exemplification. Up to now these approaches to popularization are confined to verbal modes neglecting the fact that “some of the most dramatic and memorable encounters with science are primarily visual, rather than verbal” (Myers 2003: 272). However, the approach to conceptualize popularization as a form of recontextualization implies the potential to expand its analysis on all dimensions which constitute the affordances of the context of a discourse: modal, functional, propositional, thematic, normative or ethical affordances.

How contextual affordances influence discourse was analyzed on a rather general level by Paul Grice, which makes his approach appropriate to be applied to all forms of communication. In his article “Logic and Conversation” he makes a proposal on how one can generalize the situational affordances of those forms of discourse that serve the purpose of a “maximally effective exchange of information” (Grice 1975: 47): “Make your conversational contribution such as is required, at the stage at which it occurs, by the accepted purpose or direction of the talk exchange in which you are engaged. One might label this the Cooperative Principle” (Grice 1975: 45). As a consequence of the Cooperative Principle he proposes four maxims that govern all communication

(Grice 1975: 45–47): the *maxim of quantity* (make your contribution as informative as is required); the *maxim of quality* (do not say what you believe to be false or for which you lack evidence); the *maxim of relation* (be relevant); and the *maxim of manner* (be perspicuous, avoid obscurity, ambiguity and be brief and orderly). These maxims are not conceived as normative demands, but as constitutive conditions for the possibility of communication generally. Hence, it is consistent to label these maxims as “conversational imperatives” (Grice 1989: 370) or as “the psychological infrastructure of human communication” (Tomasello 2008: 107).

One can use these maxims to analyze the difference between expert and non-expert discourse as they differ both in “stage” of discourse and “purpose of talk” and therefore require different criteria of cooperation, informativity, relevance, plausibility or comprehensibility. What is informative or comprehensible for an expert is normally under-informative and obscure for laypersons because of their lesser degree of pre-knowledge (“stage of discourse”); what is relevant for an expert or a layperson differs because of their different intentions to participate in a discourse – for example the expert’s intention to review a theory or the layperson’s intention to infer information which is applicable in everyday-life. A *principle-based approach* to discourse therefore provides a measure to conceptualize popularization systematically: popularization is a conversational strategy to adapt a scientific contribution to criteria of cooperation, informativity, relevance, plausibility or comprehensibility which are typical for a context in which the speaker assumes that the addressee exhibits less or different knowledge and competences and a more personal motivation to engage in the discourse. Therefore the difference between expert and non-expert discourse does not lie on the level of the maxims, but on the level of the criteria of these maxims. As a consequence expert discourse is not superior in virtue of for example plausibility or relevance, but differs in virtue of the criteria of plausibility and relevance.

Furthermore a principle-based approach leads to the question of whether a special form or format of discourse is ruled by special maxims which go beyond the constitutive ones analyzed by Grice because for example “maximally effective exchange of information” is not the only purpose. In case of popularization we can assume that to appeal or to maintain attention or motivation of the audience a *maxim of entertainment* is functionally necessary to ensure the Cooperative Principle. The epistemological problem of popularization can be ascribed either to conflicts between different principles or different criteria of the same principle. To make a newspaper story about cancer research interesting and readable it could be journalistically appropriate to neglect qualifying information about the probability of the results and to present them in a deterministic and simplified manner (Brechman, Lee, and Cappella 2009). But this kind of simplification and overgeneralization, culmination in gene-based causal explanations and terminological shortcuts like “fat gen”, “breast tumor gene” or “cancer gene” can of course be violations of conversational maxims like accuracy, completeness or relevance. Therefore examples of critical analyses of science communication in the media (Kua, Reder, and Grossel 2004; Darley 2003; Bromme, Kienhues,

and Porsch 2010; Anderson et al. 2014; Walsh 2015) indicate that even popularized science communication is submitted to the same principles and maxims although the context and the criteria of fulfillment are different.

The consequences and the range of application of this principle-based approach to popularization can be demonstrated using the example of *science comics* which beyond doubt are an example of popularized science communication (Jüngst 2010; Negrete 2013; Bucher and Boy 2018). For transferring scientific knowledge with the help of comics a multimodal format of entertainment is employed, which applies different modes of discourse like drawings, pictures, speech-bubbles, text, icons, color, pictorial runes, panels, page-layout (Cohn 2013; Bateman and Wildfeuer 2014) and which is committed to format-specific principles and maxims of communication characterizing the comic-format. A characteristic feature of comics is its narrational structure of telling a story. Popularization in this case means to integrate scientific information into the narration of a story. In principle, there are two strategies for how information and narration can be combined, and which – according to narratology (Genette 1980) and film theory (Smith 2009) – can be labeled *diegetic* and *non-diegetic*: *diegetic* strategies convey information narratively as a part of the story (the author informs or teaches the recipients by telling a story); *non-diegetic* strategies present information through additional elements, such as charts, text boxes, captions and the like. In these cases, the author tells a story and additionally informs the addressees. In the first case, the information is part of the narrated world, in the second case it is part of the narrator's world. The diegetic strategy can be performed for example in telling a story which allows to infer the relevant information as the implicit "message" of the story, or in telling a story about an expert who delivers scientific information in the form of a teaching lesson or a lecture. Applying a non-diegetic strategy scientific information can be implemented between the panels of a comic as charts or tables or they can be placed as numbers or icons within a panel as a kind of information placement comparable to product placements in commercials (for more details see Bucher and Boy 2018).

With regard to knowledge transfer the most relevant question is, which of these strategies that can be labeled as infotainment are most successful. The result of an empirical study (Bucher and Boy 2018), integrating the methods of eye tracking and supported and non-supported knowledge tests indicate that diegetic strategies combining expert information and information placement in comic narration seem to be the most effective strategies for knowledge transfer in information comics. Non-diegetic strategies which enrich comics with additional informational elements like information graphics, tables, or textual explanations tend to interrupt the flow of the story and therefore confront the recipient with the problem of coherence between narration and information. In the case of science comics one can conclude that popularization can be an adequate strategy to transfer scientific knowledge if a popular format of discourse is not only deployed to lure the recipients but as a carrier of scientific information. Only in the latter case popularization corresponds with the fundamental

maxims of communication mentioned above as well as with a maxim of entertainment.

However, some other audience studies also indicate the flip sides of popularization. In an experimental study comparing audience effects of different scientific depictions for laypersons and for experts, Scharrer et al. (2016) prove an “easiness effect of science popularization”: popularized depictions lead readers to overestimate their own epistemic capabilities, to judge the received information as being more credible and to rely more easily on their own judgment instead of consulting people with expert knowledge (Scharrer et al. 2016: 6). A reception study of science articles on climate change and biodiversity with humor inserts concluded “that humor is risky and can undermine the credibility of these articles” (Pinto and Riesch 2017). These examples indicate that the maxim of entertainment can conflict with other maxims like the maxim of plausibility or relevance. Considering other “pop formats for presenting science” like science slams (Carlsson 2018) Bucchi (2017) warns that this tendency could contribute “to shaping an image of science as ‘easy’ and quick to make, as well as to understand, that undermines all the uncertainty, the patience and hard labor and thereby encourages superficial, horizontal criticism by users, just like in travel or food users reviews (Bucchi 2017: 892). On the basis of these differing empirical results one can conclude that popularizing science is indeed a “double-edged sword” (Walsh 2015) which has to be applied carefully and based on the conversational maxims mentioned above. While in science comics or in a science slam the differences to a typical scientific description and the relevance of an entertainment principle are obvious for the recipients and can promote a distanced and critical reception, this is not guaranteed for other sometimes hyper-real formats of science communication (Darley 2003). If science communication deploys the advantages of popularization, the popularized descriptions should be transparent and reflexive empowering the recipients to discover the strategical measures – for example of entertainment – and to verify its effects on the conversational principles which are constitutive for a “maximally effective exchange of information” (Grice 1975: 47).

## **5 Digitalization of science communication: science in a network public sphere**

In the last decades digitalization and the Internet have had an important impact on internal and external science communication as well as on the research process itself (Nentwich 2003; Nentwich and König 2012). These technological innovations have triggered a fundamental transformation of science into “cyberscience” (Nentwich and König 2012): they have enabled new research methods, new ways of storing and processing data, the analysis of “big data”, participatory formats of peer-reviewing (Gloning and Fritz 2011) or the collaboration of interdisciplinary and international

research groups (Trench 2008). In contrast to previous times the new practices of production of knowledge have amplified the process formerly labeled “mode 2” in which “knowledge is accumulated through the repeated configuration of human resources in flexible, essentially transient forms of organization” (Gibbons et al. 1994: 9). In addition digitalization and the Internet have also changed the distribution of and the access to scientific knowledge in all arenas of science communication. Analyzing the specific logic of digital communication can help to systematize the transformation that science communication has undergone in this process. In contrast with traditional forms of media communication digital online communication has expanded the potentials of communication in different dimensions:

*The dimension of the actors and their roles:* In the traditional model of science communication scientists provide knowledge for journalists who distribute it via media to the audience. In a digital media environment scientists are able to communicate directly with an audience bypassing the gatekeeping of journalism. It characterizes the logic of social media that even recipients can become communicators, either by engaging in interactive feedback-communication like forum communication, by participating in cooperative platforms like Wikipedia or by starting their own scientific media channel for example on YouTube. The transformation of “users” to “producers” is supported by the reduction of costs of production and by digital production tools which are easy to handle (Erviti and Stengler 2016). As a consequence of the suspension of traditional roles of mediating communicators – journalists, scientists, experts – and addressees the border between a public sphere of experts (professional public sphere) and a public sphere of laypersons (general public sphere) gets blurred, which undermines the principle-based gatekeeping of scientific information as well as the difference between experts and layperson (Neuberger and Jarren 2017). In contrast to a sceptical perspective on user-generated content the example of Wikipedia demonstrates the positive potentials of collaborative knowledge production in which experts and layperson work together and an intelligent infrastructure helps to organize the discourse in a transparent fashion (Pentzold 2011; Loveland and Reagle 2013; Bilić 2015; Segev and Sharon 2016).

*The dimension of the dynamics of communication:* By transforming one-to-many-communication into many-to-many-communication the dynamics of discourse has changed from one-way to interactive and recursive communication expanding its structure in temporal, spatial and social respects. Besides the audience’s participation in the discourse, the discourse can also extend in longer sequences of communication exchange transforming it into a decentralized network structure. Digitalized communication can be archived for later references or can be globally distributed which makes media discourses systematically searchable but stretches online-based sequences of interactions sometimes beyond the coherence of turn adjacency. This new “logic of connective actions” (Bennett and Segerberg 2012) contributes to make science communication more democratic and transparent. On the other hand it leads to a loss of control over accuracy, relevance or scientific quality in general. As a conse-

quence of these discourse dynamics professional science journalism loses the monopoly of gatekeeping and has to face competition with other sources (Neuberger and Jarren 2017; Schäfer 2017). In some cases this unfiltered and direct communication into the public domain leads to a “crisis of mediators” (Bucchi 2017) mirrored in an increasing number of retracted papers or cases of plagiarism (Bucchi 2017: 891).

*The dimension of distribution and access:* Especially the applications embedded in social media like sharing, retweeting, favoriting, commenting and hashtagging are conducive to spread content over time and space and to trigger recipients to participate in a discourse even on a very low level. Hence the effect of a scientific depiction is not only dependent on the original content but is additionally influenced by the reactions of the audience which are themselves publicly accessible (Tenenboim and Cohen 2015; Weber 2014). Labeling a depiction with a hashtag classifies it topically and can contribute to the formation of a “hashtag public” around a special issue of science (Rambukkana 2015).

*The dimension of modality:* Digital communication allows to combine all modes of communication like spoken language, written text, all type of pictures, moving images, color, layout, design or icons into different multimodal orchestrations like videos, slideshows, interactive information graphics and all kind of text-picture-combinations (Mautner 2005; Smith et al. 2011; Adami 2015; Bucher 2017). The question how multimodality influences comprehensibility and attractiveness of science communication is still one of the most urgent desiderata of research. Answering this question can be supported by results of recipient studies and audience researches on scientific presentations (Bucher and Niemann 2012), text–image relations in print media (Bateman 2014) or on audio-visual TV-stories (De Cheveigné and Véron 1996; Peters 2000; Mellor 2009). But investigating online science communication as a multimodal discourse is still an exception (Cha and Chan-Olmsted 2012; Benson 2015).

*The dimension of forms of interaction and discourse formats:* Changes in media history are never limited to a socio-technical dimension but have always generated new forms of interaction and discourse. The potentials of a communication ecology enabled by the Internet are dependent on the special media logic of the different platforms be it a website, a Weblog, Facebook, Twitter or YouTube. Twitter discourses for example are determined by a limited number of signs per tweet, the forms of interaction which are enabled by the applications like retweeting, commenting, replying favoriting or hashtagging integrated into the platform (Boyd, Golder, and Lotan 2010; Housley et al. 2018; Bucher and Boy 2018) or the @-operator which allows addressing special persons (Honeycutt and Herring 2009). New formats can arise spontaneously as imitations of older routines and patterns as well as intentional innovations to solve special problems of cooperation or collaboration as has been described for science blogs, mailing lists or homepages of scientists (Glöning and Fritz 2011; Bader 2018).

The impact of these expansions of communicative potentials is a completely new and in some respect confusing landscape of discourse in which science communication undergoes a radical change (Schäfer 2017). Paradigmatic examples of this new

communication ecology of science communication are online-video-platforms which transform audiovisual science communication, formerly a monopoly of television, into a publicly networked space of user-generated content which affects all the dimensions mentioned above (Shapiro and Park 2015; Allgaier 2016; Erviti and Stengler 2016). In contrast to televised science communication with journalists as main actors, the dominating actors on video-sharing platforms are private persons, so-called YouTubers, followed by research organizations, business companies and universities (results of the author's research project *Audiovisual Science Communication on Television and Video-Sharing Websites*). In terms of professionalization and commercialization the most successful YouTube science channels are supported in the production of their videos by the YouTube Creator academy or by Multi-Channel Networks intending to optimize the monetization of the content.

Private persons are not only a dominating type of actor, user-generated content by laypersons is also significantly more popular on YouTube than professionally generated content by scientists, research organizations or interest groups (Welbourne and Grant 2016). The special media logic of social media has generated new digital audiovisual formats. Among them are some which are more personal, having a presenter communicating directly with a community thus simulating a kind of face-to-face conversation. Another typical format is *animationvideos* like simulated live drawings, live writings, animated cartoons or 3D-animations whose editing is supported by digital online tools and which also have a personal and distinctive look and feel (Morcillo, Czurda, and Robertson-von Trotha 2016). *Presenter-based videos* and animation videos are typically deployed by laypersons and – based on a survey of 400 German YouTube videos – they are in comparison to more TV-oriented formats like explanatory or expert-based videos the most frequent and the most popular video types. This shift of attractiveness can indicate that science communication in social media tends to undergo a personalization and in terms of its quality a de-professionalization.

Investigations on audience behavior on YouTube reveal that video suggestions presented by the platform and generated by its algorithm are one of the most important sources for the selection of a YouTube video (Cheng et al. 2014). This can be interpreted as a network effect which promotes the disposition to search for information which confirms one's own position. This tendency in the end results in filter bubbles, which have already been detected in political communication. Several studies demonstrate negative effects of this network virality on the quality of science communication especially on controversial issues like climate change, global warming, vaccination or genetics. In the absence of professional gatekeepers opponents of mainstream science like creationists or chemtrail-supporters are able to frame controversial issues with professionally edited videos (Allgaier 2016) or by dominating the comment section with sceptical or uncivil postings (Anderson et al. 2014). An analysis of the comment section of YouTube videos on global warming provides clear evidence “that people are likely to respond to claims about the science of climate change in ways that politicize (or reference the politicization of) the issue” (Shapiro and Park 2015: 130) instead of

discussing the topic or content of the video itself. In contrast a discourse analysis of about 1,700 comments under ten videos with non-controversial content like black holes, déjà vu, borderline personality disorder (BPD) or drinking water reveals that most of the public responses in the comment forum refer to the issue of the video and have an epistemic function like checking questions, objections, agreement, or request for a proof or additional information (results from the author's research project *Audio-visual Science Communication on Television and Video-Sharing Websites*). Affective publics or echo chambers (Papacharissi 2015; Himelboim et al. 2016) arise especially if the discussed issue is relevant for everyday life decisions. Obviously YouTube and social media in general only promote polarized publics and allow the spread of conspiracy theories according to already controversial issues. The question if online media have the potential to turn a neutral issue into a controversial one is still on the agenda of future research.

## 6 Conclusions

The transformation of science communication, internal and external, is critically dependent on the history of media in general. This interconnection must not be misunderstood in the sense of a technological determinism: media innovations only provide potentials which the different actors can apply in science communication as a reservoir of different modes of discourse to provide different arenas with scientific information. One impact of this interconnection is the fact that the “structural transformation of the public sphere” analyzed by Jürgen Habermas (1989), affects science as well as politics. Like in the public sphere of politics the medialization of science has not only extended the potentials of communication, but also generated some problematic repercussions which can endanger the autonomy of science and downgrade the quality of science communication. On the one side, media developments facilitate participation of laypersons and contribute to make science communication more transparent and easily accessible for the public. On the other side, the medialization of science communication goes along with commercialization, de-professionalization, service-orientation or the concentration of power over the means of production and distribution of communication in the hand of organizations, companies and networks. If it comes to evaluate the described tendencies of visualization, popularization and digitalization the metaphor of a double-edged sword seems to be appropriate.

The concept of medialization implicates that all media and all media formats are involved in this process of transformation. Previous analyses of the media–science relation are considerably imbalanced focusing solely on the print media and almost exclusively on newspaper coverage (Hansen 2009; Schäfer 2012). The overview in this article demonstrates that the science of science communication has to be extended



beyond written text and spoken language to audio-visual modes and to other types of media like television, online and social media formats, or all formats of scientific presentations (Niemann, Schrögel, and Hauser 2017). The interactivity of some of these formats in social media or in face-to-face formats of presentations like science slams lead to a new dynamics in science communication which cannot be analyzed appropriately by content analysis but requires approaches from theories of interaction in multimodal settings. In order to get a comprehensive understanding of the phenomenon of medialization future research should also address the process of reception more extensively be it in the form of audience studies or discourse analyses of comment sections in social media.

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## 4 Analyzing science communication through the lens of communication science: Reviewing the empirical evidence

**Abstract:** From the 1960s onwards, communication scientists have analyzed science communication. This article provides an overview of the empirical evidence that this research has generated. First, it describes the structures of the research field based on available meta-analyses. Then, it describes what is known about the communicators of science (such as scientists, journalists, PR experts, NGOs, and others) and about the portrayals of science in news media as well as online and in social media, and examines what is known about the uses and effects of science communication. For each of these subfields, the questions in focus, typical theoretical approaches, main results, and gaps are identified and reflected upon. In addition, the article identifies research gaps and potential avenues for future research.

**Keywords:** science communication – science communicators – content analysis – media use – media effects – communication science – literature review

### 1 Introduction

Science communication encompasses all communication focused on science, scientific work, and its results (cf. Bubela et al. 2009; Bucchi and Trench 2014; Schäfer, Kristiansen, and Bonfadelli 2015). This includes the communication of scientific knowledge to non-scientists, public communication and dialogue about science and its ethical, societal, or political implications, and direct communication between scientists and various publics (Kahan, Scheufele, and Jamieson 2017; Trench and Bucchi 2010).

This broad understanding has developed over several decades and was associated with the evolution of different paradigms of science communication (e. g., Akin and Scheufele 2017; cf. Schmidt-Petri and Bürger in this volume). The debate started with the *deficit model* and concepts of *scientific literacy* but shifted to the paradigm of *public understanding of science* and further from mere communication to a dialogue between science and society, toward the *science in society* and *public engagement with science* models (Bucchi and Trench 2014). The *deficit model* was developed in the 1980s. It assumed that people's attitudes about science were strongly tied to their knowledge about science, i. e., their *scientific literacy*, and, therefore, saw science communication as an instrument to transfer scientific knowledge to non-scientists. Accordingly, research on science communication in this period focused on the effi-

ciency of information transfer from scientists to laypeople. Later, the focus shifted to *public engagement with science* models in which non-scientists were seen as equal partners in science and, as a result, were encouraged to participate in science debates and policy formation (Bubela et al. 2009). Recently, Akin and Scheufele (2017) promoted a third model, focusing on *science communication in context*. They examined a cross-section of public stakeholders and argued that the framework corresponds to an era of public communication in modern democracies in which science communication is shaped by its societal and political environments (see Chapter 5, this volume).

Associated with the three models were different objectives of science communication. Early on, knowledge transfer was seen as paramount in educating the population, increasing their decision-making power concerning science and science-based innovations. Since then, establishing a dialogue between scientists and society and enabling participation of non-scientists has become an important objective of science communication (Akin and Scheufele 2017). In recent years, building the legitimization of science and its protagonists has become another major aim of science communication. Particularly regarding strategic communication from scientific institutions and individual scientists, the need to legitimize themselves has become more important in recent years (e. g. Weingart 2005).

The importance of science communication not only for the scientific community, but also for society and individuals, has been widely acknowledged (Bubela et al. 2009; Fischhoff and Scheufele 2013). Analyses of science communication from the social sciences and from communication science in particular emerged from the late 1960s onwards, at the intersection of science education, social studies in science, mass communication, museology, etc. (Trench and Bucchi 2010). It aimed to understand the underlying mechanisms, structures, and effects of science communication, and in doing so produced a large number of empirical studies on the communicators, content, and impact of science communication.

The present article provides an overview of these empirical studies. It proceeds in five steps: First, it describes the structures of the research field itself, based on available meta-analyses (section 2). Second, it focuses on studies of the communicators of science communication (section 3). Third, it provides content analyses within science communication (section 4). Fourth, it examines studies on the uses and effects of science communication (section 5). Fifth, it identifies research gaps in this study and offers possible perspectives from which to launch future research (section 6).

## 2 The meta-perspective: Empirical analyses of the research field itself

Meta-analyses and literature reviews have provided overviews of the field, indicating several trends (e. g., Bucchi and Trench 2014; Guenther and Joubert 2017; Kahan, Scheufele, and Jamieson 2017; Rauchfleisch and Schäfer 2018; Schäfer 2012b; Trench et al. 2014).

On the one hand, they show that the field has grown significantly in recent decades, visible, for example, through the rising number of publications on the issue. Between 1979 and 2016, the main journals of the field – *Science Communication* (SC), *Journal of Science Communication* (JCOM), and *Public Understanding of Science* (PUS) – have provided a steady increase in output (Guenther and Joubert 2017), and publications on science communication have increased in general as well (Schäfer 2012b) from the 1960s onward.

On the other hand, meta-analyses have repeatedly shown that the field has diversified in several ways. First, it has internationalized. Most research into science communication has come, and still comes, from predominantly Western, English-speaking countries, with the US and UK being analyzed most often and most intensely (see Guenther and Joubert 2017). However, science communication has been slowly shifting toward a more international scope (Schäfer 2012b). Second, the field has become more diverse in its objects. Studies in the field have not only analyzed communication in traditional media (TV and, in particular, print) more, but also in online media and social media (Metag 2017; Schäfer 2017b). Third, the research field has been institutionalized, which is visible, for example, in the emergence of scientific associations and working groups devoted to science communication in university chairs, introductory textbooks, and specific journals (e. g. Gascoigne et al. 2010; Rauchfleisch and Schäfer 2018). Fourth, the scientific disciplines analyzed by these studies have changed over time. Overall, research was and is still biased toward the natural sciences, specifically biosciences and medicine (Schäfer 2012b). However, in recent years, the social sciences and humanities have come into view more (Cassidy 2005; Summ and Volpers 2016). Fifth, meta-analyses have shown that researchers in the field increasingly employ a variety of research strategies and methods: longitudinal studies, studies that compare different media outlets, and temporal, or cross-media comparisons, in addition to applying contextual information to their respective findings (Schäfer 2012b). Table 1 summarizes these diverse research perspectives.

**Tab. 1:** Overview of core perspectives, questions, approaches, and results of empirical analyses of science communication

|                                | <b>Analyses of communicators in science communication</b>                                                                                                                                                                                                                                                                                                                                                               | <b>Analyses of science communication content</b>                                                                                                                                       | <b>Analyses of use and effects of science communication</b>                                                                                                                                                                                                                            |
|--------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Main questions                 | Actors involved in public communication of science, especially science journalists, science organizations, and alternative-science communicators such as NGOs, think tanks, etc., who deal with questions of development of the professional fields, institutionalization of the communication function within science organizations, roles of certain speakers, and objectives and strategies of science communicators | Overall amount of scientific content in media, media characterizations of science and its protagonists, accuracy of reporting measured by scientific standards, and framing of science | What information people use regarding scientific topics, through which media they acquire this information, and how this usage affects people's knowledge about science, science-related attitudes, interests, beliefs, and trust, and on a macro-level how public opinion is affected |
| Typical theoretical approaches | Heterogeneous approaches from journalism and organizational communication/PR studies, as well as basic theories from social sciences, such as role theory, news value theory, and framing                                                                                                                                                                                                                               | Wide range of theoretical approaches, such as public-sphere theory, framing theory, and news-bias theory                                                                               | Theories mostly on a macro- or micro-level concerning a range of disciplines, including psychology, pedagogy, sociology, and communication science                                                                                                                                     |
| Typical methods                | Mainly survey research and content analysis, qualitative approaches focusing on different interview formats, and a large share of single-case studies                                                                                                                                                                                                                                                                   | Quantitative or qualitative content analyses, variants of discourse analysis                                                                                                           | Standardized methods, particularly representative surveys and experiments; more recently, online research                                                                                                                                                                              |

**Tab. 1:** (continued)

|              | <b>Analyses of communicators in science communication</b>                                                                                                                                                                                                                                                                                                                                                            | <b>Analyses of science communication content</b>                                                                                                                                                                                                                                                                                        | <b>Analyses of use and effects of science communication</b>                                                                                                                                                                                                                                                                                                                                                        |
|--------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Main results | Science journalism is an institutionalized field of journalism in many countries, but organizational science communication is growing and becoming more professional and strategic. Scientists engage only sparsely in public science communication. There is a field of “alternative” science communicators, such as NGOs and think tanks, that have hardly been addressed from a science communication perspective | Science is not a major media topic; long-term growth of science-related coverage in legacy media; media do not cover all scientific fields equally; two ideal-type modes of coverage: popularization vs. mediatization of science; media coverage almost always deviates from science; evaluation of science in media changes over time | Many people come in contact with scientific information mainly through the media; scientific communication may affect, at an individual level, science-relevant cognition, emotions, and behaviour; different psychological, social, and cultural characteristics of audience members are linked to the effects; the effects of science communication are strongly mediated by their target group and their object |
| Gaps         | Scant research on organizational science communicators and alternative science communicators; more international comparison approaches would be useful                                                                                                                                                                                                                                                               | Most studies focus on Western countries, print media, STEM subjects; more studies on online presentations of science are necessary                                                                                                                                                                                                      | Integration of national and international longitudinal surveys; effects on the meso- and macro-levels of society; theoretical development with a focus on the impact of science communication                                                                                                                                                                                                                      |

### 3 Analyses of the communicators of scientific communication

Compared with other objects of science communication research, the *communicators* of science have been less in focus. The studies that do analyze the production side – i. e., those actors who produce, select, and disseminate science-related content for the public – focus on different analytical levels, from the micro-level of individuals (such as journalists or scholars), to the meso-level of organizations (such as publishing houses, newsrooms, or universities), and to the societal macro-level (e. g. science journalism in general). In empirical studies, the micro- and meso-levels have received the most attention. Methodologically, analyses are based on responsive methods such

as standardized surveys (Entradas and Bauer 2016; Post and Maier 2016), qualitative interviews (Guenther and Ruhrmann 2013; Poliakoff and Webb 2007), focus groups, and, partly, content analyses (Sumner et al. 2014) or rhetorical analyses (Fährnich, Danyi, and Nothhaft 2015) and observational techniques (Felt and Fochler 2008; for an overview of methods, see Post 2017).

Early on, the respective research focused mainly on science journalists (cf. Dunwoody and Wormer in this volume). News media were seen as central in the “deficit model” approaches of science communication that were prevalent in the 1980s and 1990s, with journalists being the main translators of scientific knowledge for lay audiences (Bauer 2017; Bauer, Allum, and Miller 2007). Accordingly, scholars focused both on institutionalized science journalism, for example, on the organization and workings of media desks and newsrooms (Clark and Illman 2006), as well as on the role concepts, working routines, normative orientations, and backgrounds of individual journalists (e. g. Blöbaum 2008) (see Chapters 20 and 21, this volume).

Along with the paradigm shift toward more dialogical approaches, strategic science communication by universities and public relations (PR) departments (Marcinkowski et al. 2014; Entradas and Bauer 2016), museums and science centers (Schiele 2008), and individual scientists (Horst 2013) came into focus.

Recently, along with the emergence of a contextualized model of science communication (Akin and Scheufele 2017; cf. Schrögel and Humm in this volume), non-scientific science communicators, such as non-governmental organizations (NGOs), think tanks, political organizations, corporate communicators, etc., received more attention (cf. Fährnich 2018; Yearley 2014) (see Chapter 23, this volume).

But while research on science communicators has evolved in recent years, systematic data is still missing on many aspects. Most studies analyze communicators in a small number of countries (e. g. UK: Hansen 1994; Bauer and Gregory 2007, Germany: Blöbaum 2008; Post and Maier 2016, US: Nisbet and Fahy 2015, Argentina: Kreimer, Levin, and Jensen 2011; Australia: Metcalfe and Gascoigne 1995; New Zealand: Ashwell 2014; Portugal: Entradas and Bauer 2016). Only a few country-comparative studies exist for science journalism (Bauer et al. 2013).

### 3.1 Studies on science journalism

Empirical studies show that science journalism and its output are “governed and shaped by both macro-level factors, such as ownership and cultural resonances, and by the more micro-level factors of journalistic practices, professional values, and organizational arrangements” (Hansen 1994: 111). Research shows an institutionalization of science journalism in many countries, leading to specific science desks and specialized science journalists working for print and broadcasting media or as freelancers from the 1970s and 1980s onwards (Dunwoody 2014; Gregory and Miller 1998). However, science journalism has not been as institutionalized as other fields of

journalism. The US National Association of Science Writers, for example, has approximately 2,200 members (NASW 2011) and, thus, accounts for only a fraction of the approximately 122,000 US journalists (Weigold 2001). Blöbaum (2008) showed that only 1 percent of German journalists work in science journalism, with Kristiansen, Schäfer, and Lorencez (2016) reporting a proportion of 4.5 percent in Switzerland. With the rise of the Internet, science journalism and its working conditions have changed (Fahy and Nisbet 2011). As media organizations in many countries downsize due to eroding economic conditions, science writers “are often the first to go” (Bauer 2013: 5) and wind up working as freelancers or in science PR jobs.

Sociodemographically, science journalists have a specific profile: On average, they are older and hold higher academic degrees compared with other journalists. Moreover, a higher percentage of them – at least in Germany – are women (Blöbaum 2008).

Many science journalists’ *role conceptions* seem to be rather traditional ones, but that may be changing; at least in continental Europe, they see themselves as gatekeepers aiming to “depict reality as it is” (Kristiansen, Schäfer, and Lorencez 2016: 136), to inform the audience about scientific facts, and to explain complex issues (Blöbaum 2008). In recent years and in certain situations, however, these role conceptions have diversified. An interview study (Stocking and Holstein 2009) showed that science journalists adopt different roles when approaching doubts about scientific findings. They work as “disseminators” who focus on “simply reporting”; “interpretive/investigative” journalists, who assess science information carefully; “populist mobilizers”, who also refer to lay actors and their positions; or “adversarialists”, who take sides. In addition, Fahy and Nisbet (2011) showed that the roles of science journalists have also diversified with the rise of online and social media. On the Internet, science journalists function as curators, conveners, public intellectuals, and civic educators, among other roles.

Science journalists share some *working routines* with other journalists, but differ in some as well. Badenschier and Wormer (2011) have shown that science journalists’ selection of topics is based on specific news factors, such as scientific relevance, actuality, intention, and astonishment, which differ from other fields of journalism. Furthermore, studies have shown that science journalists are more source-dependent than their colleagues, i. e., “[t]hey rely on a rather small number of influential scientific journals as primary sources, particularly ‘Nature’ and ‘Science,’ [...] and generally exhibit a rather strong source dependence” (Schäfer 2011: 406). Apart from their professional self-conceptions and specific working routines, journalists’ understanding of science and their audience perceptions influence their work as well (ibid.). Focusing on journalists’ knowledge of science-related issues, depending on their sources, Wilson (2000) showed that reporters working primarily on complex environmental issues and using scientists as core sources have the most accurate knowledge on climate change. Lehmkuhl and Peters (2016) analyzed how journalists deal with scientific uncertainty against the backdrop of their professional norms “to provide



the most accurate representation possible because otherwise, journalism risks losing credibility” (Lehmkuhl and Peters 2016: 910). Based on the case study in the field of neuroscience, researchers found that journalists deal with uncertainty by omission, by contrasting conflicting messages, or by explicitly addressing the problem.

### 3.2 Studies on strategic science communication

Recent studies have focused on the “changing rationale of science communication” (Marcinkowski et al. 2014), demonstrating that science journalism becomes less important in building the public agenda on science, whereas strategic communication by science organizations is on the rise (e. g. Bauer and Gregory 2007). But so far, few studies have analyzed this interrelationship (for a summary of those, see Chapter 22, this volume). An input-output study of scientific articles, university press releases, and news stories, for example, found that exaggeration in news stories is associated with exaggeration in press releases (Sumner et al. 2014).

Two types of studies focus on the strategic communication of science organizations: those focusing on structural aspects, i. e., the organization or rationale for the institutionalization of strategic science communication, and those looking more analytically at instruments or strategies of organizational science communication and their effectiveness.

Regarding the structural dimension, surveys indicate that strategic communication has become institutionalized and professionalized in science organizations in recent years (Peters et al. 2009; Marcinkowski et al. 2014). German universities, for example, have become “medialized” in this way because university boards increasingly demand public visibility for their universities (Kohring et al. 2013), which has become a core driver for the institutionalization and professionalization of organizational communication. Accordingly, media visibility is regarded as an objective in its own right (Peters et al. 2009). Entradas and Bauer (2016), looking at the Portuguese case, demonstrate that public visibility is also important for sub-units of universities such as institutes and chairs, who often develop strategic-communication functions themselves.

Many studies have focused on the instruments, channels, and techniques of organizational science communication, such as branding and marketing (Hemsley-Brown and Oplatka 2006), media relations (Serong et al. 2017), online communication (Metag and Schäfer 2017), and science events (Kawamoto, Nakayama, and Saijo 2011; Bultitude 2014). For instance, Serong et al. (2017) show that in the course of universities’ media orientation, press releases are a core instrument, representing a “dominant link between academia and the media” (Sumner et al. 2014: 1). As a tool they have been rising in importance, although at different levels for different types of universities. Moreover, empirical studies show that online communication is growing in importance for organizational science communication and marketing. As Metag

and Schäfer (2017) demonstrate, in German-speaking countries, science organizations hardly use the dialogical functions of social media, but rather stick to established informational communication strategies. In the framework of more engagement-oriented science communication, science events are on the rise, too (Fähnrich 2017).

In addition, the importance of individual scientists in science communication has risen (again). Historically, they were crucial for communicating science to the public until the early 20th century (Bauer 2011). With the rise of organizational communication at scientific institutions, and fostered by the development of online media, scientists have become even more visible as public communicators. In the public sphere, they either appear as representatives of their organizations (Horst 2013; Marcinkowski et al. 2014) or as individuals, often on social media such as blogs, Facebook, or Twitter (Brossard 2013; Wilkins 2008). Different studies show that most scientists think public engagement is important (Dudo and Besley 2016). However, results on attendance and motivation of researchers to take part in outreach activities such as public events differ. Whereas Peters et al. (2009) reported a rather high attendance rate for biomedical researchers, other studies claim that only a minority of scholars would actually engage in public science communication (Neresini and Bucchi 2010). Reasons for the lack in attendance are regarding it as pointless, no fun, or else they believe they lack the necessary skills (Poliakoff and Webb 2007), do not have the time, or fear damage to their careers (Riesch, Potter, and Davies 2013). Accordingly, there are few experts who are highly visible in the public sphere to impact the overall public perception of science (Davies 2008). They regard themselves as experts and mediators, but such visible scholars are particular scientists who do not necessarily represent entire scientific communities (Medvecky 2017). It is mostly senior scientists who are willing to talk to the media, to contribute to their organizations' media relations, and to represent science in the public sphere, but they are rather unwilling to "take part in activities aimed at the less-qualified 'lay public'" (Kreimer, Levin, and Jensen 2011: 45; cf. Bauer and Jensen 2011).

### 3.3 Studies on other communicators

Beyond actors from scientific communities, other actors are involved in science-related communication. There is a heterogeneous field of research on non-governmental organizations (NGOs) and think tanks (Yearley 2014), and their public communication in science-related fields, such as nuclear energy (Ho 2014; Aday and Livingston 2009) and climate change (Post and Maier 2016). Moreover, these actors are researched as "alternative-science communicators" (Maesele 2009: 55) who, due to their strategic use of science, challenge notions of expertise, scientific certainty, and issue closure (Eden 2010). This is also the case for climate-change skeptical think tanks which – at least in the US – impact policy and public discourse (Dunlap and Jacques 2013). Accordingly, such communicators are not only "alternative", but also strategic science

communicators who impede the public perception of science (Eden 2010; Post and Maier 2016).

## 4 Analyses of science-related content

Analyses of science-related media content make up a considerable portion of social-scientific analyses of science communication (see Chapter 20, this volume). A meta-analysis found more than 200 such studies published before 2010, as well as an increase in annually published articles over time (Schäfer 2012b; cf. Guenther and Joubert 2017: 8 f.).

Based on either quantitative or qualitative content analyses, or variants of discourse analysis, studies on science-related media content aim to extract information from textual, audio, and/or visual media data. Common analytical foci are the relative importance of different communicators in media content (e.g. Summ and Volpers 2016; Painter et al. 2016), the overall amount of scientific content found in media (e.g. Elmer, Badenschier, and Wormer 2008), media characterizations of science and its protagonists (Peters 1994; Schäfer 2009), the accuracy of the reporting as measured by scientific standards (e.g. Guenther et al. 2017), and the interpretative “framing” of science (Ruhmann et al. 2015) and scientific findings (Kessler 2016).

Respective studies have scrutinized diverse objects. They exist in countries like the US (e.g. Pellechia 1997), UK (Cassidy 2005), and Germany (e.g. Metag and Marcinkowski 2014), tackling disciplines such as nanotechnology (e.g. Metag and Marcinkowski 2014), biotechnology (e.g. Holliman 2004), evolutionary psychology (Cassidy 2005), climate science (for an overview, see Schäfer 2015), and astronomy (e.g. Kiernan 2000) and appearing in media such as newspapers (Gavin 2009a), TV (Kessler 2016) or websites (Madden et al. 2012).

Notwithstanding the described diversity, several findings can be distilled from the field. First, the respective studies show that science is not, and has never been, a major media topic. Even though only a few studies have analyzed the extent to which science is represented in the media, they point in the same direction: Findings from the US, Australia, Germany, and Greece indicate that science-related content accounts for 1 percent to 3 percent of total media content (Dunwoody 2014).

Second, individual studies and meta-analyses (for an overview, see Bauer 2011) have shown long-term growth in science-related coverage in legacy media. After considerable fluctuations in the extent of science coverage in the late 19th and early 20th centuries (Bauer 2011), data indicate “a clear, almost linear increase of media stories about science and technology” (Schäfer 2017a: 58). Elmer, Badenschier, and Wormer (2008), for example, described an “unprecedented boom” in German legacy media coverage of science between 2003 and 2007. Similarly, Clark and Illman (2006) documented an increase in the *New York Times*’ science-related coverage between 1980

and 2000; Bucchi and Mazzolini (2003) found a rise in science journalism in Italy's leading newspaper over a 50-year timespan; Bauer et al. (2006) found a rising science journalism trend in UK and Bulgarian media; and Albaek, Christiansen, and Tøgeby (2003) documented how the representation of "scientific experts" has increased in Danish newspapers over the past 40 years. But this trend seems to have halted in the early 2000s. Until 2006, the share of science content in mass media seemingly stagnated when compared with other news content (Bauer 2011).

A third finding is that the media are not covering all scientific fields equally. When studies analyze the designated "science" sections of mass media, they find a strong focus on the natural sciences. Elmer, Badenschier, and Wormer (2008), for example, found hardly any social sciences or humanities in the science sections, which are dominated by medical research, environmental sciences, and biology (cf. Nelkin 1995). Beyond the "science" sections, however, a more pluralistic set of disciplines appears. Albaek, Christiansen, and Tøgeby (2003), for example, show that most scientific experts appearing in general media are social scientists, and that their representation increased considerably between 1961 and 2001. STEM scientists appear less often, and their share among experts has decreased over time. The proportion of scholars from the humanities has remained constant over time at roughly 10 percent. Similarly, Summ and Volpers (2016) found that social sciences and STEM subjects account for the largest shares of the media's science coverage, with humanities making up 17 percent of 1,730 analyzed newspaper articles.

Apart from the degree of media coverage on science-related disciplines, research has focused extensively on *how* science was portrayed. Generally, and as a fourth result, scholars have described two ideal-type modes of media coverage of science. On one hand, they have shown that it often corresponds to a "popularization" (cf. Peters 1994: 169; Meier and Feldmeier 2005: 203) or "science du chef" (Bucchi 1998) mode. This type of coverage is often found in science sections (Evans and Hornig Priest 1995) and mirrors the communication within the scientific community in several respects, except that it is carried over to a lay register while trying to stick to the scientific content. Coverage is typically triggered by scientific events or publications, relies heavily on scientific sources, and views science inherently positively. On the other hand, studies have described a "contextualized" (Brossard and Scheufele 2013) or "mediatization" (Schäfer 2009) mode of coverage in which general criteria for journalistic reporting and the media apply to science coverage. These articles often appear outside the science sections and are triggered by socio-political or socio-cultural events. This coverage relies less on scientific sources, is considerably more conflictual, and often confronts scientists with politicians, NGO representatives, citizens, etc. (Peters 1994; Schäfer 2009). Such reporting has been used to cover controversial issues such as animal (Weingart, Salzmann, and Wörmann 2006) or human cloning, (Holliman 2004) and stem-cell research (Nisbet, Brossard, and Kroepsch 2003).

Overall, the foci of content analyses of science-related media content have shifted over time. Early on, studies often tried to assess the accuracy of media coverage, either

by comparing it with scientific publications (e.g. Sumner et al. 2014), or by asking scientists to evaluate its accuracy (Haller 1996). These efforts have shown, for the fifth result, that media coverage almost always deviates to some extent from scientific descriptions. Ankney, Heilman, and Kolff (1996), for example, found more than 200 errors in 42 newspaper articles on medical research. Furthermore, media reporting has been described as exaggerated and sensationalist (e.g. Knudsen 2005), simplified, and devoid of complex issues (Brechman, Lee, and Cappella 2009), or as stereotyping scientists by portraying them as magicians or heroes (LaFollette 1990). In addition, media have been shown to be struggling with the uncertainties that often accompany scientific information. These qualifiers are either not represented – “News reports of scientific research are rarely hedged [and] do not contain caveats, limitations, or other indicators of scientific uncertainty” (Jensen 2008: 347) – or are transformed into news themselves by interpreting them as controversies within the scientific community (Rödder and Schäfer 2010).

With this shift from a “public understanding” model of science communication toward more constructivist models that understand media not merely as translators of science, but as active producers of content, the analytical focus of content analyses also has changed. Many scholars have analyzed how science is “framed” in media reporting, i.e., the interpretive devices used to embed and make sense of scientific issues. Framing research has shown that different facets of science can be selected and made salient in media coverage. Genetically modified organisms, for example, can be framed as antidotes to world hunger or as manipulations of God’s creation (e.g. Durant, Bauer, and Gaskell 1998), and climate change can be interpreted as a threat to mankind or as a scientific theory that is not yet fully proven (for an overview, see Schäfer and O’Neill 2017). Even the same scientific finding can be framed in varying ways throughout the media (Kessler 2016; Ruhrmann et al. 2015). Studies have shown that the framing of many scientific issues is context-sensitive and differs among various media (e.g. Boykoff 2008; Carvalho 2007) and for different countries (e.g. Boykoff and Boykoff 2007). Still, cross-national framing analysis across longer time-spans has tried to develop generic frame sets that work across topics, distinguishing frames such as “progress”, “Pandora’s Box”, or “ethical implications” (e.g. Durant, Bauer, and Gaskell 1998).

Partly connected to the framing perspective, studies also have focused on the evaluation of science in media coverage and have shown that it has changed over time. They have described a more affirmative bias in coverage early on, in which science was covered mostly affirmatively (Nelkin 1995), with a more critical science journalism developing in the 1970s and growing stronger until the 1990s and early 2000s (Bauer et al. 2006; Elmer, Badenschier, and Wormer 2008). This was accompanied by media coverage on issues such as stem-cell research, green biotechnology, climate science, and gene editing becoming more pluralistic and partly contested, with large swaths of coverage appearing outside of science sections, featuring mostly non-scientists as sources discussing ethical, legal, and social frames

in ambivalent or even critical tones (Schäfer 2009). More recent analysis, however, hints at a less-critical science journalism emerging again due to a combination of science journalists' working conditions worsening in many countries (for overviews, see Dunwoody 2014; Schäfer 2017a) and the corresponding growth in science communication from different societal stakeholders and science PR representatives (or agencies, experts, or groups). Several scholars have diagnosed a development "from a logic of journalism [...] towards a source-driven reportage of science" (Bauer and Gregory 2007: 33) in recent years. When communicators outside science are proliferating more information about science, "time-pressed reporters [are again] increasingly reliant on information subsidies from scientific institutions, universities, and public relations agencies to find material" (Fahy and Nisbet 2011: 784), a development that may move science coverage (again) toward a more-affirmative, less-critical style (Bauer et al. 2013: 27).

Analyses of science-related legacy media content – which is also partly presented online – increasingly have been supplemented by studies of online and social media communication recently (cf. Brossard and Scheufele 2013). Even though the extent of science-related content online is difficult to assess, research has shown that a large amount of such content is available online (e. g. Schäfer 2012a: 532).

Many studies have focused on the accuracy of online representations of science, often driven by the assumption that the lack of quality control and journalistic gate-keeping online might result in substandard portrayals of scientific issues. They have shown that online, highly detailed and exact presentations of science can be found, as well as "extreme and unorthodox viewpoints" (Ladle, Jepson, and Whittaker 2005: 235; cf. Bubela et al. 2009; Cacciatore et al. 2012). Revolving around issues such as climate science, vaccinations, or evolution theory, and particularly in Anglophone countries, accurate portrayals of science are accompanied by massive criticism and rhetoric anti-science (e. g. Barr 2011; Gavin 2009b). Connected to this, studies have also shown that deliberative quality in online discourse on these issues often seems to be lacking. While "a much wider set of individuals and organizations" (Carvalho 2007: 1) can participate in comments sections, Facebook or Twitter timelines, online forums, etc., this does not improve the quality of the debate, as measured by normative standards of public-sphere theory. Communication is often "limited and unstructured" (Zavestoski, Shulman, and Schlosberg 2006: 386), "polarized and sometimes ideologically driven" (Holliman 2004: 834), and can "descend to playground level" (Gavin 2009b: 469).

## 5 Analyses of the uses and effects of science communication

A large body of studies on science communication focuses on the audience. It analyzes what information people use regarding scientific topics, which media they use to acquire this information, how they use it, and how this usage affects both individuals and public opinion.

Historically, studies adhering to the *deficit model* of science communication have focused on effects on people's knowledge about science or on effects on people's attitudes toward science. Studies subscribing to the *public engagement with science* paradigm, however, did not employ a deficit heuristic and analyzed a broader range of communication effects on science-related attitudes, interests, beliefs, and trust (Metag 2017; Nisbet and Scheufele 2009).

In recent years, several shifts have been identified in the respective research. Nisbet and Markowitz (2016) identified a change from theoretical and descriptive studies on public opinion formation to a more applied and practical focus, accompanied by an increased focus on developing and testing specific communication methods and approaches, and on strategically defined goals, such as gaining public attention and generating concern about a problem, responding to or correcting false information, or mobilizing members of the public to become involved. In this process, studies have adopted disciplinary theories from communication science, psychology, pedagogy, or sociology to analyze the use and impact of science communication (Metag 2017; Trench and Bucchi 2010). A second shift is visible in the goals of science communication and respective research. Many scholars have moved from focusing on the awareness and understanding of audiences to their engagement with and participation in science (Bucchi and Trench 2014). Finally, a third change is visible in the media that were analyzed, with studies moving away from legacy news media toward science communication online (Brossard 2013) (see Chapters 28 and 31, this volume).

### 5.1 How individuals use science communication

Many studies have analyzed where individuals inform themselves about science, what sources they choose, how they perceive these sources and their content, and how this information is processed (Akin and Landrum 2017; Nisbet et al. 2002). Such questions are regularly asked in surveys in the US (e.g. National Science Board 2016), Europe (e.g. European Commission 2013), and elsewhere, and they are the focus of numerous other studies.

They show that many people come in contact with science mainly through traditional mass media (BBVA Foundation 2011). TV and traditional newspapers, in this regard, appear to remain the most common sources in many countries (European

Commission 2013). But the role of online sources is increasing. For nearly half of Americans, the Internet was their primary source of science information in 2014, compared with only about a tenth of Americans in 2001 (National Science Board 2016). People also come in contact with scientific information through diverse informal science and cultural institutions (National Science Board 2016; Falk and Needham 2013).

Representative surveys show that citizens' interest in science and scientific issues is medium to high in the US and Europe (see Besley 2013 for an overview). Over half of respondents said they are interested in scientific developments (BBVA Foundation 2011; European Commission 2013; National Science Board 2016; Schäfer et al. 2018). However, a third of Americans (like in many other OECD countries) said that it is not important to know about science in their daily lives (National Science Board 2016). The wider European population particularly has little to do with science and feels it is not that well-informed about scientific issues (BBVA Foundation 2011; European Commission 2013). Swiss people, for example, deal with scientific topics mainly out of pure curiosity, to gain knowledge, to better understand scientific topics, to have a say, and to get information from others (Schäfer et al. 2018).

Regarding sociodemographics, it becomes apparent that people with higher education levels in particular are more interested in science (European Commission 2013) and more involved in science-related activities, such as visits to science and technology museums (BBVA Foundation 2011). Focusing on Internet searches for scientific information, gender, age, and education are clear determinants of activity frequency (BBVA Foundation 2011). Public interest differed among specific issues. Most people are very interested in new medical discoveries, health issues, and environmental research, and are only moderately interested in space exploration or political issues (BBVA Foundation 2011; National Science Board 2016). Attentiveness to specific science issues varied significantly between and within countries (BBVA Foundation 2011).

At the same time, studies from different countries have shown that populations can be segmented into people with different attitudes toward science who also differ in their information and media-use patterns. Such segmentations were detected repeatedly for issues such as climate change (for an overview, see Hine et al. 2014) and health (Maibach et al. 2006), and sometimes for science in general (Kawamoto, Nakayama, and Saijo 2011; OST and Wellcome Trust 2000; Research Councils UK 2008; Schäfer et al. 2018). Studies found that the segment with different science-related attitudes can be reconstructed, and that, for example, the “technophiles” identified in the British study use quality media extensively to get information about science, while the “not for me” segment mainly consumes entertainment shows on TV and rarely encounters scientific content (OST and Wellcome Trust 2000). Science communication is more likely to reach those who are already highly interested in science (Bubela et al. 2009; Fährnrich 2017).



## 5.2 Effects of public science communication on individuals

Numerous studies have tried to assess the effects of public science communication on non-scientists. A wide variety of phenomena can be understood as effects, such as cultivation of ideas about science through media, setting of topic importance for the public (agenda setting), mediating of interpretation patterns (framing effects), increase in knowledge (gaps), or persuasion (Metag 2017). Therefore, studies have focused on different potential dimensions in which such effects may manifest themselves, such as people's awareness of certain scientific issues; their knowledge about science, i.e., their *scientific literacy*; and their attitudes toward science, including trust toward science and their behaviour regarding scientific knowledge and issues (see Chapter 2, this volume). The effects of science communication differ strongly – apart from individual, sociocultural, and other factors – depending on these dimensions.

In accordance with the background of deficit model and scientific literacy, studies have hypothesized that providing scientific information to a broader audience will reverse negative attitudes and perhaps even help foster favored social or political action. Several surveys indicate that knowledge and attitudes about science research partially depend on the availability of science-related news (European Commission 2013; National Science Board 2016); or precisely, those who are interested in it and feel informed are much more likely to have a positive view of science (European Commission 2013). Factors such as formal education, involvement in informal education (e.g. visiting museums or watching science TV programs), and media usage play a central role in how people think about science (National Science Board 2016). But many studies demonstrate that gaining knowledge does not necessarily change attitudes about scientific issues because they are complex and tend to be issue-specific, depending on personal involvement, and are driven by personal predispositions (Akin and Scheufele 2017; Varner 2014). Higher levels of public knowledge will not necessarily increase public support for and interest in science; the public's attitudes about science are entangled in individuals' social and political environments, which are shaped by mass media portrayals and confounded by interpersonal and cultural influences (e.g. Akin and Scheufele 2017; Hallman 2017; Kahan et al. 2012; Pennycook and Rand 2017).

In addition, studies have shown that for the audience, it is sometimes difficult to deal with scientific information to make personal, professional, and civic decisions because of a limited understanding of how scientific knowledge and epistemological processes work and because of their influence on individual cognitive, affective, and behavioural psychological processes (Bromme and Goldman 2014; Kahan et al. 2012; Pennycook and Rand 2017). The audience's trust in science is important for each citizen, even for completely modern societies, and is mediated by and also mediates science communication (Akin and Scheufele 2017; Bromme and Goldman 2014; Fischhoff and Scheufele 2013).

Most studies on the impact and reception of scientific communication investigate the effects at an individual level and show the impact on science-relevant cognitions

such as epistemological beliefs (Guenther and Kessler 2017) or issue-specific beliefs (Kessler 2016), emotions such as risk perception (Slovic 2010), behaviours such as willingness to vaccinate (Donahue et al. 2018), or information seeking (Kessler and Guenther 2017; Kessler and Zillich 2018). Many findings on the impact of science communication are generated in special research fields, such as health communication or risk communication, and standardized experiments usually are carried out as part of analyses (Metag 2017).

Media coverage often sets the public agenda and, as mentioned above, the science communication process is also a process of framing, which frames the debate in relation to scientific issues. Audiences pay more attention to certain aspects of an issue or of a science debate depending on how an issue is framed in scientific communication (Bubela et al. 2009; Kessler 2016). However, research indicates that different media have different effects on attitudes toward science (e. g. Dudo et al. 2010). Empirically linked to the effects of science communication processes are different psychological, social, and cultural characteristics of audience members, such as personal values, issue proximity, and familiarity, which shape mental models, schemes, and beliefs about particular issues, furthering their interpretations of scientific communication (Akin and Scheufele 2017; Fischhoff and Scheufele 2013; Kessler 2016).

Research has also shown that the effects of science communication are strongly mediated by their target group and their object. Populations can be divided into many public segments, each with its own understanding of science via previous knowledge, beliefs, attitudes, trusts, etc. (Bubela et al. 2009; Bucchi and Trench 2014; Nisbet and Scheufele 2009; Scheufele, Jamieson, and Kahan 2017). Because these segments inform themselves differently about science and science communication, the effects of science communication may differ among them (Metag and Schäfer 2018; Schäfer et al. 2018). In addition, the effects of science communication also vary depending on the scientific issue discussed (Schäfer 2014). The media's reporting on scientific issues not only influences public perceptions, but also shapes policy and even science debate (Bubela et al. 2009).

## 6 Biases, desiderata, and research perspectives

Analyses of science communication from the social and communication sciences have matured as a field of academic inquiry (Rauchfleisch and Schäfer 2018) and produced robust findings on science communicators, the diversifying media ecosystem, and its audiences (Bubela et al. 2009). At the same time, some aspects of science communication have been systematically under-researched, and several gaps and biases require scholarly attention in the future.

Several of these gaps are specific to the described subfields of the science of science communication:

- Among analyses of science communicators, science journalists and, more recently, PR experts and individual scientists have received much attention. In turn, organizational communication from universities or research centers, which are becoming more important, have not received much scholarly scrutiny (Entradas and Bauer 2016; Fährnich et al. 2019). The same can be said for “new” actors in science communication, such as think tanks, NGOs, and corporations that have just emerged in the realm of science communication research, along with the appearance of the “context” model of science communication (Akin and Scheufele 2017). Moreover, interactions among different science communicators have rarely been examined. In addition, international and comparative studies could enrich the understanding of science communicators in an age when public-agenda building and the perception of science extend beyond national boundaries.
- While media representations of science have received much scholarly attention, this subfield also shows gaps and biases. More studies should focus on non-Western countries, non-print media, and disciplines beyond STEM subjects. Some of these research shifts are occurring (such as a rise in studies on Asian countries or online media; see Schäfer 2012b), but others seem to be persistent (such as the focus on STEM disciplines). This seems particularly necessary as existing content analyses have shown that media coverage differs strongly from one context to another. Content analyses of online communication about science exhibit additional gaps. The specifics of online presentations of science merit more attention, such as novel contextual cues like social recommendations, commentary, “likes”, or “shares” that accompany almost all online content and that have been shown to influence interpretation as well (e. g. Anderson et al. 2014; for an overview see Hanauska and Leßmöllmann 2018).
- Research focusing on the uses and effects of science communication, including its recent productivity, also exhibits desiderata. Future research should focus on effects on the meso- and macro-levels of society (Akin and Scheufele 2017), as well as take into account feedback effects on science, its protagonists, and institutions (e. g. using the mediatization of science frameworks; see Schäfer 2014). In addition, making use of the increasing availability of complex data should provide researchers with new opportunities. An integration of national and international longitudinal surveys and complementary data streams of media content could allow scholars to develop dynamic models of science communication (Bauer and Falade 2014). A great challenge remains in reaching audiences who lack an interest in science and ignore scientific content on the web; this is a risk concerning the public’s degree of engagement with science policy debates (Bubela et al. 2009). Apart from any effects from science communication on audiences outside of scientific communities, effects are also possible on scientific communities and science themselves – both at the micro-level of individual scientists (Ivanova et al. 2013), the meso-level of scientific institutions such as universities (Kohring et al.

2013; Marcinkowski et al. 2014), and at the macro-level of science as such (Peters et al. 2009).

- In addition to these gaps within the three subfields, a stronger connection between these three subfields is needed. Coupling analyses of communicators' positions, aims, and strategies with analyses of their public or online representation would be illuminating, as would the combination of analyses of media and online content with studies of their use and effects.

In addition, the research field would certainly profit from more theoretical work. Further theoretical development, with a focus on the impact of science communication, especially on a macro-level, is needed to give researchers, students, and professional practitioners better tools to describe, classify, and explain what they observe to understand relations and processes, and to assess effects and outcomes (Metag 2017; Trench and Bucchi 2010). Scholars should use empirical methods and studies to consequently develop and validate models of science communication, further differentiate and characterize the public's desire for science, and evaluate methods for effective science communication (see also van der Sanden, Maarten, and Trench 2010). The social transformation and changes in media technology have created new public spaces for science communication, and they demand more complex and dynamic theoretical models to properly grasp the mutual exchanges between science and public audiences (Bauer and Falade 2014; Bucchi and Trench 2014). Theoretical development in the field could be assisted by further imports of theories and approaches from various disciplines with which it is associated.

Related to this is the need for continued *reflection on the nexus of the science of science communication and science communication itself*, i. e., on the practical importance of research on science communication. It should be discussed how science can best be communicated within ever-shifting social, scientific, and political landscapes; how the public can best be involved; how the increasingly diverse media landscape, especially the Internet, incorporates selective exposure of scientific communication; and what the consequences of those processes are. What makes scientific communication effective, how can the interest and understanding of audiences be increased, and how should science communication adjust to audience characteristics – empirical questions for future research on science communication (Akin and Landrum 2017; Scheufele, Jamieson, and Kahan 2017; see also Chapter 31, this volume). A principal future challenge is the production of comprehensive research that includes a diversity of media platforms and audiences, and facilitates conversations with the public that recognize, respect, and incorporate differences in knowledge, values, perspectives, and goals (Nisbet and Scheufele 2009). Such research would be crucially important for enabling policy debates and decisions based on the best available scientific evidence.

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Hannah Schmid-Petri and Moritz Bürger

## 5 Modeling science communication: from linear to more complex models

**Abstract:** Driven by digitalization (and particularly the advent of the Internet), science communication nowadays includes more and different types of actors who produce and consume a wide array of heterogeneous content. As one consequence, scientists or scientific institutions and newspapers – as the traditional disseminators of scientific information – have lost their monopoly online and serve as only one information provider among others. These developments have led to more egalitarian, but also more controversial, discourses on science. However, these new forms of science communication are only partly mirrored by traditional models of science communication (e. g. by the deficit model) since these models fail to trace the complex communication processes resulting from the mentioned changes. Thus in our chapter we first briefly introduce the evolution of the most important science communication models and discuss their limitations in light of current developments. Second, based on their shortcomings, we develop a network-oriented perspective on science communication, which seeks to eradicate some flaws of the older models.

**Keywords:** social network analysis – science communication – deficit model – public understanding of science – digitalization

### 1 Introduction

In contemporary societies, the significance of information and knowledge and the mode of knowledge production and dissemination have both changed (e. g. Gibbons et al. 1994; Stehr 1994). One main driver of this transformation is digitalization, particularly the advent and rapid development of information and communication technologies (ICTs), especially of the Internet. These societal changes also affect the access to and production of scientific knowledge: First, the Internet offers a huge amount of scientific information, which is easily available to everybody and has thus become the major source of scientific information (National Science Board 2018). Second, due to their low access barriers, ICTs facilitate new forms of (collaborative) knowledge production (e. g. Wikipedia, Science Blogs, or citizen science projects). This results in a greater variety of actors being involved in scientific discourses, as well as a greater heterogeneity of content and arguments. Third, scientists or scientific institutions and newspapers – as the traditional disseminators of scientific information – have lost their monopoly online and serve as only one information provider among others. These developments have led to more egalitarian, but also more controversial, discourses on science.

However, these new forms of science communication are only partly mirrored by traditional models of science communication (e. g. by the deficit model) since these models fail to trace the complex communication processes resulting from the changes described above. In line with this development, Castells (2000: 500) has argued that “dominant functions and processes in the Information Age are increasingly organized around networks”.

Thus, the aim of our chapter is to propose a network perspective as a new approach to analyzing different science communication processes. Conceptualizing science communication from a network perspective creates the possibility for modeling the described heterogeneous communication processes both theoretically and empirically. To do so, we proceed in two steps: First, we briefly introduce the evolution of the most important science communication models and discuss their limitations in light of current developments. Second, based on their shortcomings, we develop a network-oriented perspective on science communication, which seeks to eradicate some flaws of the older models.

## 2 Early models of science communication: increasing scientific literacy

Traditionally (in the time before 1985), a lack of acceptance of scientific endeavors (and their public funding) by the broader society was seen to be rooted in society’s lack of knowledge about scientific research findings, practices, institutions, and processes – that is, its general lack of *scientific literacy* (Bauer, Allum, and Miller 2007; and see Chapter 2, this volume). This concept was mainly shaped by Miller (1983), who brought forward a three-dimensional definition. According to it, “scientific literacy” encompasses as a first dimension “an understanding of the norms of science”, as a second dimension “knowledge of major scientific constructs”, and as a third dimension “awareness of the impact of science and technology on society and the policy choices that must inevitably emerge” (Miller 1983: 31). With the idea of a “societal illiteracy” of science, the scientific community ascribed a knowledge deficit to the public. Hence, the communication model to overcome this particular problem has been referred to as the “deficit model”. Other expressions used for the model are “public understanding of science”, “public communication of science and technology” or “popularization”, with the latter term mainly referring to the dissemination of routine science in contrast to controversial science (Bucchi and Trench 2014; Goulden 2011). The underlying assumption of all these terms is that effective science communication equals an increase in knowledge about science among laypersons as well as an increase in their scientific literacy, which inevitably leads to greater public support for science and legitimizes its aloof societal position. Thus, within this model, science communication is mainly seen as a didactic enterprise (Meyer 2016).

Empirical research that is theoretically guided by a deficit or dissemination approach mainly focuses on the circumstances of media production, on the depiction of scientific topics in mainstream media, and on media use and effects. We understand media not as merely technological distribution platforms but as societal actors/institutions that present content following their own (selection) rules (e.g. Bennett 2016). Despite its theoretical prominence, the model lacks empirical support. Findings suggest that public knowledge about a scientific issue might have no or even a polarizing effect on public opinion (Akin and Scheufele 2017; Hart and Nisbet 2012).

Although the peak of the deficit model's popularity occurred between the 1960s and the mid-1980s (Bauer, Allum, and Miller 2007), empirical research, as well as science communication itself, is still often guided by a deficit or dissemination approach (e.g. Davies 2008; Lee and VanDyke 2015; Su et al. 2017). This long-lasting popularity can be mainly explained by four factors: first, due to their own education, scientists tend to perceive their potential audiences as rational thinkers, and the formal education of scientists does not usually include public communication skills (Simis et al. 2016). Therefore, scientists often assume their audience to have the same interests as themselves, and then intuitively apply the deficit model when interacting with a public which they imagine as quick and eager to learn. Second, the definition of "science" itself necessarily results in a knowledge deficit. Since science is the process of producing new knowledge, due to its novelty, the gained information can never already be known by society. This conceptualization of science also claims the epistemic authority of scientific knowledge; thus, compared with other sources of knowledge, it is seen as more credible, further fostering the deficit model (Cortassa 2016; Suldovsky 2016). Third, Meyer (2016) assumes an expansion of the scientific cause that now heavily influences almost every societal issue. Because, intrinsically, public affairs related to science are often perceived to be merely technological problems, they are not resolved through democratic means of conflict resolution, such as negotiations, but rather technocratically (Meyer 2016). From a normative point of view this superior role of science might be seen as problematic because it bears the danger to circumvent democratic processes. Fourth, above all, the appeal of the model stems from its simplicity, and hence, its easy implementation: the problem is attributed to the public, not to science itself, the solution seems simple and can be implemented within the existing educational system (Simis et al. 2016).

The basic assumption behind the deficit model is a simple stimulus–response model (which has been argued to be too simple to explain communicative processes both in communication science and linguistics, cf. Brosius and Esser 1998, Bucher and Fritz 1989, Pürer 2014) in which scientists exclusively produce and then disclose knowledge, which is then explained by journalists to their audiences without questioning or critique (Meyer 2016). The model does not implement any feedback loops and, therefore, limits the communication process to a hierarchical top-down dissemination. Consequently, the public discourse is separated from and unable to influence scientific discourses.



In sum, the deficit model's main flaw is its appreciation of a linear top-down communication process that disregards important aspects of media production and reception (e. g. Bucchi and Trench 2014). In addition, the model neglects the complex interactions of almost all societal actors, since scholars are seen to act solely as experts, isolated from other fields of society (e. g. Bucchi 2008). Furthermore, lay publics are perceived to be ignorant or even hostile towards science and persuadable by clever marketing campaigns. Lastly, the theoretical and empirical focus of the deficit model is on traditional media (see also Chapters 4, 20–22 and 31, this volume).

These focuses do not reflect the situation we witness today: driven by digitalization, science communication nowadays includes more and different types of actors who produce and consume a wide array of heterogeneous content (e. g. Dickel and Franzen 2016; and see also Chapters 28 and 30, this volume). This heterogenization of knowledge production and communication is also reflected in a change in patterns of utilization. Hand in hand with an increase in information supply goes an individualization in media use. Media change has inarguably disrupted academia's monopoly on scientific expertise. Virtually anybody can now claim to be an expert in a certain scientific field and make use of Web 2.0's possibilities without being hindered by mass media gatekeeping efforts (e. g. Weingart 2017). Furthermore, in addition to mass media gatekeeping, new entities, such as algorithms, fulfill a gatekeeping function by selecting attention for and access to certain information (Just and Latzer 2016). These pluralization processes and the inclusion of non-certified scientific expertise (Dickel and Franzen 2016) tend to increase controversies in societal debates on scientific issues, but they also enable society to hold these debates in ways that are more egalitarian than the early communication model suggests.

### **3 More complex models of science communication: interacting with society**

Based on the above critique and on the missing empirical proofs for the deficit model, basic assumptions have changed. Science and scientists are no longer seen as standing apart from society; instead, the importance of interactions and dialogue among different stakeholders has been emphasized (Scheufele 2014; Akin and Scheufele 2017). In line with this, attempts have increased to include laypersons at all stages of scientific research and knowledge generation (i. e., citizen science; Meyer 2016). This dialogical turn in science communication has been described as a shift “from public awareness of science to citizen engagement, from communication to dialogue, from science and society to science in society” (Bucchi and Trench 2014: 4). Hence, the newer models assume a closer relationship between science and society, both of which then dialogue on scientific topics. “Engagement” and “dialogue” are now the key terms, and these models are usually called “dialogue models” or “public

engagement with science". Following this idea, various authors conceptualize scientific communication as a more complex communication process with feedback loops and mutual exchange between different actors (e. g. Lewenstein 1995; Goulden 2011).

One specific interaction between science and society emphasizes the thesis of "medialization". It states that, due to the increased impact of the media on the public's political attitudes and perception of the world, as well as the increased competition over scarce resources within science and between science and other societal subsystems, science increasingly orients itself towards the media (Bucher and Niemann 2015; Weingart 1998, 2015 [2001]). Medialization can affect *inter alia* norms, roles, rules, and organizational structures of scientific actors and institutions. With regard to science, examples could be a norm to inform the public of research results, a rule to control the access of journalists to scientists working at an institution, the inclusion of media competence in the job requirements for managerial staff (role), the funding of research programs on the condition of implementing effective communication tools, or the expansion of a university's public relations department (organizational structures) (Scheu 2015). Hence, medialization effects on science can be witnessed on three levels: First, adaption of the individual scholar's behaviour; second, adaption of the scientific organization; and third, adaption of the scientific knowledge production itself (Franzen, Rödder, and Weingart 2012). Considering these repercussions, a hegemonial approach towards medialization is highly critical of this phenomenon. It argues that transformations in the media system force other societal systems to adapt to the media's requirements and, therefore, to lose autonomy, power, and function. However, medialization can also be understood in terms of Giddens's theory of structuration as a process in which agents' actions are, on the one hand, shaped by structural preconditions, but can, on the other hand, also influence these conditions (Bucher and Niemann 2015). From the latter point of view, scientists and scientific institutions do not appear to be merely the helpless puppets of an overwhelming attention economy. Instead, they can potentially take advantage of the mass media's logic by building an agenda, exerting influence on other societal actors, and increasing their own capabilities and reputation (Scheu 2015).

Research on science communication that follows a more complex model of science communication including various interaction processes among different stakeholders focuses on the following aspects and, to varying degrees, takes into account recent changes in science communication: First, one branch of studies focuses on the definitions of "experts" or "expertise" and distinguishes among different types. Thus, these studies reflect the heterogeneous actor constellations of contemporary science communication (e. g. Collins and Evans 2002, for an overview see Akin and Scheufele 2017). Second, a growing body of research is studying all forms of online science communication (e. g. Arlt, Rauchfleisch, and Schäfer 2018; Büchi 2017; Schmid-Petri 2017). Third, meta-analyses show that more and more studies analyze public engagement in science (e. g. Smallman 2016; Suerdem et al. 2013).

In sum, science communication is much more complex than the early linear models suggest. According to Hilgartner's (1990) conception of science communication, the deficit model contains only a one-directional flow of knowledge from its source of production in the scientific field ("upstream" in Hilgartner's terminology) towards the lay publics located "downstream" in the flow of knowledge and information. Here, the communication of science gradually changes in style and context as it flows downstream: from a highly specialist jargon, spoken within the respective scientific community during the process of knowledge production, via interdisciplinary exchanges on the subject matter, towards a simplification for educational and popularization purposes (Bucchi 2008). A dialogic model could then distinguish between an upstream involvement, meaning an early-stage consultation with the public on new scientific developments, and a downstream involvement, that is, a late-stage communication on already negotiated outcomes (Bucchi and Trench 2014). Thus, the presented dialogue and participation models show a variety of bi- or multidirectional communication and address many of the deficit model's flaws.

The emphasis on scientific engagement with the public sphere also implies a normative stance on science communication, now understood as a process between equal and active actors (Bucchi and Trench 2014; Schäfer 2009). In line with this, scientific knowledge is not perceived to be superior to other forms of knowledge; it differs from lay knowledge only in terms of its composition. Non-experts might compile their own personal knowledge using factual information, value judgments, experiences, and other forms of knowledge and, thus, form a unique and sophisticated corpus (Bucchi 2008; Schäfer, Kristiansen, and Bonfadelli 2015; Suldovsky 2016).

However, the public engagement or dialogue models are also criticized – for mainly four reasons: First, the value of engaging the public with scientific endeavors might often be formally taken into account – for example, when stakeholders are consulted in public hearings – but that does not guarantee an actual influence on content, such as science-related policies, regulations, or research programs. Moreover, even if the engagement between science and its stakeholders is designed in a participative way, it seems highly doubtful whether the norm of participation can be fulfilled in reality (Brossard and Lewenstein 2010). Thus, often, although science in principle recognizes the importance of acknowledging other societal groups, the autonomy of the scientific system is nevertheless defended against public influences, and elitist prejudices towards broader society prevail. Thus, often a superior and advising role is still attributed to academia in comparison with other actors (e. g. Brossard and Lewenstein 2010; Bucchi and Trench 2014). Second, dialogue models conceive science communication as a multidirectional form of communication and emphasize the direct interaction between scientists and laypersons. But scientists and the lay public are not two homogenous and separated groups. Every scientist is a layperson with respect to almost all scientific fields and both groups do not speak with one voice, but are characterized by a wide variety of opinions, interests, and expressions. Added to that, other possibly relevant stakeholders like political or economic

institutions are not taken into consideration by the described models. Furthermore, only a very special, interested, and predisposed audience is directly engaged with science communication (Scheufele 2014). For the majority, information contained in all kinds of traditional mass and online media is still their most important source of knowledge about science. Thus, science (communication) does not directly shape the realities of a majority of the population, as the dialogue model suggests, but it influences the way how science is represented in the media, which then can influence the knowledge and attitudes towards science of a broader audience (Scheufele 2014). In sum, in most cases, direct or dialogic communication between scholars and publics might be the exception. Third, deficit as well as dialogue models focus on routine science and are thus incapable of accommodating extraordinary scientific events or to adapt to sudden changes in communication routines (Goulden 2011). Fourth, dialogue models do not take into account the various possible interaction effects between traditional and new media in science communication (for a linguistic approach towards understanding dialogue-oriented science journalism in new media see e. g. Hanauska and Leßmöllmann 2018).

Summing up, although dialogue models assume processes of interaction on an abstract level, they still fail to trace or model different paths of communication among groups of actors in detail. Furthermore, the models are often merely descriptive and do not allow for inferences on the intentions, contexts, or effects of the communication in question. On a more general level, Trench (2008) has argued that the often-mentioned historical shift from a deficit to a dialogue or participation model never took place in this form. Instead, he distinguishes among one-way, two-way, and three- (or multiple-) ways of science communication, with the first two approaches being linear and the last proposing a multidirectional flow of communication. According to Trench (2008) the different models of science communication all coexist in time and, depending on the context and the topics discussed, “participants may move from one approach to another” (Trench 2008: 132).

## **4 A network-oriented perspective on science communication**

As described above, in contemporary societies, processes of science communication have changed – mainly due to the rapid development of ICTs. Nowadays, multiple different types of actors take part in discourses on scientific issues and, based on the huge amount of available information, media use patterns have become more individualized. Taken together, all these developments result in more complex communication processes that manifest as complex interactions. Thus, institutionalized science and traditional mass media have lost their monopoly on the selection, presentation, and dissemination of (scientific) information. Although the newer models of science

communication (e. g. dialogue or participation models) point in the right direction, they still are incapable of conceptualizing these manifold communication paths and interactions in detail, and furthermore, they fail to make them accessible for an empirical analysis. This results in a deficit in the description and explanation of processes of internal as well as external science communication and its effects.

Based on the mentioned desiderata of the hitherto existing models, we propose to conceptualize science communication from a network perspective and thus to transfer and apply concepts known from the field of social network analysis (SNA) to the modeling and analysis of science communication. The analysis of social structure or communication processes from a network perspective has a long tradition in other disciplines (e. g. in sociology, anthropology, and social psychology; for an overview see, for example, Marin and Wellman 2011) and has risen in popularity in recent years (Borgatti and Halgin 2011). Basically, all social interactions (and thus also all communication patterns) can be conceptualized applying a network perspective. However, in the field of science communication, this approach has not yet gained much attention.

Generally speaking, social network analysis emphasizes the importance of all kinds of relationships among different units of interest and, thus, highlights the dependence of observations (Wassermann and Faust 1994: 4). Following this idea, a social network can be defined as “a set of socially-relevant nodes connected by one or more relations [...] [with] [n]odes, or network members, [being] the units that are connected by the relations whose patterns we study” (Marin and Wellman 2011: 11).

According to the definition above, the two central features of a social network are the nodes and the relations among them. The nodes or units of a network could be all types of actors (e. g. single persons, institutions, organizations, countries, neighborhoods), as well as documents (e. g. web pages, journal articles), or even single words. Borgatti et al. (2009) have identified four broad categories of relations: similarities (homophily), social relations, interactions, and flows. The concept of homophily states that nodes with similar characteristics often relate to each other. These similarities could be based on the same spatial or temporal location, on a joint membership (e. g. in an organization), or on shared attributes (e. g. same position towards an issue, same actor type). Ties based on social relations include, for example, kinship, work, or friendship relations and affective (support, critique) or cognitive links (knowledge of each other). In comparison with social relations, Borgatti et al. (2009) understand interactions as discrete events (e. g. actor A talked to/gave advice to/helped/... actor B). Flows, as the fourth type of relations, describe those things that are disseminated through interactions (e. g. information, beliefs, resources). Usually, one network under study comprises one type of ties, and different types of relations are modeled using separate networks. In addition, one could study whole networks (e. g. a co-authorship network or a discussion network around a certain topic) or ego networks (i. e., the network of one single actor). It is important to notice, however, that there are close relationships between the structure of networks, the interactive moves within network communication and the actors: The more or less dynamic structure of networks is the

result of the complex interaction of many actors that contribute dynamically over time (see Chapters 3 and 10, this volume).

The research aim within social sciences is often to explain the formation of ties in different network types (e.g.: Why is there a link from one website to another? How do authors choose co-authors?). Based on previous research, three different explanations for the formation of relations can be distinguished: opportunity-based ties, benefit-based or instrumental ties, and more symbolic or identity-building ties (Borgatti et al. 2009; Baldassari and Diani 2007). The first describes the likelihood of forming a tie based on the opportunity for two actors to become aware of each other (e.g. due to geographic or social proximity). The instrumental perspective explains the establishment of a relation based on some kind of utility (e.g. the access to or exchange of resources), and the third explanation points to the fact that ties are built to form a collective identity or to create a sense of “we-ness” among certain actors (see also Pilny and Shumate 2012).

Regarding science communication, manifold applications of a network perspective are possible. Different types of actors who are involved in internal and external communication processes can form the nodes of a science communication network. As described above, communication processes nowadays are characterized by the wide variety of actors. Thus, our nodes can be actors such as universities, single scientists, journalists, economic or political actors, civil society organizations, bloggers, or laypersons. These actors differ in their degree of organization (e.g. a company or a non-profit organization vs. a layperson), as well as their professionalization (Schmid-Petri, Häussler, and Adam 2016) or degree of expertise. Additionally, all actors incorporate different individual attributes (e.g. cultural background). Nonetheless, all these actors are part of several communication networks around scientific topics or within (scientific) institutions. The huge advantage of a network perspective is that all these actors with their different attributes and backgrounds can be integrated into a single network (or various networks), depending on the specific research interest.

Following Borgatti et al. (2009), relations among these actors can be based on similarities (e.g. scientists in the same field coauthor papers), social relations (e.g. communicative support or critique in the discussion about a scientific topic), flows (e.g. the diffusion of a new scientific finding), and interactions (e.g. retweets). With regard to the latter, a network is usually only concerned with modeling one type of interaction at a certain point in time. Hence, several networks are needed to model sequential interactions.

Based on the characterized actor types that are normally involved in science communication and the described possible social or communicative relations among them, we distinguish among three prototypical network types. In the following, we briefly describe these networks and provide some empirical examples.

## 4.1 Communication about scientific topics from a network perspective

Studies analyzing the coverage of scientific issues in various types of media form a huge part of the research on science communication (see Chapter 4, this volume). Most of these studies use content analysis techniques (quantitative or qualitative) to analyze the amount and type or tone of coverage on a certain scientific topic (e. g. climate change). Additionally, they often focus on one single media type (e. g. legacy media or some type of online content). Thus, these studies disregard the fact that nowadays media are often only one source among others – part of and embedded in heterogeneous actor constellations, in which all actors join a discussion on a scientific topic and may influence each other. This involvement of a wide variety of societal actors and the increased salience of actor types other than the media itself is incorporated into the notion of a networked public sphere (Friedland et al. 2006) that evolves around certain issues. Based on the arena model of the public sphere developed by Gerhards and Neidhardt (1991), Raupp (2011) has distinguished three levels of these networked public spheres: networks among individuals, interorganizational networks, and networks on the societal level. Most relevant for networks that evolve around the discussion of certain issues of contemporary society is the idea that vertical ties among all three levels may emerge.

With regard to science communication, this perspective incorporates the analysis of networks that evolve around certain scientific topics (e. g. discussion of climate change or stem cell research). Thus, the focus is issue-driven, and the research aim is to identify those actors that shape a certain issue field (see also Adam et al. 2016). This approach is often inductive, as we seldom know in advance all the actors who will take part in a discourse. Thus, an advantage of this approach is that we do not have to define the boundaries of the network in advance; rather, this too becomes part of the research process.

The result of such studies is a network focusing on one specific issue, which possibly includes a wide variety of different actor types (e. g. mass media, economic actors, universities, and single persons such as bloggers). For example, Häussler (2017) has studied the fragmentation of the German online debate about climate change by analyzing a hyperlink network, starting from the more prominent climate skeptics and climate advocates (see also Miltner et al. 2013 for food safety). Another example of a hyperlink analysis is the study by Kaiser et al. (2016) that is concerned with the energy transition discourse in Germany.

Another possibility for studying the communication on scientific topics from a network perspective is a more linguistic-driven or semantic analysis that builds networks in which the nodes are words and the relations among them are formed by their co-occurrence within a certain space in a document. Veltri and Atanasova (2017), who have also been concerned with climate change, would be such an example. Their study analyzed the content, external sources, and sharing habits of over 60,000 tweets on

this issue. Semantic network analysis was used to identify the more salient topics and macro-topics of the conversation (see also Shapiro and Park 2015; Kim 2011).

## 4.2 Networks of communicators of scientific communication

Another area of research within science communication deals with the communicators and their goals. It can be located in the wider field of strategic communication (see Chapter 22, this volume). In contrast to the issue-centered approach described above, here, the focus is on the actors involved in manifold communication processes. These networks of certain communicators are, in principle, independent from certain scientific topics.

An analysis of networks of communicators often follows a deductive approach focusing on the relations among a predefined set of actors. An advantage of this kind of research is that the network's boundaries are clearly defined. However, at the same time, the network is of course also limited to actors identified in advance, creating the possibility that further relevant communicators will be missed (Adam et al. 2016). Additionally, being able to identify relevant actors in a specific field beforehand requires solid knowledge (or a comprehensive database).

Regarding science communication, different types of actor networks can occur. One example is networks among universities or single scientists, which can be analyzed for possible interactions or collaborations. The approach taken by Leifeld et al. (2017) was to analyze co-authorship networks in political science in Germany and Switzerland, respectively. The studies showed research clusters, the centrality of individual researchers, and the more prominent research topics or subfields. For the German-speaking communication science community, Rauchfleisch (2015) conducted a study on Twitter usage with the aim of assessing its relevance for science communication purposes and evaluating its success within the scientific community.

Further possible research questions focusing on scientists and their networks could include analyzing how scientists are related to practitioners in a certain field and how scientific evidence is disseminated from scientific institutions to other stakeholders. Additionally, the broad research area addressing the role of scientists as advisors in policy formulations could benefit from a network approach: The application of a network perspective to the science/policy interface could help to analyze the manifold interaction processes and relations between scientists and politicians. Based on this, it would be possible to identify powerful, central actors who might be able to influence certain policy outcomes. Furthermore, the public engagement with science and the dialogue between scientists and laypeople could be conceptualized from a network perspective.

Besides these networks that focus on scientists and their embeddedness in relations with other actor types, another important group of communicators within science communication is civil society actors (e. g. non-profit/non-governmental



organizations, think tanks, social movements, and their countermovements, activists). On the one hand, these actors form strategic alliances with other like-minded actors or groups to increase their influence and successfully promote their causes. On the other hand, they oppose and try to attack and delegitimize their respective countermovement (e. g. Meyer and Staggenborg 1996). A network perspective could help to identify certain coalitions and to disentangle and trace possible power relations in more detail (argumentation theory has also developed an approach to study such coalitions of actors from a qualitative point of view, see e. g. Aakhus and Lewiński 2017).

Empirically, for example, Sharman (2014) has focused on the blogosphere of climate change skeptics and their alternative expertise formation in opposition to the scientific mainstream (see also Elgesem, Steskal, and Diakopoulos 2015). On a broader level, Ackland and O'Neil (2011) have studied environmental activist organizations and their online frame and hyperlink networks. They mapped them according to characteristics such as their main issues of concern. Fisher, Leifeld, and Iwaki (2013) have analyzed discourses on climate change in the US Congress. Their study focused on the formation of coalitions and consensus among the actors who testified before it on this issue.

### 4.3 Audience and effect perspective

Many studies in science communication deal with the use of and search for scientific information, as well as possible effects of certain frames or campaigns. However, most of these studies do not take into account the embeddedness of individuals in various social structures (e. g. families, friends) or test campaign effects isolated from actual use patterns (Akin and Scheufele 2017). Thus, first, applying a network perspective could help to analyze audiences' information seeking, as well as audience fragmentation across different media platforms (see Fu 2016). In doing so, one could possibly conceptualize news outlets as nodes in a network, with a relation between two media occurring when an individual consumes both. Additionally, the flow of audiences among different media types and outlets could be studied this way.

Regarding analysis of the effects that different kinds of scientific information can have, knowledge about the social structures an individual is part of (e. g. friendship or family ties) can help to understand campaign effects and the formation of certain opinions (Fu 2016). Thus, "affinity relations among individual consumers (e. g. friendship) can facilitate the understanding of media effects, news consumption choices, information diffusion, and public opinion" (Fu 2016: 307).

In this field, up to now, not many empirical studies have analyzed the structure of audiences or effects from a network perspective (but see Mukerjee, Majó-Vázquez, and González-Bailón 2018), especially with regard to science communication.

All described network types can of course be modeled dynamically, for example, by collecting several networks comprising the same actors or formed around the same

topic at different points in time. Furthermore, for most research questions, additional information (e. g. about certain actor attributes or the concrete content of documents) is needed, which can be collected via manual or automated content analysis techniques.

## 5 Conclusion

Current science communication is subject to various changes mainly due to the rapid development of ICTs and digitalization processes. One of the more central consequences are heterogeneous actor constellations that can now participate in the scientific process itself, as well as in discussions on scientific issues. Thus, science (and especially scientific institutions) has lost its leading position concerning the production of knowledge: everybody can now easily claim to be an expert in a certain scientific field. Additionally, traditional mass media have lost their monopoly to select, present, and disseminate scientific information: everybody can now easily publish and distribute content online. And lastly, science communication effects on audiences cannot be universally modeled, but depend heavily on the (social) contexts in which individuals are embedded.

However, the traditional models of science communication cannot describe these manifold interaction processes, and more importantly, they cannot trace them in detail. Thus, we call for research using a network perspective in science communication. Applying social network analysis to science communication processes has several advantages: First, it furthers the initial attempts to model complex relationships in science communication and allows for the inclusion, both theoretically and empirically, of heterogeneous actor constellations in various settings. Second, it does not make linear or top-down communication processes obsolete (e. g. the communication of research findings to a lay public) but includes them as one possibility among others. Third, it offers the possibility of integrating phenomena on different levels, that is, micro-, meso-, and macro-perspectives. Fourth, it can be seen as a theoretical innovation, as it requires thinking in relations and dependencies.

In sum, an integration of science communication approaches and network theories could lead to a more complete and more complex picture of science communication, assist in the understanding of new phenomena, and provide new possibilities for modeling and studying science communication in a digital world.

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Gábor Á. Zemplén

## 6 The contribution of laboratory studies, science studies and Science and Technology Studies (STS) to the understanding of scientific communication

**Abstract:** During their development, science studies fused the interest in large-scale structures, in temporally extended, often quantitative analysis of scientific communication with *in situ* observation of scientists and the analysis of their discourse. The chapter overviews the developments in macrosociological and scientometric research as well as in microsociology and anthropology studying laboratory communication. Both internal and external communication is discussed, as is a selection of technocratic and critical strands of the heterogeneous field. Science studies could keep up with new techniques generating, circulating and evaluating scientific content. Overviews of research foci (the journal article, controversies, boundary-work) and methodological debates (over the units of analysis and the use of quantitative methods) link the historical development of the field to current areas of interest and challenges to knowledge structures (open science, platform capitalism). The bulk of the chapter is on constructivist case studies that relate discourse analysis to the patterns of research and the networks of power. The increasing focus of the research field on the citizen, the recipient and user of science is evident, as is its responsiveness to normative challenges resulting from technological and social change.

**Keywords:** constructivism – case-study approach – boundary work – scientific expertise – technoscientific complexity – technoscience

### 1 The rise of science studies

One of the dynamically developing research fields after World War II is often broadly referred to as science studies, or, by a more traditional name, science and technology studies (STS). At some point in time other promising labels were used, like “sociology of (scientific) knowledge” (SSK), or “science, technology, and society” (also abbreviated as STS); some of these are by now out of fashion. The discipline was at first closely tied to an adjacent field, history and philosophy of science (HPS). The institutionalization of first HPS from the 1950s to the 1970s and of STS, starting about a decade later, went hand in hand with the spread and stabilization of methodologies to study localizable patterns of science-related activities.

During their development and maturation, science studies maintained relatively strong ties with the history of science, but for periods parted ways with neo-positivist



philosophies of science. The discipline inherited much from anthropological methods of observation, exemplified by laboratory ethnographies and other fieldwork, carried out by social scientists on groups of scientists, engineers or other experts. One view of looking at the historical development of the field suggests a move from macro-sociological – mostly quantitative and inherently policy-relevant – studies of scientific communication, towards developing the conceptual apparatus to help description of scientists' communication on many levels, including personal communication, and interactions with technological devices. The shift resulted in a highly fruitful exploration of methodologies from the 1980s that shed light on many aspects of scientific communication.

A dominant characteristic of much of the innovative work of the discipline from the 1980s to the early 2000s is a “constructivist” view of science, regarding scientific knowledge as primarily the product of human activities and interactions. There are significant differences in the approaches as to what aspects of scientific communication they study. There are also various analytic tools utilized for the study of communication. Studying the processes in which scientists in local, situated cultural contexts with limited material resources come to globally endorsed conclusions leads to a number of intriguing research questions. It is hardly a tenable position that the social is *irrelevant* for scientific research, but it is not easy to say *how* the social is important. Science is a heterogeneous set of activities, and communication plays a key role on many levels, from the stabilization of phenomena in a lab to stabilizing the status and funding of a discipline in public and policy discourse. A social account has to be able to incorporate aspects of cooperation and stability as well as dissent, controversy, stretching from the generation of novel representations to the generation of new social realities and sociotechnical imageries. The rather trivial starting point of the empirical studies, that is, the social dimension does have epistemic relevance, received strong criticism in some cultural contexts as this view can clash with the view of science where the scientist “speaks for” nature.

Work in science studies generally focuses on case studies, and the inquiries have never developed a shared conceptual framework. As opposed to some “grand theory”, STS textbooks and popular introductions (some discussed below) portray the plurality of approaches, and multidisciplinary and internationality have characterized the field from early on. Many note the surprising speed of the conceptual and terminological innovations in the field, some applaud it, but for others, this characteristic is superfluous: “the simple fact is that many STS writings have lost any sense for a well-controlled use of language. The half-lives of STS jargon and proposed reconceptualisations become shorter and shorter...” (Ibarra and Mormann 2003: 246).

Some expert groups number few individuals, and some several thousands. The differences of cultures of science *in size* already imply that different methodologies for the analysis of a specific type of communication can be optimal. For various levels of scientific expertise, intense in-group knowledge-transmission is needed with hands on experience and tacit elements, but some can be mastered by watching media or

reading books. Social scientists can focus essentially on oral communication in a small group or large file-repositories with automated classification of texts and over a million downloads per week, like ArXiv. This span cannot be easily bridged by one methodology. Added to this difficulty is that scientists communicate in all possible ways: scientific creativity always outdoes the theories that try to contain *all relevant* aspects of communication.

Scientific communication is a moving target: scientific knowledge is constantly in the process of creation and change, and stabilization and conventionalization can take many forms. The layout of a scientific article has changed and evolved, the way a position is argued for is constrained, and novel discursive practices emerge in response to technological and social change. Many of the early works in science contained a “dedication” to a patron, and today most journal articles include a section on “conflict of interest”. As digital technologies spread, so do the ways a scientist can err: today some articles are retracted because of the visuals or the figures and not because of the data, the propositions, and other linguistic features. There have been many successful attempts at “cross-fertilization”, merging sociological and linguistic, rhetorical, and computer-assisted analyses in the last two decades. If one traces the use of “logic”, “rhetoric”, or “controversy” one is baffled by the many ways the study of society, of communication, and of science can inform and supplement one another. In a review, Keith and Rehg map the “boundary concepts” that fostered interdisciplinary engagements between science studies and disciplines such as rhetoric, speech communication, philosophy and logic, composition, linguistics, and computer science (Keith and Rehg 2008). In general, polysemy is to be expected, and bridge terms, like “rhetoric” or “discourse” are often used in a fairly broad sense. When better specified, they relate to various fields of inquiry from natural language-analysis to analysis of ideologies of groups.

In the new millennium, the discipline is increasingly involved with the normative aspects of scientific communication; in recent years there has been an upsurge of policy-relevant analyses and the field has become an arbiter in tackling recent challenges to current knowledge structures (anti-democratic and “post-truth” scenarios, Sismondo 2017). Approaches of science studies share many methods and concerns with the science of science communication (for an overview of topics of interest, see Jamieson, Kahan, and Scheufele 2017 and Chapter 5, this volume).

To introduce the varied and heterogeneous field, the following two sections explore some aspects of the disciplinary development, including the rise of constructivism and the “practice” turn in Anglo-Saxon contexts, the emerging focus on *local knowledge production*, and the methodological debates on how to tackle the units of analysis in STS (sections 2 and 3). This chapter also introduces some landmark ethnomethodological case studies, with the bulk of section 4 revisiting a preeminent example of studying *Laboratory Life*. Section 5 overviews some of the other foci of interest, boundary work and controversy analysis, specific publication forms, and challenges of “open science” that have relevance for the study of scientific com-

munication. The aim is to present a few samples from the array of tools that have been developed to study both the spaces of communication and various types and acts of communication. In studying scientific communication, a particular challenge is that representational tools co-evolve with science, and science studies have to keep up with the developments. Scientific representations can include diagrams, graphs, “paper tools”, even tangible 3-D models (Chadarevian and Hopwood 2004), as well as scientific visualizations of new imaging technologies of current scientific practice (Coopmans et al. 2014). Section 6 discusses issues pertaining to the complexity of modern technoscience and some of the challenges of future research.

For a finer grained impression of the field, it is instructive to take a look at the handbooks of the scholarly society of the field, “4S” or the “Society for Social Studies of Science”. The Society was founded in 1975, has over 1000 members, and runs the prestigious journal *Social Studies of Science*. By now the Society has published the 4th edition of its handbook (Felt et al. 2017). The shifts of disciplinary focus affected the ways the handbooks were organized, the latest edition shows how interest in the citizen has increased, and the field has established a transcontinental network focusing on the user and specific constellations of science, technology, power, and information. The third edition (2008) is probably the best entry point for an overview of interdisciplinary developments relevant to scientific communication. The second edition (*Handbook of Science and Technology Studies*, 1995) has useful chapters on laboratory ethnographies and gives a good sample of the endemic “technocratic” and “critical” traditions of science studies, the strong ties with feminist critique as well as an interest in education, technologies, and the state.

The next section of this chapter starts off with traditional sociology of science, characterized by studies of large-scale structures, and temporally extended, often quantitative analysis of scientific development. Investigations carried out from the 1960s and 1970s by Harriet Zuckerman, Jonathan Cole, Stephen Cole, and Joseph Ben-David uncovered several salient properties of scientific communication. Two of the key figures of the period were Robert Merton (the first President of the Society) and Derek J. de Solla Price, one of the editors of the first STS handbook (*Science, Technology & Society: A Cross-Disciplinary Perspective*, 1977). Borrowing from a popular narrative of the historical development of STS, advocated by Harry Collins and Robert Evans, this first wave of researchers took the success of science for granted (Collins and Evans 2002, 2007). This chapter utilizes their tripartite structure as well as an introduction that discusses in more detail the relevance of STS for science education and communication in a Galileo-inspired dialogue (Kutrovátz and Zemplén 2014). Another dialogue links the growing interest in expertise, argumentation, and social epistemology (Kutrovátz and Zemplén 2011), and these issues are marginally discussed here. Some early representatives of what has become science studies used the format of Galilean dialogues (including Ludwik Fleck and Paul Feyerabend), and there are various ways in which didactic dialogues can foster an understanding of science in a

classroom setting. This way of presenting ideas, arguments, and positions is generally not considered today to be scientific (enough) and therefore appropriate for inclusion in journals or handbooks (see also Chapter 10, this volume).

## 2 From social structure of science to social construction of scientific knowledge

The systematic study of how science as a social institution functions yielded important insights from well before World War II and uncovered some interesting inequalities in communication. Lotka observed that the majority of all publications is written by a small minority of all scientists (Lotka 1926), and the number of authors publishing a certain number of articles is related to the number of authors publishing a single article in a field. Science exhibited signs of gerontocracy, a bias in attention towards the “already recognized”, that is, usually the elderly. The older, already famous get more attention than their share of the work. Robert Merton called this the Matthew effect (Merton 1968), based on a quote from the Bible: “For whosoever hath, to him shall be given, and he shall have more abundance: but whosoever hath not, from him shall be taken away even that he hath.” (Matthew 13:12, King James Bible, Cambridge Ed.)

Other inequalities uncovered by the quantitative sociology of science were also noteworthy, like the prominent differences in the speed of uptake of new results in various fields. In some sciences, the immediate knowledge base that researchers rely on is more up-to-date and recent than in other fields. The Price Index gives the proportion of those publications, cited by a scientific journal of a field or discipline, that are not older than five years, relative to the number of all citations. Price found significant variation: 60–70 % for sciences like physics, and only 20 % for philosophy. Disciplinary differences were found in other domains, like in different rejection-rates. Merton’s study of prestigious journals on biological, physical, and geological areas had much lower rejection rates (20–30 % of manuscripts) than journals on literature, philosophy, political science, sociology, and, especially, on history, with a staggering rejection-rate of 90 % (Zuckermann and Merton 1971).

As scientific communication is affected not only by the technological development but also by the growing number of scientists, a short overview of some of the demographic observations of the first wave of science studies should be referred to. In 1963, Price recognized that the total population of scientists was growing more rapidly than the population of non-scientists since the emergence of modern science (Price 1986). Most indicators of the size of science from the end of the century doubled in a period of approximately 15 years, and *in toto* increased about 1000-fold in the last 150 years. Half of the scientists of our history have worked in the past 15 years, a scientist having worked for 45 years is contemporary to more than 90 % of all the scientists who have lived so far.

Because of the immense ever-present growth of communicated content (published in journal articles), selection has to be made by individuals (with limited time for research) but also by institutions (with limited financial resources). In the 1960s, in a study of over 30,000 scientific journals, Price found that half of all the interest in libraries was focused on the “most prestigious” 170. Inequalities in citation patterns were significant, too: most papers will never get cited and a few influential and highly visible papers get a lot of credit (1986: 67–73).

The turn from paper format to mainly Internet-based research created further mechanisms by which inequalities arise. To decrease bias in the uptake of scientific research, some modern online archives now take precautions to reduce herding behavior. For example, Paul Ginsparg, founder of the landmark physics preprint server noted:

On arXiv, we have seen some of the unintended effects of an entire global research community ingesting the same information from the same interface on a daily basis. The order in which new preprint submissions are displayed in the daily alert, if only for a single day, strongly affects the readership on that day and leaves a measurable trace in the citation record fully six years later. Some researchers, wise to this, time their submissions to arrive just after the daily afternoon deadline to maximise their prominence in the next day’s mailing. Filters that highlighted ‘popular’ materials over longer periods of time would exacerbate this effect. (Ginsparg 2011: 147)

As science is an institutionalized sub-system or field of society that grows faster than the general population, and as growth inevitably leads to increasing specification and specialization, the whole system gets increasingly intricate and less easy to track. With the “first wave” of sociological studies of science, a by now mostly independent field evolved. Scientometrics focuses on communicative practices, like quoting, that are easily quantifiable, and allow for some measurement of scientific output by counting and ranking publications, calculating impact factors (citations within usually two years of publication), and other indicators, like derived indices (like the Hirsch index). By the new millennium, scientometrics had become a major tool for assessing research and hence influencing funding and rating of scientists and institutions. This strand of research developed in parallel with improving models of knowledge-diffusion, focusing on patents, articles (easily measurable kinds), and economies of technological innovation and change (Lerner and Stern 2012). These fields today provide very rich resources for policy-considerations.

Many of the landmark “second wave” STS case studies retained an eager interest in incorporating the different scientometric tools in the analyses. They used citation-analysis techniques but prioritized qualitative research and embedded the quantitative aspects in narratives or “anthropological accounts” of studies of scientists’ activities. Too much reliance on the easily quantifiable aspects of scientific communication received criticism as a closer look showed that the desire to measure tends to travel together with an inappropriately positivist and realist approach. Systematic measuring techniques “rationalize” science in a way that obscure key features of the processes, and “an ‘overall objective’ view of science ‘as it is’ [...] shift attention from

the dynamic perspective of the scientists' themselves: account[]s derived from quantitative methods are intended to 'correct' the 'partial' perceptions of participants" (Edge 1979: 108).

A major challenge for the emerging qualitative, case-study based research was to develop tools to study the not-so-easily quantifiable aspects of scientific communication. The production of reliable knowledge is carried out by a highly complex social institution and its members, shaped by economic, cultural, and ecological factors, and structured both "vertically" in a hierarchical order, through complex power-relations, and "horizontally" according to disciplinary maps and interfaces with other parts of society. Sociological analysis can tackle some resources fairly easily, like financial conditions (salaries, grants). It can also investigate "symbolic" resources, like ranks, degrees, positions and institutional structures of research institutes, universities, etc. But how to analyse in-group communication is less trivial, and it is not easy to ascertain the role that the technical and instrumental paraphernalia of science plays in the relevant novel communicated content.

The break with the functionalist sociology of science was only temporary and never too severe but the pluralist and "relativist" epistemological stance that was developed by the "second wave" clashed with the mainstream neo-positivist philosophy of science. Various other philosophical allies were recruited, among them hermeneutics, phenomenology, semiotics, standpoint-theory, and even deconstruction, or, to name individuals, Derrida, Heidegger, Foucault, or the late Wittgenstein and Whitehead. Probably the most important of the HPS-related influences was that of Thomas Kuhn (1970 [1962]). Philosophical debates surrounding Kuhn highlighted the epistemological stakes of non-linear developmental narratives that fit well with the emerging mosaical view of the sciences. Kuhn's "paradigm"-concept was not unambiguous, and the concept of incommensurability between paradigms was heavily criticized as it threatened the traditional notions of objectivity and scientific rationality, but the implications for social studies of science was that *some* form of differentiation of groups is possible. There could be meaningful (emergent) units of analysis, different "styles of reasoning". One can locate many precursors from the first half of the 20th century like Ludwik Fleck's research of thinking collectives, thought styles, and the communal stabilization of facts. The notion of "style of thinking" (Denkstil) was also adopted by Karl Mannheim and informed later philosophers like Ian Hacking as well as historical research (Crombie 1995).

Kuhn mainly targeted historical theories and never developed the methodology of analysis but his approach linked epistemological questions with sociological investigations of the dynamics of groups. Kuhn's historiographical position had empirical benefits: it helped to delineate social realities with specific rules, values, goals, and (epistemic) norms. In his late writings, Kuhn softened his philosophical position and exploiting an evolutionary metaphor stressed the dynamic features of his theory. The emergence of new subdisciplines is analogous to speciation in evolution, and "lexicons" of research communities (not just the lexical items, but also the structural rela-

tionships) can be translated by learning the conceptual system guiding their world-view (Kuhn 2000). Communication between “lexicons” (the tuned down version of incommensurable ways of seeing the world) is possible but this does not make science into a unified enterprise. Post-Kuhnian authors of science studies argue for the disunity of science (Galison and Stump 1996), and constructivists often view different scientific fields as different epistemic cultures. For an overview, a good starting point is Sismondo (2010 [2004]).

The turn to practice in science studies loosened many of the links with philosophical takes on science and, instead, linked the domain to methodologies of the social sciences. Authors worried less about reconstructing conceptual structures than about social structures, and attention shifted from “thought” to “utterance”. Focusing on the practical activities that offer themselves to observation also coincided with a move from “grand theory” to “case study” (Galison and Biagioli 1999).

### 3 The potentials of case studies and the question of units of analysis

A crucial link in the development of science studies was the so-called “Strong Programme” in the sociology of scientific knowledge (SSK), developed by the Edinburgh School including David Bloor, Barry Barnes, John Henry, and others. Extension of prior work on sociology of knowledge (Mannheim 1936) and utilizing frameworks from early anthropology and sociology (Durkheim, Mauss), it posited four key desiderata of a successful, empirically informed social explanation: it should be (1) causal, “concerned with the conditions which bring about belief, or states of knowledge”, (2) impartial “with respect to truth and falsity, rationality or irrationality, success or failure”, (3) symmetrical, as “the same types of cause would explain, say, true and false beliefs”, and, finally, (4) reflexive: “its patterns of explanation would have to be applicable to sociology itself” (Bloor 1991: 7). The Strong Programme developed an approach to analysis (endorsing a finite semantics), where meanings of concepts change just as our norms of justification and the rules we follow. This was in stark contrast to some of the philosophical tradition’s assumptions on semantics. A massive result of the programme was that applying sociological analysis to terrains of scientific and even mathematical knowledge became possible (Bloor 1991 [1976]).

These developments mirrored some HPS approaches that tackled the domain of mathematical knowledge, most notably the approach of Imre Lakatos. His work on research programmes outlined a “hard core” and a “protective belt” of theories and was mainly interested in the argumentative strategies of scientists (like “monster barring”, *ad hoc* defence of core assumptions). In contrast, much of the early SSK movement deliberately looked for social causes (goals, interests) to explain the development of scientific knowledge.

The historical case studies published by members of the Edinburgh school generally made claims that were both causal and macrosocial, tying individuals' beliefs to factors such as social class or location. This practice, however, was not true of the landmark contributions that were inspired by SSK. Versions of the programme were employed in studies of scientific laboratory work (Knorr-Cetina 1981, Latour and Woolgar 1986 [1979]), analyses of scientific controversies (Collins and Pinch 1982, Pickering 1984), theories of technology (Bijker, Hughes, and Pinch 1987), etc. SSK motivated many trends in the social studies of science, and at least two of the early book-length case studies of controversies informed by SSK should be mentioned.

Probably the most cited is the book by Steven Shapin and Simon Schaffer, *Leviathan and the Air-Pump* (1985). The book investigated the practices of experimental science in the early Royal Society and embedded the study of a scientific controversy in the broader social context and period, a search for societal stability after the mid-17th-century civil wars and hostilities in England. The work offered arguments for linking the analysis of the controversy with the material culture and practices of social groups. As such, it offered no novel toolbox of analysis of communication but focused on novel issues: the build-up and breakdown of trust and social roles of experiments. Of commensurable merit is Martin Rudwick's magisterial work on a later, 19th-century debate among geologists, *The Great Devonian Controversy*. It starts off with several chapters of historical analysis and context-rich introduction to the positions, ending with a reconstruction of the controversy *in toto*, offering a complex diagram of how individual contributions (articles, books) relate to the gradual shifts in position, and finally merge in a near-consensual new position (Rudwick 1985).

Shapin and Schaffer concentrated on the debate of individuals (Boyle and Hobbes) and discussed the positions as both local, and at the same time global, perennial, living up to our present day, and informing the stance taken by the analysts (endorsing reflexivity). Rudwick focused on the study of a small group of individuals but the analysis highlighted a global, perennial problem, the question of outliers: some (supposedly rational) members at some point diverge from the emerging consensus. A narrative of historical development accounting for progress requires coercion of individual beliefs but in reality, full closure is rarely attained (supporting the need for impartiality and symmetry). Although both books were radical, they upheld the idea that the epistemically privileged state of the scientific community is a state of consensus.

Controversies became a focal area of sociological analyses, and *local* elements of the "social" became more and more pronounced (see also Chapter 15, this volume). Harry Collins argued that in many cases, negotiations in a small group of specialists, the "core set" lead to closure of a controversy (Collins 1985), and the *constitutive fora* (conference presentations, academic journals) are the standard places where expert-disagreement is resolved, but some debates reach the *contingent fora* (appeals to public opinion, popularization, or advertising). Larger-scale social structures and invoking (class) interests thus cannot provide fully satisfactory accounts of the social processes.



The tools adapted from sociology and anthropology facilitated the study of science as an activity, with a growing focus on scientific practices, including linguistic ones. Looking at science not purely as an intellectual accomplishment but as a cluster of practices, however, had methodological problems. The world of social actors is complex enough, but in an account of the technology-bound production of knowledge, somehow the material engagements also have to be incorporated. The “standard” humanist perspective, taking individual humans as the basic units of a system, became challenged from many angles. The “sociology of knowledge” tradition could delineate supra-individual units of analysis, but the entanglement with the material world could only be accounted for as long as it had imprinted the “social” world; for example, once it has been linguistically formulated (see also Chapter 8 on terminology research in this handbook). From the perspective of technoscience, knowledge-production is not just a human affair; just as a grant agency can refuse to sponsor research, some model organisms might refuse to grow in the lab, and an automated process can malfunction. Should an account of the activity not give room for these types of constraints of the research?

A number of frameworks were designed to overcome these challenges and uncoupling sociological and historical inquiry from issues of truth, realism, and objectivity “opened the way to a remarkably productive period in the understanding of science as a human enterprise” (Golinski 1998: xviii). The “actor-network theory” (ANT) by Bruno Latour, Michel Callon, John Law, and others had significant success from the late 1980s. The material-semiotic approach came with a relational, not to say, fudged ontology, where the social world and scientific knowledge are co-created in systems and networks of humans and non-humans. A whole strand of “posthumanist” frameworks survived the periods of controversies (Pickering 1992) and are used presently. Post-humanists like Andrew Pickering focus on multiple (not just human) agencies and portray science as both material, conceptual, and social, evolving open-endedly and emergently in the “mangle of practice” (Pickering 1995).

## 4 Communication and the spaces of knowledge-production

The case studies based on *in situ* observation of scientists’ daily activities could portray the everyday scientific practices that turned raw data and individual opinions into facts. The richness and variety of the communicative practices and the spaces where knowledge is produced, when combined with various methodologies, yielded a plethora of case studies, by now reaching into the thousands. As a few specimens can show, ethnomethodologists developed a wide array of tools to “make sense” of how activities are transformed into knowledge.

One of the influential examples is the pioneering work by Bruno Latour and Steve Woolgar, *Laboratory Life: The Social Construction of Scientific Facts* in 1979, with a second edition in 1986, where the “social” was dropped from the subtitle. As an early piece of field-ethnography in science, the approach was still positioned with respect to the debate on the insider and outsider perspective in anthropology and linguistics (emics/etics, mirroring the difference between phonemes of a linguistic system and a phonetic transcription of a speech-event). The authors aimed not for an etic validation, as they described Mertonian analyses, and were explicitly going for emics to “follow” the practitioners under study. The narrative offered a look at the laboratory activities as seen through the eyes of a total newcomer, constructing an account in his own terms of the activity he saw.

The book portrayed the “routine” work in a laboratory but picked a prestigious one, as a member was awarded the Nobel Prize for Medicine in 1977 while the manuscript was prepared for the publication. It is instructive to note that “reality” was portrayed as the consequence rather than the cause of the construction, and the notion of anthropological strangeness helped depict scientists’ activities as directed towards operations on statements like the dropping of modalities. The constructivist stance stressed the semiotic relations between instruments, data, statements, publications, and citations, and contrasted significantly with the view that research is concerned with “Nature”. By the end of the day in the laboratory, fact-construction lead to increase (or decrease) in the credibility of a few statements. Not “reifying” the process by which a substance is constructed, it assumed that the presence of objects of research was not a *pregiven* and claimed that it is a *misleading* impression that science is about the discovery of hitherto concealed truths.

The analysis utilized a number of key notions from earlier scholarship, like Gaston Bachelard’s “phenomenotechnique”, where scientists through material techniques and with the use of inscription devices constitute phenomena and construct facts: “The molecular weight of proteins could hardly be said to exist except by virtue of the ultracentrifuge” (Latour and Woolgar 1986: 65). Facts were made possible by processes of literary inscription and required the complex apparatus and craft skills of several fields. Hence, they were costly: for the studied period, the cost of producing a paper by the lab was \$60,000 in 1975 and \$30,000 in 1976. To decide whether a paper is an expensive commodity or a bargain required the investigation of the impact. Several chapters of the book discuss not just the laboratory activities (internal communication) but also the patterns of the uptake of research (external communication), linking scientometrics with discourse analysis and discussions of group dynamics.

The authors’ analysis of the credit cycle in knowledge production fused the political and epistemological readings of science: the massive amounts of text produced in the lab, the phenomenotechniques, together with the strategies employed by participants in the agonistic field (debating results, competing for resources), jointly influence the quality of science produced. To bring together aspects of laboratory activity that are usually discussed under the rubrics of sociology, economics, and epistemol-

ogy, the authors developed an extended notion of credit as reward of past scientific achievement *and* as credibility when creating original information.

Analysis of exchanges in the lab could be related to practical (credit-seeking) activities like carrying out assays, or discussion of long-established facts, usually related to theoretical matters. A lot of the conversations discussed other researchers: statements of a particular paper were often evaluated in light of the author's strategy or psychological make-up, and not the argument. Evaluations of a statement were contested during intense negotiations in the lab on the basis of available documents, and

[...] grammatical modalities ("maybe," "definitely established," "unlikely," "not confirmed") often acted like price tags of statements, or, to use a mechanical analogy, like an expression of the weight of a statement. By adding or withdrawing layers of documents, scientists could increase or decrease qualifications and hence the weight of the statement was modified accordingly. (Latour and Woolgar 1986: 84)

A whole chapter of the book was devoted to studying the historical construction of one particular fact, and the process could be depicted on diagrams that plotted the appearance of a term in titles and a drop in citations to certain publications. Different kinds of statements were found in the papers, and the successful operation of various processes of literary inscription together with microprocesses of negotiation continually taking place in the laboratory resulted in transformations of the types of statements that were published in new papers. The analysis tracked citing strategies of groups, borrowing, and plus and minus transforming operations on modalities. It could map transition points in both what the research questions were and how the substance was reconstituted within a new network. The neuropeptide TRF(H) could take on a different meaning and significance depending on the particular networks it was used in. Success, "facticity" was achieved in the field when readers were sufficiently convinced that there is no debate about the fact once no one any longer had the resources to challenge a claim. A new fact was born as the contingencies of its emergence were decoupled from the processes of literary inscription that created it.

Latour and Woolgar's *Laboratory Life* also provided a topology of the analysis of communication (1986: 167) with links in the book between transcripts of fieldwork and quantitative analysis, work on semiotics, deontic operators, and modalities. Several other early case studies would deserve a similarly detailed treatment, and some will be mentioned briefly below.

The need to develop tools for the study of scientists' communication increased as overambitious causal explanations gave way to multi-perspectival analysis. Analysis of oral communication showed that in interview situations, admission of possible weaknesses can resemble rituals of initiation (Pinch 1986) and that metatheoretical commitments of scientists respond to contexts: many scientists are constructivist on weekdays and inevitabilist on Sundays, as Hacking noted (1999: 79). As first the challenges of the methodology of reconstruction was subordinated to the problems of

sociological analysis, various approaches existed before problematizing the data on the utterance level.

Previous approaches have been designed to use scientists' symbolic products as resources which can be assembled in various ways to tell analysts' stories about "the way that science is." Discourse analysts, in contrast, begin from the assumption that participants' discourse is too variable and too dependent on the context of its production [...] (Gilbert and Mulkey 1984: 13).

*Opening Pandora's Box* was one of the most pronounced attempts to engraft analysis of communication into STS, but generally, the sociological or anthropological problem (where discourse is a social frame) instructs the methodology to tackle natural language and oral communication (discourse as understood by discourse analysis).

Another famous case study by Knorr-Cetina (1999) contrasted two, differently structured communities, and describing the differences of language use was crucial in getting a grasp of the differences between epistemic cultures. In molecular biology, authorship and priority quarrels are normal, and groups are generally small. In strong contrast, experimental high energy physics is organized into large networks or "trust cohorts" that outlast collaborations. Confidence pathways keep individuals connected, motivated by (technical) gossip:

Gossip is a kind of mangle through which all significant events and entities within an experiment and in its relevant surroundings are put. Technical gossip mixes report, commentary, and assessment regarding technical objects and regarding the relevant behavior of persons. It often involves evaluative assessments of physicists' work, intentions, and competence, but it may also refer to groups or whole experiments (significant "theys"). Technical gossip reproduces a personalized ontology in that it cuts across and transcends the boundaries of an experiment and of experimental groups: friends and colleagues from other experiments, from other divisions in the lab, from other labs, from institutes, and in fact any relevant professional (and others) can be senders or recipients. Gossip circles overlap confidence pathways, but they appear more extended in their reach. (Knorr-Cetina 1999: 203).

Knorr-Cetina, like a growing number of authors, also discusses gender differences in epistemic cultures. Mono-gender physicists are contrasted with the duality of gender that plays a role in everyday interactions in molecular biology labs, with a different style of interaction where mild flirtations and joking relationships were often observed.

The next section reviews some of the foci of interest that have been on the agenda now for decades.

## 5 Boundaries, controversies, and sociotechnical imageries

The turn to the practice of science, including the communicative activities, by and large sidestepped the earlier division of labor concerning a separate historical-sociological-psychological study of discovery and the philosophical study of justification. It is evident that “knowledge in the making” cannot be studied by reading only *published* articles of scientists. Memorable moments of knowledge acquisition with potential benefit usually link to some activities (including bursts of creativity) *before* the submission of an article. And the research process can be very different from what the standardized structure of articles suggests. Illuminating differences were found between laboratory notebooks and bench-side notes on the one hand and published articles on the other. The conventional form of a scientific contribution to a field can mask substantial differences in methodology and the presentational devices are constrained by the medium as well as picked for the aim and the intended audience. It is well known that a submitted piece of scientific communication to a journal has to conform to (stylistic) constraints and that citations are not “objective” measures of influence. The Nobel Laureate Peter Medawar asked the provocative question whether a scientific paper is a fraud (Medawar 1963), but no consensus emerged as to how exactly doing science relates, or should relate, to writing science (Schickore 2008).

Nevertheless, as the scientific journal article is the primary knowledge-transmission agent of our age, scientific publications received significant attention both from hermeneutical, rhetorical, and argumentative approaches (Bazerman 1986, Gross and Keith 1997, Lenoir 1998). The scientific paper has vehicles for conveying a message: data, arguments, records of influence. And, if successful, a paper impacts a field, and it potentially impacts industry, environment, society. Also, claims made in journal articles are often challenged, debated, and, from the 2000s more and more often, retracted.

“Normal science” is not that interesting for the majority of STS studies, and the taste has been inherited from both anthropology (Garfinkel) and HPS. Controversies, an already mentioned focal area of study (Caplan and Engelhardt 1987), disclose the underlying differences in values, methodologies, and assumptions of communities. The focus has been on *closure* as opposed to a *resolution* of a controversy (implying the discovery of a rational solution). The path to reach closure can include elements of negotiation, evidence-weighting, or may mobilize outside resources (force, government authority). Today the focus on contested issues is sustained by the growing practical needs, the societal impact of science, and policy-related debates in the complex webs of experts, users, and regulators.

Science has shifting boundaries that change historically and vary according to contexts. Analysis of “boundary work” by Thomas Gieryn (1983, 1999) has proved to be a useful tool in describing the ideological and rhetorical efforts to demarcate science

from what it is not. (Again, the rhetorical is to be understood in a broad, non-technical sense, unlike in, e. g., Ceccarelli 2001.) The boundaries are flexible, and controversies arise between science and society, and between science and other knowledge systems (see Chapter 23, this volume). There are many intradisciplinary power-struggles, and a number of interdisciplinary clashes, as even allied fields can become agonistic (for an example from medical context, see Vuolanto 2015).

As in contemporary technoscience, the concept of “scientist” is becoming less and less apt, the notion of “expert” with its communicative aspects is gaining ground. The boundaries are negotiable and permeable, “boundary objects” (Star and Griesemer 1989) connect various groups, including laymen and experts in the large networks of science. There are “boundary infrastructures” (Bowker and Star 1999) and “boundary organisations” (Guston 1999) in STS. Collaborating physicists and engineers, and other groups of co-operating experts create function-specific jargons, pidgin and creole contact languages, the “trading zones” of contemporary technoscience (Galison 1997).

Science impacts our society in ways we earlier did not even think possible. We live in an age of self-driving cars (some kill people), and algorithms (some unethical). STS has been growing in response to these challenges as its methodological flexibility allowed it to adapt to the unforeseeable (local) conditions, to the most unexpected and challenging scenarios to contemporary societies and technoscience. For a good overview of “open science” and Science 2.0, the fuse of platform capitalism with science, and current challenges see Mirowski (2018).

Chains and networks of communication can be analyzed to shed more light on individual practices, emerging consensus, and standardization of forms of communication, as well as to better understand dissent, polarization of opinion, and the birth of new groups and social realities. Latour blurred the distinction between things and beliefs about them, and the distinction between Nature and Society (Latour 1993); and we enter a period where the boundaries of agency and with it notions of responsibility become blurred, but the need for action is pressing in civic, environmental, and policy domains (see Chapter 22, this volume). Contemporary science is socially distributed, increasingly application-oriented, trans-disciplinary, and subject to multiple accountabilities as research priorities are influenced from supranational to local levels (Novotny, Scott, and Gibbons 2003). It is also increasingly commercialized and the sociotechnical imageries now created both enable and constrain the next moves.

## 6 Science, complexity, and societal impact

Shortly after World War II, Warren Weaver published an overview of the 350 years since the emergence of modern science. His *Science and Complexity* contrasted the success of the physical sciences before 1900 with the complexity of living organisms.

The amazing successes in technological development were brought about in the period in which physical science was mostly concerned with problems of simplicity (usually two variables) or of disorganized complexity (where statistical techniques have proved to be very effective). Recognizing that biological and medical problems cannot escape the *problem of the living*, the complexly organized, he demanded a third great advance: “Science must, over the next 50 years, learn to deal with these problems of organized complexity” (Weaver 1948). The essay ended with another call for action:

The great gap, which lies so forebodingly between our power and our capacity to use power wisely, can only be bridged by a vast combination of efforts. Knowledge of individual and group behavior must be improved. Communication must be improved between peoples of different languages and cultures, as well as between all the varied interests which use the same language, but often with such dangerously differing connotations. A revolutionary advance must be made in our understanding of economic and political factors. Willingness to sacrifice selfish short-term interests, either personal or national, in order to bring about long-term improvement for all must be developed.

None of these advances can be won unless men understand what science really is; all progress must be accomplished in a world in which modern science is an inescapable, ever-expanding influence. (Weaver 1948)

STS has followed a path that diverged from trying to give one answer to the question “what science really is”, and instead organically grew around the studied topics. The object of study is changing, as traditional long-term theoretical research confined within certain disciplines (“Mode 1 science”) is losing its former ground, and Mode 2 science focuses on specific real world problems, favoring multidisciplinary projects (Novotny, Scott, and Gibbons 2001).

Merton still sought to identify a peculiar set of norms that govern scientific activity, a “scientific ethos” (Merton 1942). Merton’s norms were: (1) universalism (where the origin, class, or gender of the scientist making a claim plays no role in the acceptance or rejection of theories); (2) communalism (or communism, taking scientific knowledge to be the intellectual property of the community, where every member has equal right to access it, contribute to it, or criticize it); (3) disinterestedness (the assessment of scientific claims should be kept independent of the local interests and group-biases); and (4) organized skepticism (all scientific claims are to be submitted to the scrutiny of critical thinking, and no dogmas should be considered as beyond skepticism). Merton’s fundamental aim was to find the norms that can provide ideal circumstances for scientific development when implemented in institutional practice (Merton 1938). His counterexamples where some norms were not respected included Nazi Germany and the Soviet Union. When ethnic and cultural circumstances of the proponents influence the reception of ideas, the norm of universality is clearly violated.

With the development of science studies, it was recognized that Merton’s norms are becoming obsolete (Ziman 1984) and his norms describe an ideal state further out of reach than in most periods of the history of modern science. In a world of deadlines

and short-term projects, a firm result is expected by the end of the given period of research, and the increasing pressure to publish results acts strongly against organized skepticism. Financial interests can influence citizens' views on scientific issues (from the effects of tobacco smoke to the magnitude of climate change) and delay adequate policy response (Oreskes and Conway 2010).

Since the last decades of the 20th century, focus on the recipient and user of science has increased. The questions the public is interested in can rarely be answered by “ready-made science” deposited in textbooks, they belong to “science in the making”. These are typically questions that are (still) controversial, and non-experts are faced with different and partly contradicting expert opinions from which they have to build their own system of beliefs. Some people find it amusing to know how pendulums move, to which already consensual answers exist, but it does matter to all of us whether certain materials or activities are healthy or not. For example, traditional and complementary and alternative medicine (CAM) services register over a billion patient-visits yearly but formulating policies is a serious challenge in most countries as technology and health-care systems are fused with CAM before science could (fully) translate it. The first two advances mentioned by Weaver gave us excellent tools for the regulation of *products* like herbal medicines but is moderately helpful when *practitioners, healing techniques, and ideologies* are to be regulated.

Today much of STS research centers on how science, embedded in society, and as part of society interacts with other parts. The scope and diversity of the methods of analysis helped to understand social processes as well as communicative practices of science and can help to optimize regulation. The “third wave” in science studies focuses on the layman as a problem-solver in the context of technological, social, and everyday needs and offers assets for conceptualizing decision-making in mixed policy settings.

Apart from being useful, STS has always been unsettling for science and traditional communication of science. From early on, engaged factions of the field clearly took positions in political matters and interdisciplinary boundary work by scientists jeopardized careers. The most salient example was the “Science Wars”; a textbook from the period is Hess (1997), and a reconciliatory edited volume is Labinger and Collins (2001). Scientistic fundamentalism is likely to see a “postmodernist” threat in some strands of the discipline, even though it is needed and more used by science and society than ever since its inception. At present, STS is a stable part of academia, better networked into research and development and policy-making than into curricular reforms or science education (Allchin 2004), and little of the results entered the classrooms, where the view of science is institutionally transmitted to the next generation.

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Nina Janich

## 7 The contribution of linguistics and semiotics to the understanding of science communication

**Abstract:** The essay presents a brief overview of the development of linguistics research on scientific language and science communication as well as a selection of the key findings of linguistics and semiotics research concerning science communication. Science communication is understood in this article as a fundamentally discursive and rhetorical phenomenon. A key conception of science is that science is a laborious process of research that is repeatedly renewed and developed further and that is affected by a teacher–student relationship that characterizes every scientific discipline. The resulting discursive construction and establishment of scientific knowledge is the motivation for linguistics research not only about the linguistic features and stylistics of scientific language or the genres of science but also about scientific intertextuality and controversy and about challenges in contexts of interdisciplinarity and knowledge communication/public understanding of science. To conclude the overview, there is a brief look at the semiotic resources evident in science communication and at some approaches to describe scientific multimodality linguistically. It has never, indeed, been possible to imagine science without visualizations, and text layout and typography have performed important functions in the construction and ordering of scientific knowledge for many centuries.

**Keywords:** knowledge communication – discourse communities – scientific genres – scientific writing – rhetoric of science – scientific uncertainty – multimodality

### 1 Linguistics and semiotics research on science communication – a historical overview

This essay begins with a brief overview of the development of linguistics research on scientific language and science communication before going on to present some of the key findings of linguistics and semiotics research in the sections that follow. By way of conceptual clarification, it should be noted that “science communication” here refers to communication in and about science in the broadest sense, as indicated in the introductory chapter of this handbook.

In Europe, linguistics research on science communication in this broad sense begins with research on the *language* of science. The constitution of science through language is one of its fundamental features (alongside its capacity to reflect on this linguistic constitution): scientific research, publishing and teaching are inconceiva-

ble without linguistic acts of description, definition and explication and without the formulation of hypotheses, arguments and proofs (cf. e.g. Gross 1990: ch. 1; Liebert 2002: 69–77). From antiquity (Aristotle) onwards, scientific discourse has been based on dialectics and eristics (Fritz 2010: 460), that is, on critical engagement with other approaches and hypotheses, with their terminologies, basic theoretical assumptions, their arguments and conclusions (see Chapters 15, 25, and 27, this volume). In a reference to sophistry, Gross (1990: 3) postulates: “Rhetorically, the creation of knowledge is a task beginning with self-persuasion and ending with the persuasion of others.” He therefore defines and analyses science communication from a fundamentally rhetorical perspective (for further detail on this, see section 2.2).

For a long time, European linguistics has dealt with the language of the sciences mainly from the research perspective of languages for special purposes (LSP) and scientific writing – in other words, predominantly in terms of lexicology, language varieties and stylistics (cf. e.g. articles contained in Bungarten 1981; Kretzenbacher and Weinrich 1994; Hoffmann, Kalverkämper and Wiegand 1998; see also Chapters 8 and 13, this volume). Roelcke (2010: 14–28) describes the history of research over the last 40 years as a process in which conceptions of language have continually been shifting and developing further: (1) from the “systems theoretical model of inventories” (*systemtheoretisches Inventarmodell*) with its emphasis on descriptions of scientific terminology and syntax, and (2) the “pragmalinguistics context-related model” (*pragmalinguistisches Kontextmodell*), which takes account of genres of scientific languages and their discursive functions, to (3) the “cognitive linguistics model of language function” (*kognitionslinguistisches Funktionsmodell*), in which the (co-/re-)construction and transformation of knowledge are most prominent. Kastberg (2010) charts a similar development in distinguishing “classical” linguistics research on scientific language from the more recent, strongly interdisciplinary research field of “knowledge communication”. According to Kastberg (2010: 59), traditional European research on scientific language is characterized by a set of shared basic theoretical assumptions, namely, by “(a) an expanding linguistic ontology, (b) an ideology of opposition and (c) a commensal relationship to (non-linguistic) host discipline(s)”. In other words, it assumes that scientific language serves to represent scientific objects and subject matters (“ontology”) and, in systematic terms, is in “opposition” to everyday language; this is why, for a long time, linguistics research on it was conducted largely in parallel (“commensal relationship”) to the scientific disciplines to which it referred. According to Kastberg (2010), a strongly interdisciplinary field of research, “knowledge communication”, has since emerged in contrast to this. The newer approach essentially takes as given that knowledge is jointly negotiated and co-constructed by those involved in the communication and thus exists in a “mutual relationship” with the non-linguistics disciplines it studies, engaging in reciprocal research and intensive exchange. Crucial to this field of research, according to Kastberg, is that it starts out from concrete problems rather than from underlying linguistic theories, and only then develops suitable methods.

Both strands of research have continued to this day and are mutually fruitful, with linguistics research on scientific language(s) looking more at the linguistic form (especially terminology and syntax), cultural specificity and diachronic development and differentiation of scientific texts and genres on the one hand, and the constructivist/discourse linguistics perspective focusing on the construction of knowledge and the processes by which it is justified, established and disseminated in science and society on the other (cf. e. g. Gotti 2003; Hyland 2004; Hyland and Bondi 2006; Hyland and Shaw 2016; Atayan, Metten, and Schmidt (forthcoming); for an overview of international research cf. also Pahta and Taavitsainen 2010; Gloning 2018; Bachmann-Stein 2018). Over the last few years, the research lens has increasingly widened: linguistics nowadays, much like other disciplines, also incorporates forms of visualization and multi-modal communication in and about science into its research (see section 4).

In the following I shall outline a few fundamental questions, key findings and current perspectives in order to give an impression of what linguistics and semiotics/multi-modality research can contribute – indeed, what they already have contributed – to research on science communication. While this will not be an exhaustive account, it at least points to a number of key distinctions and specific highlights.

## 2 Basic distinctions and research emphases in linguistics studies of science communication

Research on scientific language(s) not only has various pragmatic dimensions (e. g. intradisciplinary vs. interdisciplinary vs. non-disciplinary/non-scientific communication) but also a genuinely diachronic dimension (the following comments draw on Pahta and Taavitsainen 2010: 554–558). When we speak of scientific languages, we are generally referring tacitly to a European phenomenon of the last 500 years. Prior to this, Latin (after Greek) was the universal language of science in the Western world, being prominent in European universities and continuing thus, in some instances, into the 19th century. In a process of vernacularization, various individual languages gradually emerged as languages of science during the early part of modernity, having been increasingly institutionalized with the emergence of scientific journals in the 17th century. While the early 20th century still saw competition between French, English and German as *linguae francae* of the sciences, it is now English that dominates as the universal language of science. The development of other individual languages of science today and linguistic comparisons between different period- and culture-specific styles of science in particular constitute a research field of its own (in addition to the references to English, Swedish and Spanish found in Pahta and Taavitsainen 2010, cf. e. g. Pörksen 1986 and Prinz and Korhonen 2011 on German; for explicit comparisons of language and culture, cf. e. g. Galtung 1981; Clyne 1987; Gunnarson, Bäcklund, and Andersson 1995; Redder, Heller, and Thielmann 2014).

## 2.1 Dwarfs sitting on the shoulders of giants: Scientific discourse communities

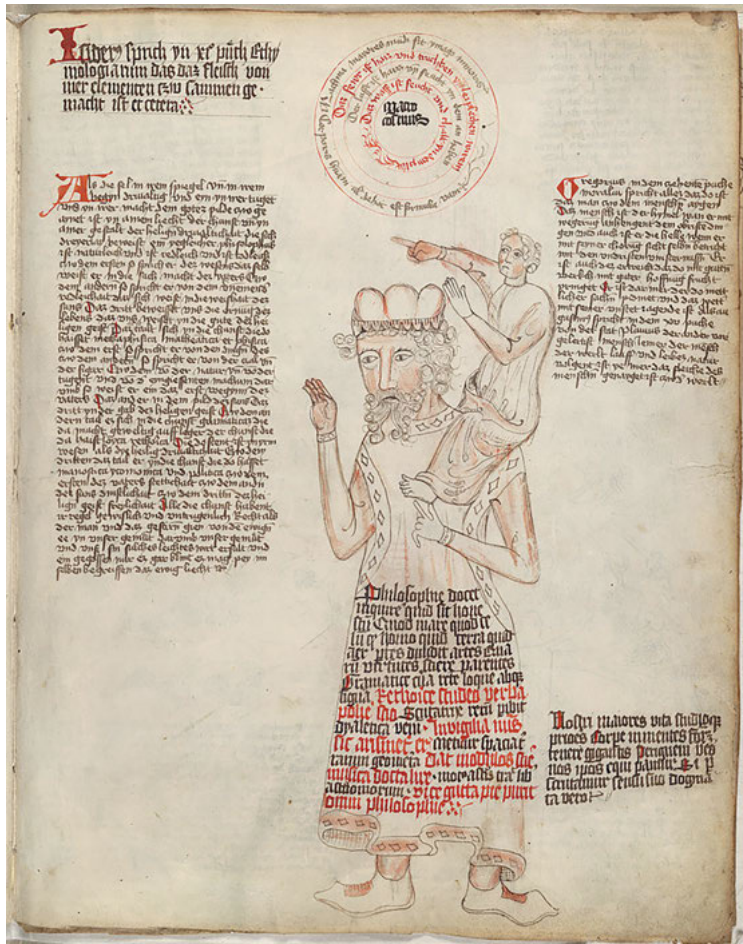


Fig. 1: A page from a 15th-century handwritten manuscript (Library of Congress, Rosenwald 4, sheet 5r.jpg; cf. [https://commons.wikimedia.org/wiki/File:Library\\_of\\_Congress,\\_Rosenwald\\_4,\\_Bl\\_5r.jpg](https://commons.wikimedia.org/wiki/File:Library_of_Congress,_Rosenwald_4,_Bl_5r.jpg))

The idea of the “dwarf sitting on the shoulders of a giant” (orig. from Bernhard von Chartres; also cf. Merton 1993 [1965]) (cf. Fig. 1) is a key conception of science in the sense that science does not take place in a vacuum; rather, it is a laborious process of research that is repeatedly renewed and developed further – as Max Weber (1922 [1919]: 534) pointed out: “We cannot work without hoping that others will advance beyond us.” Legitimacy within this process of research arises not just from observation and experiment, from describing and explicating (i.e. from the *logos*) but quite crucially

also from reference to authorities (and therefore from a specific *ethos*) – not least, due to the teacher–student relationship that characterizes every scientific discipline:

To become a scientist is to work under men and women who are already scientists; to become a scientific authority is to submit for an extended period to existing authorities. These authorities embody in their work and thought whatever of past thought and practice is deemed worthwhile; at the same time, they are exemplars of current thought and practice. [...] As long as science is taught as a craft, through extended apprenticeship, its routes to knowledge will be influenced by the relationships between masters and disciples. [...] By this means, research traditions are founded, and the methodological and epistemological norms that determine the legitimacy of arguments are passed on as tacit knowledge. (Gross 1990: 14)

This fundamental discursivity of science, referred to in the introduction above, leads at the level of the text to a high degree of intertextuality. Drawing on surveys of scientists and textual analyses, Jakobs (1999) describes intertextual referencing in scientific texts as the “outcome of linguistic acts” and reconstructs a broad spectrum of functions and effects. This includes above all (summarized in Jakobs 1999: 132):

- providing an overview by summarizing the current state of research;
- establishing strands of debate, safeguarding continuity, building tradition;
- supporting an argumentative (and evaluative) text structure;
- using citations as a means of conducting relationships in the scientific community, e. g. building acceptance for the specific interests of individuals or groups;
- shaping the text rhetorically and making the author’s task easier by borrowing formulations.

The question of which function is performed by which reference in which text depends on a range of issues and considerations:

These include the textual variety to which the text containing the reference belongs and what its purpose is; cultural, disciplinary and group-specific conventions and interests; the positioning of the author in the research community (expert vs. novice, status, etc.); educationally specific as well as personal skills and routines, and the prior stocks of knowledge possessed by both author and potential addressee. Not to be underestimated are the stipulations applied by places of publication, i. e. journals and publishing houses. (Jakobs 1999: 133; translated from German)

One essential function of scientific intertextuality, apart from “juggling with constraints” in the course of text production as described by Jakobs (1999: 133), is the discursive construction and establishment of scientific knowledge accomplished by honoring the precept of debate (see also section 2.3). Here, too, linguistics – starting out from the Aristotelian distinction between dialectic and eristic (Fritz 2010: 460) – offers more differentiated distinctions and analyses. Dascal (1998, 2006), for example, proposes an ideal-typical three-way division into debate, dispute and controversy. He differentiates these from one another on the basis of their different structures (aims, reference, procedures, method, possible ending, possible cognitive gain). Thus, while the aim of *debate* is to find a solution to a clearly defined problem by means of proof



or experiment and thereby ultimately to eliminate a false belief, the aim of a *dispute* is to achieve victory over an opponent – by means of deceit, if necessary. Here, the fundamental agonal positions ultimately remain irreconcilable; at best, they are acknowledged as being such. The ideal type of a Dascalian *controversy*, by contrast, is a more comprehensive process which, while starting out from a specific question or problem, gains in breadth and depth and is disputed by means of argumentation. Recognizing and accepting the existence of opposing views as a possible ending and a possible gain is just as feasible as resolving them, perhaps by creative means. In specific cases, these forms usually blur into one another, yet identifying such different structures (and thus communicative practices) promises to enable a clearer systematization in linguistics research on controversies (Fritz 2010: 460 f.; see also Chapter 15, this volume). Such a systematization is still lacking, however, as is a systematic overview of the numerous language- and culture-specific (or comparative), synchronic and diachronic studies of scientific controversies (cf. e.g. Engelhardt and Caplan 1987; Salager-Meyer 2005; Liebert and Weitze 2006; van Eemeren and Garssen 2008).

The fundamental discursivity of science acquires a new dimension, of course, in the age of digitalization. Very recent studies therefore address issues of digital research environments and infrastructures (looking at scientific editions, e.g. Bender 2017) and the way processes of publication and debate are digitally supported and constituted (e.g. Gloning and Fritz 2011; Engberg and Maier 2015; Meiler 2018).

## 2.2 Rhetoric of science

If science is described as a discourse community (Swales 1990), or rather as a network of discourse communities, the question that arises is what counts – contingent upon time and culture – as “scientific” at all in a society or a scientific community (cf. Gross 1990: 8–9). The postulate widespread in linguistics is that knowledge (and therefore also science) is straightforwardly socially constructed and that, as such, it is also shaped by socio-cultural phenomena such as epistemic cultures (e.g. Knorr-Cetina 1999), thought styles (*Denkstile*, e.g. Fleck 1980 [1935]) and habitus (e.g. Bourdieu 1997). As Gross demonstrates with reference to historical examples from the natural sciences, this leads to a rhetorical view of science communication:

The rhetorical view of science does not deny ‘the brute facts of nature’; it merely affirms that these ‘facts’, whatever they are, are not science itself, knowledge itself. Scientific knowledge consists of the current answers to three questions, answers that are the product of professional conversation: What range of ‘brute facts’ is worth investigating? How is this range to be investigated? What do the results of these investigations mean? Whatever they are, the ‘brute facts’ themselves mean nothing; only statements have meaning, and of the truth of statements we must be persuaded. These processes, by which problems are chosen and results interpreted, are essentially rhetorical: only through persuasion are importance and meaning established. As rhetoricians, we study the world as meant by science. (Gross 1990: 4)

Here Gross (1990) shows very convincingly – and in a way that renders his point applicable to the social and human sciences as well – how classical terms from rhetoric can be applied analytically to scientific texts, their objects and their arguments. Examples include:

- *stasis* as the degree of validity of scientific knowledge (“Particular scientific texts emphasize particular *stases*. [...] Differently interpreted, the *stases* can lead – in fact, have lead – to radically different conceptions of science.” Gross 1990: 7–9; on the significance of “environments of understanding” (*Verstehensumgebungen*) for the acceptance of plausibilities as facts, also cf. e. g. Böhnert and Reszke 2015);
- *topoi* at the level of the *logos* as “important sources for arguments in science” (Gross 1990: 10 f.: “common topics” such as comparison, cause and definition or “special [scientific] topics” such as precise observation, prediction and mathematization). The activities labelled here as *topoi* can also be modelled as linguistic acts such as formulating arguments, explicating and interpreting (on this, cf. Liebert 2002: 69–77, especially 71);
- the participation of scientific texts in various *genres of speech*: “A scientific report is forensic because it reconstructs past science in a way most likely to support its claims; it is deliberative because it intends to direct future research; it is epideictic because it is a celebration of appropriate methods.” (Gross 1990: 10 f. cf. also 2.1 and 2.4);
- the role of *ethos* and *pathos* in scientific texts whose purpose, given the state of existing research, is to establish legitimation (*ethos*), attest innovatory power and defend against attacks (*pathos*) (cf. Gross 1990: 12–14);
- the epistemic or ontological functions of the arrangement and style of scientific texts (cf. Gross 1990: 16–18).

While Gross bases his account rather narrowly on the classical rhetorical system of description and focuses on the natural sciences, his approach is also reflected – more openly in both respects – in studies that engage critically and normatively with the issue of what constitutes a (good, appropriate, prototypical) scientific style (e. g. for the German language, cf. Jäger 1996; Ehlich 1998; Janich 2004, 2015).

## 2.3 Pragmastylistics and normative approaches

In traditional (Western) research on language for special purposes and scientific language, debates are centered around at least four normative principles for generating scientific texts (cf. for example Weinrich 2006: ch. V; Auer 2007; Steinhoff 2007; Roelcke 2010). These are: exactness, unequivocalness, context independence and neutrality. It is assumed that exactness and unequivocalness in expression and reference are achieved above all through the use of scientific terminology, while context independence and neutrality are accomplished more by means of grammatical pref-

erences and deagentifying syntax (e.g. use of the passive, noun-based style). The various lists of stylistic prohibitions and precepts, however, generally remain unsystematic – not least because these norms relate to highly varied contexts, exist at very different linguistic and content-related levels, and do not apply to the same extent to all genres of scientific language or all specialist and linguistic cultures. In addition, they are often too seldom traced back to their functionality and thus remain too detached, as stylistic norms, from the purposes of science communication and its associated textual functions. Yet the key feature of all scientific communicative practices – given the specificity of their objects and of the scientific theories and methods associated with these – is their high functionality, which is what makes it possible to discover their corresponding textual procedures and linguistic features in the first place (cf. e.g. Halliday 2004 [1999]). Textual procedures refer to specific “methods of text(ualization) that are socially integrated and serve the purposes of text building and communication” (Steinhoff 2007: 119; translated from German); these methods are “routine acts connected to the general demands of scientific practice” (Steinhoff 2007: 118; cf. also Feilke and Bachmann 2014). Czicza and Hennig (2011) have therefore endeavored to assign syntactic phenomena to pragmatic functions both systematically and qualitatively in order to enable a more functionally oriented rationale and interpretation of the grammatical features of scientific texts. In Czicza et al. (2012) they put their theoretical model to the test empirically by taking a highly unscientific text (a children’s novel by Erich Kästner) and a highly scientific text (a linguistics journal article) and deriving figures to reflect the contrasts observed for each procedure (in the sense of frequencies of selected grammatical resources), the aim being to quantify the poles of maximum vs. minimum ‘scientificity’ of language use. To define the pole of feature-rich scientificity (scientific language use) in qualitative terms, they arrange the norms of use of scientific language systematically, relate them to one another as textual procedures that can be variously realized in language, and condense them into four cardinal precepts (overview in Czicza and Hennig 2011: 52):

1. The *precept of economy* is linked to the procedure of condensing; condensing is achieved, for example, by using compound nouns, extended noun phrases or adverbial prepositional phrases to present matters of fact.
2. The *precept of precision* (often referred to also as the precept of exactness or of clarity in research) is linked to the procedure of characterization; this is realized, for example, through determinative compounds, adjuncts and linguistic resources used to express explicative relations.
3. The *precept of origo-exclusivity* (frequently referred to in research as the precept of anonymity and neutrality) is linked to procedures of deagentifying and detemporalizing; these are realized, for example, through the passive voice and by a preferential use of the 3rd person and the present tense.
4. The *precept of debate* (i.e. the “precept of critique” in terms of Weinrich (2006: 2010), or the “eristic” structure of scientific texts in Ehlich 1993) is linked to the procedure of relativization; this is realized, for example, by the subjunctive or

by linguistic resources and syntactic turns of phrase that express concessive or adversative relations.

Janich (2016) extends these four precepts from a more markedly discourse linguistic perspective and by reference to the “Zurich Text Analysis Grid” (Nussbaumer 1991; summarized in Sieber 2008), and introduces three further precepts at the levels of comprehensibility/coherence (5), aesthetic suitability (6) and relevance of content (7):

5. The *precept of intersubjective transparency* is linked to various procedures of explication and text structuring. This includes, for example, the use of metacommunicative elements for reader orientation, the naming and explicit marking of definitions, hypotheses and methods, etc., structuring elements at the level of content, language and typography as well as via text design, illustration using examples, pictures or diagrams as well as via expressions aimed at establishing causal and conditional relations.
6. The *precept of pleasing aesthetic form* is linked to the procedure of gestalt-giving formulations (in a pragmatist sense that sees style as social gestalt, which in turn can be variously suited to the subject matter, audience and situation; cf. Fix 2007). It is difficult to list individual linguistic resources specifically, because it is generally hard to establish stylistically how great the “linguistic risk” is that authors are willing to take and that appears acceptable to them in terms of both audience and genre. Processes whereby a text is rendered attractive or comprehensible might be included in this.
7. The *precept of scientific integrity*: this precept (which in no small measure refers to postulates in the sociology of science put forward long ago by Weber (1922 [1919]) and Merton (1973 [1938])) places responsibility for the argumentation and style of the text squarely on the writer via the procedure of self-critical reflection (for example in the form of adhering to professional maxims of communication and of showing integrity in the style of argumentation).

Since, in addition to learning specialist terminology and acquiring relevant knowledge of theories and methods, novices must first learn the textual procedures and conversational conventions corresponding to these precepts, a broad field of research on writing and the production of scientific texts has become established over the last several years. Researchers in this field are interested in the genesis and development of students’ textual skills and in didactic strategies for furthering these skills (for the German language, see e. g. Pohl 2007; Steinhoff 2007; Feilke and Bachmann 2014; for the English language, see e. g. Hyland and Sancho-Guinda 2012, Hyland and Shaw 2016).

## 2.4 Disciplines, practices, and genres

As will have become evident in the preceding sections, the use of scientific language depends on discourse communities on the one hand and specific communicative purposes on the other. From a linguistics perspective, then, both the variety of scientific specialisms and their specific cultures as well as different communicative practices ought to be differentiated just as much as the various above-mentioned cultural and temporal dimensions of science communication and those relating to individual languages. Drawing boundaries between specialisms and disciplines and thus also between specialist *languages* within science is not easy, however, because classical divisions into different core specialisms or basic disciplines barely do justice anymore to today's scientific reality with its division of labor and differentiation within disciplines as well as the widespread practice of working in interdisciplinary and transdisciplinary contexts (cf. e. g. the division into first-, second- and third-level disciplines in Kastberg 2014). The question of an appropriate division into and distinction between specialisms cannot be satisfactorily addressed here, but the horizontal differentiation of scientific languages must always be borne in mind and addressed in linguistic analyses. Added to this is a necessary vertical differentiation according to the addressee group and its corresponding discourse community. In the tradition of research on specialist languages a distinction is often made according to the level of abstraction of various communicative situations. This means, for example, that communication (and thus also linguistic register) in the highly specialized theoretical sciences can differ, in principle, from communication that occurs in the context of applied science conducted, say, in inter- or transdisciplinary cooperation. Communication for the dissemination of knowledge at the level of university teaching, in turn, should be distinguished from communication with a broader, not necessarily academic public (see also sections 3.1 and 3.2). Traditionally, these horizontal and vertical distinctions have been analyzed by focusing on specialist vocabulary, i. e. for example, on the description of discipline-specific sets and systems of terminology (cf. e. g. Faber 2012; Roelcke 2015) and on corresponding practices of definition and legitimation in the disciplines (cf. e. g. Müller 2011; Kalwa 2018). The more the communication moves away vertically from the abstract level of theoretical science, the more interesting it becomes to see which strategies are deployed to explain, paraphrase, replace or eliminate the terminology that otherwise appears necessary to express a given subject matter (cf. e. g. Niederhauser 1999: 141–158).

In the disciplines and possibly even more narrowly constituted discourse communities that are to be differentiated thus (e. g. in the sense of specific schools or specialist foci), different communicative and linguistic practices are deployed in the course of academic praxis. “Communicative practices” should be taken here to refer to what Habscheid (2016: 137; translated from German) has described as “processes of an embodied mode of conduct” (*Prozesse eines verkörperten Betragens*) which “first, are anchored in a general ‘infrastructure’ of interpersonal interaction [...] and, second,

become comprehensible as action – and therefore as praxis – on account of, among other things, the situated use of signs”. *Linguistic practices*, as a subcategory, are those *communicative practices* which are materialized (e.g. via the written word) *through language* in a semiotically situated way and in separation from the body (Habscheid 2016: 137). Such linguistic practices are realized in the form of types of scientific text and conversation shaped by different inventories (e.g. discipline-specific terminologies) in a given language, cultural and specialist conventions (e.g. different patterns of text type in the natural sciences as opposed to the human sciences), technical forms of communication (e.g. various forms and degrees of multimodal-capable print vs. online vs. live formats), and the institutions and organizations that form the backdrop to these practices (e.g. universities vs. industry) (cf. Habscheid 2016: 139). At the performative level they are interwoven with *non-linguistic* communicative practices (cf. e.g. Rhein (2015: 417) on the role of humor, expressed through laughter, in scientific debates) and are, above all, embedded in the wide variety of *non-communicative* practices that constitute science (such as experimenting and observing).

The “scientific article” and the “scientific monograph” are the principal genres of communication within science and within disciplines. However, they are merely condensed forms and fixed points of a highly complex specialist and social praxis that needs to be further differentiated both horizontally and vertically:

Scientific books and journal articles are just the most visible products of verbal interaction within the community, posed photographs of a continuous activity captured at certain ritually significant moments, designated occasions suited to studio portraiture. We need to investigate not only the finished products but also the earlier stages of the complex persuasive process by which new science passes from private to public, from laboratory notebook to student textbook. (Gross 1990: 129)

In addition, these two genres are interwoven and interconnected at a functional level with other linguistic practices (e.g. with genres such as the “abstract”, the “review” as well as the “textbook” and the “handbook”), which differ according to their length and structure, function, intended addressees and/or degree of publicness. Text linguistics, conversation analysis, stylistics and pragmatics have already generated numerous detailed descriptions and insights and have also produced temporal and/or cultural comparisons of prototypical textual and conversation structures in various specific languages/scientific cultures (for a small selection, cf. e.g. Swales 1990; Göpferich 1995; Ylönen 2001; Gross, Harmon, and Reidy 2002; Gotti 2003; Fløttum, Dahl, and Kinn 2006; Auer and Baßler 2007; Gunnarson 2009; Gotti, Berkenkotter, and Bhatia 2012; cf. also the various accounts of selected genres in this volume). This field of research has become increasingly interdisciplinary in the context of debates around the concept of praxis/practices, not least due to the inclusion of social scientific approaches, as the aim is to consider shared conventions, symbolic systems, values and norms as foundations of sociality (cf. Habscheid 2016: 139), especially epistemic cultures and thought styles (cf. e.g. Hyland 2004; Andersen, Fix, and Schiewe 2018).

### 3 The bigger picture: special contexts and discourses

#### 3.1 Interdisciplinarity

In the following, interdisciplinarity refers to a multi-perspectival view of a problem that can be solved only when different disciplines are involved whose scientists cooperate with one another. Transdisciplinarity, by contrast, generally refers to the additional involvement of non-scientific partners in the research process.

From a linguistic point of view, the key difference between communication *within* disciplines, which formed the main focus of section 2, and communication *between* disciplines, addressed here, concerns the different prior knowledge of the respective partners to the communication. Knowledge asymmetries are assumed to exist from the outset in interdisciplinarity, as those who are experts in their own discipline are usually laypeople in other disciplines. This gives rise to a range of challenges for written and oral communication which can be studied linguistically (cf. e.g. the chapters in Hyland and Bondi 2006; Grove Ditlevsen and Kastberg 2011). This is especially the case, for example, in collaborative writing done for project applications or publications emerging from interdisciplinary projects and in collaborative project work, but also applies to lectures given at interdisciplinary conferences. As a rule, then, communication between different disciplines is initially based on shared basic scientific values, communicative practices and linguistic norms (see 2.3 and 2.4) and a non-discipline specific “everyday scientific language” (*wissenschaftliche Alltagssprache*, Ehlich 1993). However, any closer engagement with a shared research problem inevitably necessitates the use of specialist terminologies, theorems and methods – and contact between different epistemic cultures and thought styles. Accordingly, linguistics studies interdisciplinary communication not only with regard to a possible shared language and the emergence of interdisciplinary registers (e.g. Teich and Holtz 2009) but also with regard to different roles in interaction and discursive processes of negotiation at the levels of content (e.g. topics and aims, theorems, methods), relationships (e.g. handling of hierarchies) and procedures (cf. e.g. organization of writing processes) (cf. e.g. Janich and Zakharova 2011, 2014). If the disciplines involved are very remote from one another and no expectations are harbored over having to maintain agreement over an extended period of time (as in projects), then disputes, sometimes serious ones, can arise. In such cases it often becomes more important (depending on the situation) to highlight one’s own achievements and scientific expertise; expressions of criticism can also become more pointed, especially when disputes are conducted before an audience, so far largely neglected by research (for detailed conversation analyses, see e.g. Konzett 2012; Rhein 2015). In the interdisciplinary context, too, varying degrees of debate, dispute and controversy can arise (see section 2.1), nowadays additionally facilitated by various means of digital communication (cf. e.g. Meiler 2018).

### 3.2 Communication for knowledge dissemination

Another instance of knowledge asymmetry is found in the realm of science communication oriented toward a non-scientific audience. Linguistics research on this dimension of knowledge communication forms – as yet a rather marginal – part of the “Public Understanding of Science” (PUS), an international research context largely influenced by the social sciences (cf. e.g. Bucchi and Trench 2014). Genuinely linguistic research issues include the question of how scientific knowledge is adapted in science journalism and public relations materials so that it is comprehensible, plausible and credible to laypeople (often enough, interested laypeople) (cf. e.g. Myers 2003; Gotti 2014; Fløttum 2017). One of the factors involved here is the extent to which the knowledge to be disseminated or transformed remains recognizable as scientific knowledge. Niederhauser’s study (1999) remains authoritative even today (at least for German-speaking countries) because his findings are repeatedly confirmed in highly varied genres. Niederhauser compared journalistic texts about semi-conductor technology with their scientific reference texts, deriving from this comparison the dissemination strategies and techniques used by journalists to incorporate their readers’ prior knowledge and possible source of interest into their account. Niederhauser postulates the following as more formal “techniques” of popularization: a) reducing the amount of information provided, b) reducing the density of information provided, c) linking together specialist terminology and creating explanatory contexts (e.g. through definition, paraphrasing, examples), d) largely eliminating the scientific apparatus, and e) using visualizations as eye-catchers or aesthetic “hooks”, not so much for explanatory purposes. He identifies the following popularization “strategies” as those more markedly related to content: a) personalizing scientific information, often in the form of stories about research successes and discoveries, b) emphasizing the technical and societal benefits of the research for environment and society, and c) referring explicitly to the everyday experiences and notions of their presumed readers. Liebert (2002) characterizes these strategies more abstractly as patterns of action that include such elements as explication, the extension of frames of reference, or references to laypeople’s everyday lives. Above all, though, his focus is on the issue of how uncertain or contested knowledge is conveyed by science journalists (Liebert 2002: 76, 360). According to him, journalistic communication aimed at disseminating knowledge is based primarily on reconstructing the scientific argument. This is done, for example, by presenting the issue to be explored, describing the progression of the argument and alternative discursive positions, and differentiating more or less explicitly between certain, uncertain and contested knowledge. If the journalist additionally wishes to express a judgment about the relevance of the scientific argument and of the potential impact inside and outside science of the knowledge it constructs, then a space opens up for textual actions that are genuinely journalistic, such as “alluding to danger”, “warning of risks”, “urging action”, “simplifying”, “exaggerating” or “drawing on clichés”. These kinds of procedures, patterns, strategies and techniques can be found



in numerous genres (cf. e. g. Luginbühl and Schröter 2018); for purposes of entertainment, they are often augmented – as Liebert’s examples demonstrate – by procedures of emotionalization and dramatization (cf. e. g. the studies presented in Jaki and Sabban 2016).

Less explored linguistically to date are the public relations materials produced by scientific institutions, science blogs and debates around citizen science (not to mention the communication conducted *within* the context of citizen science or other participatory contexts) (cf. an overview in Kuteeva 2016 and Hanauska and Leßmöllmann 2018, as well as other chapters in this volume).

### 3.3 Scientists as actors in public discourses

In discourse linguistics, scientists are regarded as being actors among other actors, i. e. as actors who, with their specific knowledge, purposes and discursive power, make interventions in macro-social affairs – and are quoted, instrumentalized or scrutinized by other actors. In all manner of contexts – prenatal diagnostics, palliative medicine, debates about homeopathy or burnout, genetic technology, energy technology, climate change and geo-engineering – scientific and technological knowledge, experimental evidence and the credibility of research play a key role in many broader public discourses (cf. e. g. the titles within the scientific book series “Sprache und Wissen”). Here, linguistics is interested above all in discovering how agonal stocks of knowledge are constructed, legitimized and asserted or established through language (Warnke 2009; e. g. via structures of argumentation, topoi, semantic struggles, metaphors, keywords, intertextuality, etc.) and what specific role *scientific* knowledge plays in this (e. g. as an argument from authority or in the form of instrumentalization of scientific language) – at this point we have come full circle to the rhetoric of science discussed above (see section 2.2).

More recently, linguistics has begun to address questions regarding the role of scientific uncertainty and scientific ignorance in public discourse (questions considered only in the social sciences up until the last few years). What is of interest here are the ways in which grammatical resources of modality (cf. e. g. Meyer 1997; Hyland 1998; Vold 2006), negation and temporality as well as lexical-rhetorical resources of description, ascription and evaluation of ignorance and uncertainty are deployed in different scientific and popularizing genres (for an overview cf. e. g. Janich and Simmerling 2015; Janich 2018). Janich and Simmerling (2013), for example, show how ignorance in climate change discourse is variously addressed, evaluated and functionalized by the actors involved: how scientists use it as a means of legitimation, while emphasizing their expertise and the need for basic research; how politicians view it as a question of credibility and of confidence in scientific institutions and expert reports; and how journalists refer to it, sometimes in descriptive reporting and sometimes as part of a cautionary investigative piece (see also the rhetorical analysis

in Simmerling and Janich 2015). Even a single catchword or keyword can sometimes take on a major role in the discourse (such as the word *experiment* in climate change discourse concerning geo-engineering; Janich and Simon 2017).

## 4 Semiotic resources in science communication

To conclude this overview, we take a brief look at the semiotic resources evident in science communication and how they together produce certain effects in the context of multimodal texts (cf. e. g. Tufte 2000; Heintz and Huber 2001; Heßler 2006; see also Chapter 11 in this volume). As mentioned above, science communication presupposes the use of language (see section 1). Accordingly, language is the key system of signs required for constructing, negotiating and disseminating (in the sense of co-constructing, justifying and establishing) scientific knowledge. This is why the present article has focused primarily on this semiotic level. However, a cursory glance at scientific texts (including many from the early days of science) shows that very often language is not used on its own but rather in conjunction with other semiotic systems: numbers and symbols, for example, play a significant role in presenting measurements, calculations and research results, especially in the natural science. Here, language is additionally accompanied by digits, special signs and symbols. These signs serve to fulfil the precepts of economy and precision and thus fulfil typical functions of specialist and scientific language. In prose text, the semiotic resources of typography and punctuation are also influential at the paraverbal level. Thus, for example, it is broadly common in linguistics to put the so-called object language (i. e. the language being discussed and analyzed) in *italics* in order to distinguish it from so-called met-language (i. e. the language being used scientifically to analyze linguistic features of the object language). If we are talking about speech acts in the abstract, classificatory sense, however, specific designations of speech acts such as DEFINE or DISCUSS are usually printed in upper case letters as a way of signaling their character as a category. Morphemes (i. e. the smallest units of language that have meaning) are traditionally put in braces, phones (i. e. units of sound) in square brackets, and graphs (i. e. units of written language) in angle brackets in order to distinguish the different levels of writing, speech and meaningful signs from one another in written texts (e. g. {sci-} {-ence} – [saɪəns] – <science>). Thus, a verbal text can be augmented with additional information, especially with semantic knowledge or scientific categorical knowledge, through the use of typography and the addition of linguistic signs including special symbols, conventionalized punctuation, digits and formulas. Other classic examples are the systems of notation found in chemistry, physics and logic (see Chapter 17 in this volume).

Regarding the level of the text, text design can also play an important role as a semiotic resource (also cf. Gross 1990 regarding “arrangement”). Text design refers

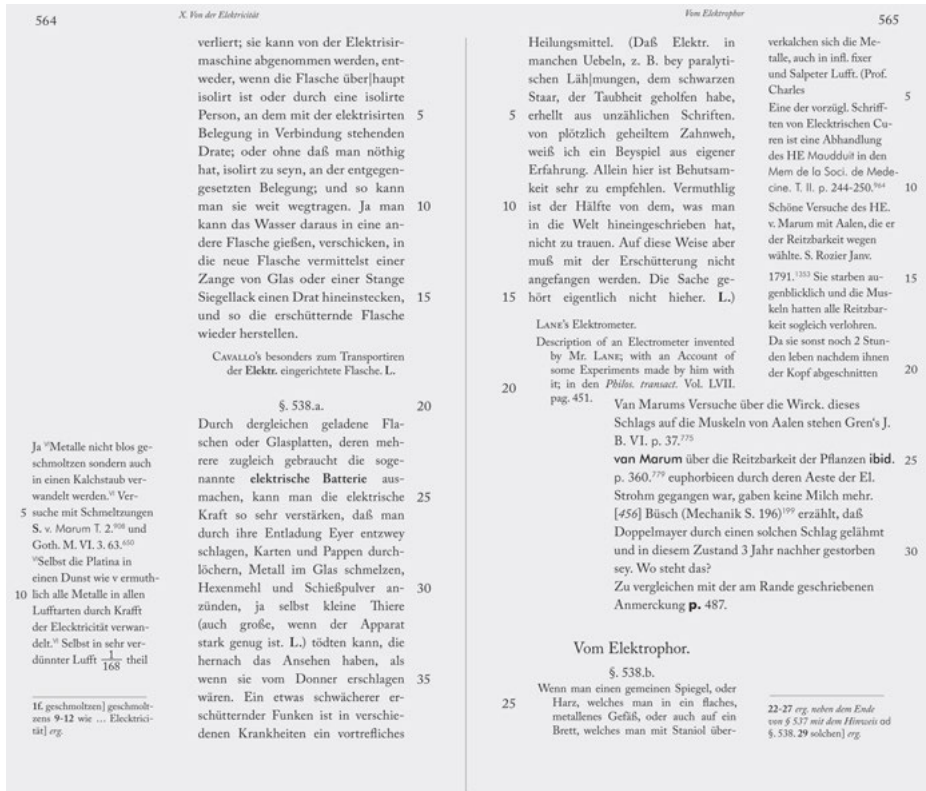


**Fig. 2:** Text design in a critical edition serves to distinguish between multiple instances of meta-textuality: a text by Ch. P. Erxleben (reference text), commented on by G. Ch. Lichtenberg (first meta-textual level), with added comments by the editors of the Lichtenberg edition (second metatextual level). (Extract from: *Georg Christoph Lichtenberg: Vorlesungen zur Naturlehre*. Lichtenberg's annotated personal copy of the fourth edition of Johann Christian Polykarp Erxleben: "Anfangsgründe der Naturlehre", ed. by the Academy of Sciences at Göttingen, Göttingen 2005 (Georg Christoph Lichtenberg: *Gesammelte Schriften. Historisch-kritische und kommentierte Ausgabe*, Vol. 1, 564 f.))

to the orchestrated arrangement of subsections of text and, where relevant, images within an overall text. The point at which text design becomes relevant to science communication is when it is used as a correlate to content-based structures or to various levels of representation, commentary and reflection – in other words, when it acquires itself the character of a sign or even of a norm. This semiotic character comes to the fore, for example, in critical editions in which different levels of commentary and source are distinguished by means of corresponding text design (cf. Fig. 2).

Text design also plays a role in distinguishing and characterizing different scientific genres: unlike original scientific publications, science textbooks and course record books make use of, for example, columns, boxes and margin notes to facilitate reception in the sense of giving orientation in the text and hierarchizing knowledge.

In contrast to this, the academic journal article – especially in the natural sciences – is strictly standardized in structural terms (cf. e. g. Gross 1990: ch. 6) and – in the humanities especially – is generally accompanied by the academic apparatus of footnotes and annotations. In the era of online communication, the potential for designing and thereby both structuring and augmenting texts has seen a huge change (cf. e. g. Engberg and Maier 2015), something linguistics is only very gradually beginning to explore when it comes to science communication.

Finally, however, mention should be made of images/drawings and – especially important for science – diagrammatic representations which, as a rule, are non-verbal semiotic resources. What is interesting here from a linguistic perspective is, first, the reciprocal relationship between image and text, including explicit references between the two modes (e. g. in the form of legends, figure notes or text within an image) and, second, how visualizations can be meaningfully included per se in linguistic analysis.

Researchers in multimodality, visual linguistics and media linguistics have recently developed a range of methods for analyzing and describing strategies of visualization and text–image relations (cf. e. g. Muckenaupt 1986; Diekmannshenke, Klemm, and Stöckl 2011; Klug and Stöckl 2016; see also overviews by Gloning 2018; Schmitz 2018). As these methods cannot be presented in detail here, two examples must suffice: Martinec and Salway (2005), drawing on systemic functional grammar and various social semiotics approaches, identify both the *varying informative status* of text and image as well as the *different semantic-logical relations* that need to be related to each other in any context involving both images and text (Martinec and Salway 2005: 343–352):

1. Status of text and image
  - *equal status: independent vs. complementary status*, both of them “realized by the whole image being related to the whole text” (Martinec and Salway 2005: 348)
  - *unequal status* (one of them modifies the other): *image subordination* (the whole image is related to a part of the text) vs. *text subordination* (“realized by deixis from text to image”, Martinec and Salway 2005: 348)
2. Logical-semantic relations between text and image
  - *elaboration: exposition* (“the text and the image are of the same level of generality”, Martinec and Salway 2005: 350) vs. *exemplification* (different levels of generality)
  - *extension*: “a relationship between an image and a text in which either the one or the other add new, related information” (Martinec and Salway 2005: 350)
  - *enhancement*: “one qualifies the other [...] by circumstantial relations of time, space or reason/purpose” (Martinec and Salway 2005: 350–351).

The claim made by the authors about this model is that it is capable of analyzing all manner of genres – and doing so diachronically. This model could be augmented

using pragmatic-rhetorical approaches which assume that images perform a specific *function* in science communication (cf. e.g. Gross 1990; Tufte 2000; Liebert 2007). Visualizations in scientific texts rarely perform a merely illustrative function: usually they are used to exemplify, to explain or – more important still – to support an argument, that is, to provide grounds or furnish proof.

An even more comprehensive linguistic proposal for analyzing multimodal genres (“multi-layered semiotic artefacts”), which additionally includes the level of functionality, is offered by Bateman (2008: 19; for detail, see ch. 3) who, likewise on a systemic-functional basis, suggests distinguishing between the following analytical levels:

- “Genre structure” (i.e. the genre-specific structure of an artefact),
- “Layout structure” (i.e. the nature and arrangement of communicative elements on a page and their functional hierarchization),
- “Content structure” (i.e. the structuring of information or propositions which constitute the content of the multimodal artefact),
- “Rhetorical structure” (i.e. the argumentative linking of elements relevant to the content),
- “Linguistic structure” (i.e. the use and distribution of linguistic resources in the layout structure),
- “Navigation structure” (i.e. the resources intended to channel and facilitate reception).

It has never, indeed, been possible to imagine science without visualizations, and text layout and typography have performed important functions in the construction and ordering of scientific knowledge for many centuries (cf. Gloning 2018, with examples). One example from early modern times are Christophe de Savigny’s “Tableaux” from 1587, in which the author sought to produce a comprehensive and well-ordered representation of early modern knowledge using tables – i.e. using diagrammatic and tree-like arrangements of text in addition to images (cf. explanations and figures in Siegel 2009). Another historical example of multimodal science communication that has already been analysed from a text linguistics perspective is Thurneysser’s book about plants (1578), in which

various multimodal resources interact in a coordinated manner to organize a specific set of information guided by the principles of Paracelsian astrological astronomy: margin notes next to two-column print, richly structured typographic elements, elements of spatial arrangement, the use of specific figures, also in conjunction with passages of text, demarcated boxes of text incorporated into the main text with their own topic-related functional purposes, ways of labelling topics using not just headings but also images relating to the topic. (Gloning 2015: 206)

The semiotic resources of science communication have been studied diachronically as well as synchronically using many different approaches, albeit to date in a highly unsystematic, isolated and disparate manner. In view of the ways knowledge

is ordered and rendered comprehensible and accessible, and how it is legitimated and established through discourse, linguistics should examine these resources more closely and more systematically in the future.

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## 8 The contribution of terminology research to the understanding of science communication

**Abstract:** The central role of terms in science communication is based on the fact that they designate and identify key objects and subject matters of an academic discipline. As will be shown, the traditional or general theory of terminology has defined the understanding of terms for a long time, specifying that a term should refer to one mental concept only, which in turn is linked to a specific object in a univocal manner, that a term should be monosemous and must be understood regardless of the context. The establishment of hierarchically ordered terminological systems would thus be a warrant for smooth and trouble-free communication between scientists, the theory assumes. One look at the use of terminology in any single discipline shows, however, that the validity of these principles is rather limited, and there are both concurring and polysemous expressions in every scientific field. Moreover, the concept of meaning advocated in traditional terminology theory is met with criticism by proponents of cognitive linguistics and pragmatics.

More recent approaches such as socioterminology and the study of terms in specialized language research focus on various aspects of term usage. These include, first of all, mapping out the knowledge organization involved in the use of terms and a new conception of terms as prototypes or frames, e. g. in socio-cognitive approaches, and, secondly, the social function of terms such as added prestige for users of particular terms, or the semantic struggles over terms; a third line of research explores how terms have been used in different academic disciplines, in different text types and at various moments in time. In recent research, processes of terminologisation and de-terminologisation have increasingly become the focus of attention.

**Keywords:** terminography, concept – concept relation – definition – term – univocity principle, prototype – frame, term formation – polysemy – synonymy – metaphor – semantic struggle – socio-cognitive approach – socio-pragmatic approach – socioterminology, terminological linearization

### 1 Introduction

Terms play a key role in the identification of and distinction between scientific disciplines and their central stock of knowledge. In the following sections I want to present different views on the notion of term in traditional terminology theory and in linguistic research on specialized communication to spell out key aspects in the development,

usage and transmission of terms. While the scientific conception in traditional terminological theory relies on the existence of taxonomically structured terminological systems to ensure scientific quality, the focus of analysis in applied linguistics lies on the actual use and weight of specific terms in different text types and on the question whether it is necessary or even practical to apply traditional criteria such as unambiguity and uniqueness to explain their use. Looking at the scientific communication process as a whole, applied linguistics also include the language users – on the producing as well as on the receiving end – and their contribution to the development and understanding of terms.

The paper starts with some general considerations on the significance of terms in science communication (see section 2). This is followed by an overview of general concepts of the traditional theory of terminology, which is closely linked to the name of Eugen Wüster. First, the principles underlying term standardization and terminography will be presented (section 3.1.); in a next step the contribution of terminology research to the understanding of science communication is looked at (see section 3.2.). Terminology considers itself as an academic subject in its own right, drawing upon theories and practices of applied linguistics but differing from the latter in its rigorously prescriptive, synchronous approach and focus on written texts. Seeking to abstract entirely from different uses of terms in authentic specialized texts, terminology brackets out the social, cognitive and ideological dimensions reflected in linguistic usage. The aim is to lay the foundations for unambiguous understanding and exchange in science communication which, from the traditional perspective, is only ensured if scientists have access to a coherent terminological system with clear-cut concepts. Since the 1990s theoretical assumptions, practical work and preferred methodologies of terminology have drawn criticism from both terminologists (e. g. Sager 1990; Cabré 1999) and applied linguists with a focus on specialized communication (see section 5). Despite sharing basic methodological assumptions including a descriptive, corpus-based approach to authentic texts, two separate lines of criticism should be distinguished: the socio-cognitive approach to terminology (in the sense of Temmermann 2000) influenced by cognitive semantics (see section 5.1.), and the communicative, socio-pragmatic approach (in the sense of Cabré 2003: 163–199; see section 5.2.) including socioterminology (in the sense of Gaudin 2005: 80–92). Shaping current theories of terminology to varying degrees, these fresh approaches describe their field of work as: “[...] corpus-based terminology (with topics like term variation, linguistic markers of conceptual relations, and changes in the meaning of terms)” according to Kageura and L’Homme (2008: 156).

## 2 Terminology and its functions in science

The link between language and knowledge is inherently strong. It is through language used in scientific communication contexts that fresh knowledge is produced and distributed, and existing knowledge is passed on and developed (Gloning 2018). Terms are a key linguistic tool for the constitution and organization of a scientific domain: terms are elements of a specialized vocabulary that are based on intersubjectively shared definitions whose meanings are (relatively) stable, which is why their use is not arbitrary and new meanings of an established term have to be verbalized and often need explicit justification. Ideally, a term should both accurately describe its specific scientific subject-matter and accurately capture that which is predicated about it (Knobloch 1987: 62).

The knowledge and use of terms distinguishes a scientist as expert in his or her speciality and is thus a sign of the successful secondary socialization in their subject field. Characteristically, the socialization process not only entails the acquisition of scientific textual skills but also, and importantly, the transfer of terminological knowledge often by means of specialist or technical dictionaries. Unlike standard textbooks and handbooks, specialized literature generally requires in-depth knowledge about terms, and the recipient has to unfold the body of knowledge associated with the terminology.

Irrespective of whether or not all the terms characteristic for an academic discipline match the criterion of well-definedness granting the correspondence between referent and predication (see section 3), irrespective of the academic culture in question and the role assigned to the interpretive acts of scientists in the process of communication (see section 4),

- a) terms always refer to the key facts, subject matters and issues within a discipline, and point to the structure and organizing principles of a field according to the specialist areas it combines; terms thus enable communication within a specialist framework – either verbally or in writing – according to the central patterns of specialized language use.
- b) terms play a key role in the identification, recognizability and distinction of disciplines; hence, the scholarly understanding of science since the early modern period implies the existence of a terminological system and apparatus.

While the process of terminologisation constitutes a decisive phase in the emergence of a new scientific field, the existence of a terminological system also helps to (critically) advance an existing subject field once the established terminology no longer corresponds to the current state of the scientific knowledge. Bleuler, for instance, who coined the term “schizophrenia” in 1908 to replace the then existing term “dementia praecox”, offered the following reason for his preference: “[...] the old concept was created at a time when the notions of both dementia and praecocitas were applicable in almost all cases they referred to. Nowadays, however, it does no longer capture the

extent of the illness adequately, because it is neither a question of all patients being essentially demented nor of a precocious state of dementia in all cases” (Bleuler 1911: 4; translation by Bettina Seifried).

Apart from the substitution of terms, terminological systems have, of course, differentiated further through new insights gained from microscopic analysis, as Gloning (2004: 293–294) shows using the example of Virchow’s “cellular pathology” (1858). This implies that in a historical perspective the change of terminology often corresponds to a change of ideas in the specialist area. Also, philosophers of science and specialists in their respective fields themselves critically reflect on the use and status of terminologies. Usually they focus on the process of concept formation and possible alternatives in a specific area (e. g. Carnap 1926 on concept formation). Key theoretical aspects mostly revolve around the kind or section of reality a concept must capture; whether – and how – concept formation is governed by somebody’s philosophy or worldview (see Ajdukiewicz 1934; Fleck 2011); and which definition – if any – will adequately capture the concept.

In addition to these functions and according to the linguistic and theoretical premises underlying the concept of term, we may also specify further functions. While traditional terminological theory (see section 3) abstracts from the context of use of terms in actual oral and written communications, socio-cognitive and socio-pragmatic approaches (see section 5) include the contexts of use in the analysis looking at the various strategies and motives of scientific actors regarding the use of terms and processes of terminologisation. This showed, for example, that although the communicative task of defining is central to all scientific disciplines, there is a wide variety of how this task is achieved linguistically due to different text types and academic cultures in the specialist fields. While in the natural sciences mostly formal languages are used to establish definitions, some scholars have drawn on everyday language as Pörksen (1986: 154) shows using the example of Freud, who avoided an overly terminological style, and represents, according to Pörksen (1986: 155), a terminological type oriented towards general language use. It is also important to take the dynamics of scientific communication into account, which frequently lead to competing views on the subject under investigation, and that, in turn, may result in different labels and designations. As a consequence the developing terminological system is usually neither consistent nor well-ordered but instead constitutes a pool/spectrum of terms indicating different positions in a scientific field; the semantic struggles analysed in studies on political communication thus also manifest themselves in scientific communication contexts through the existence of competing terms.

### 3 The traditional theory of terminology

#### 3.1 The foundations of terminology

Having precursors, for instance in the botanical nomenclature established by Carl von Linné (1707–1778), terminology as a principled activity emerges during the first decades of the 20th century under the influence of Eugen Wüster (Felber and Budin 1989: 13–19). In his dissertation thesis “*Internationale Sprachnormung in der Technik, besonders in der Elektrotechnik*. [International standardization of technical language with a focus on electronic technology]” (1931), Wüster establishes the main principles of terminological practice and terminography to develop a comprehensive theory of terminology. Apart from the Vienna school formed under Wüster himself, also the Prague school and a Soviet school evolve, as well as the Canadian Centre for Terminology (Felber and Budin 1989: 44–57), which all take a similar position: based on the findings that throughout the fields of technology and natural sciences great terminological variation and diversity prevails – which is seen as serious impediment to science communication on a national and international level – key priority is given to language planning in the hope of compensating for the deficiencies of general language. Based on terminology theory, huge national and international standards bodies were established, including the Deutsches Institut für Normung e.V. (DIN), the British Standardisation Institution (BSI) and the International Organization of Standardization (ISO) founded in 1946. The standardization of terms targets the ideal of smooth and efficient communication in scientific discourse: “[...] terminology studies have developed as a branch of applied philosophy of science” (Budin 2003: 72). According to its own understanding terminology theory seeks to clarify the role of language in the process of knowledge formation and shed light on the relationship between scientific language and scientific knowledge (Budin 2003: 72).

In terminology theory the relationship between concept, object and term is essentially based on an objectivist model. With reference to philosophers such as Bernhard Bolzano, Franz Brentano and Rudolf Carnap, this epistemological position is called “realist ontology” (Budin 2003: 76). A concept is conceived as a unit of thought that exists independently of the object and is not bound to a particular language: “[...] concepts were viewed as being separate from the linguistic designation (term)” (Faber and López Rodríguez 2012: 12). Terms are understood as labels for concepts, with the connection between object and term being arbitrary and created through the concept. Concepts are grouped into two major categories: general concepts like *cathedral* and individual concepts such as *Cologne Cathedral*. The conceptualizing process is described thus: “The cognitive process called abstraction leads to the formation of general concepts by categorizing similar objects into classes. A concept is a unit of thought made up of characteristics that are derived by categorizing objects having a number of identical properties” (Temmermann 2000: 13).



A term must have a biunique correspondence to exactly one concept, hence the crucial role of definitions (further see 3.2.). The most important ones are real or intensional definitions originating with Aristotle, who also introduced the distinction between generic terms (*genus proximum*) and differentiating features (*differentia specifica*), as well as extensional definitions and enumerative definitions, with the latter merely listing the objects referred to by a concept. The subdivision of types is consistent with the idea that a concept may be described from two perspectives: intensionally by its defining characteristics identified on an objective basis, and extensionally by specifying the objects to which the concept may be applied.

As terms cannot be looked at in isolation, terminological practice consequently operates on the distinction between generic and specific relationships, as well as part-whole relations represented in hierarchical, binarily structured stems. Hierarchical relationships are distinguished from non-hierarchical concept relations, with the latter including temporal, causal, sequential and antonymic relationships (Arntz, Picht, and Mayer 2009: 75–78). The resulting conceptual systems are regarded as ideal knowledge representations providing scientists with instantly recognizable, unambiguous information. They are meant to serve as the basis for new scientific knowledge, and thus have an epistemic function. As the foundation of any form of scientific communication, they are also attributed a discourse organizing function. A term defined according to the principles of terminology theory must unambiguously designate one concept only; it must be monosemous and understood by all scientists in the same way regardless of the context. In traditional terminology neither typical contexts of use nor collocations are taken into account, since that would require a syntagmatic, text-based analysis; also encyclopaedic knowledge associated with an object is not deemed relevant in terminological practice. While expressions in everyday language are often fuzzy and may yield (slightly) different understandings, this should not apply for science communication. That is reflected in the principles of terminological practice: What is intended is a clear-cut distinction between terms avoiding cases of synonymy, polysemy, homonymy and context-dependent meanings. Moreover, terms should be devoid of connotations and metaphors only be employed to the extent that they facilitate scientific-technical clarity. It should be noted that standardization is not only pursued within the limits of specialized subject areas but across disciplines and, most importantly, on an international scale. Terminologists see the latter as a form of “cultural diversity management” (Budin 2006: 99). Practices and techniques such as loan translations (provided that accuracy is ensured) – e. g. the French *aérotrain* is not to be translated as *Luftzug* in German (which corresponds to the meaning of the English word *draft*), although the German “Luft” means *air* and “Zug” can mean *train*, instead it must be rendered as *Schwebebahn/suspension railway*. Besides, cross-disciplinary introduction of new designations for differentiating purposes are used to close terminological gaps. Looking at term formation principles, links to systemic linguistics are evident: recourse to lexemes and metaphors of the general language is permitted if the use for scientific purposes clearly differs from their everyday usage.

Moreover, according to ISO 740:2000 (7.3.1) (as cited in Arntz, Picht, and Mayer 2009: 113) for term formation the following principles apply: transparency, consistency, appropriateness, linguistic economy, derivability, linguistic correctness, and a preference for the original language. Apparent semantic transparency – as in the German word *Halleffekt* (= Hall effect/ echo effect, Hall = proper name, and German for “echo, reverberation”) – must be avoided.

### 3.2 Benefits of traditional terminology

Traditional terminology as an applied discipline has, in practice, contributed to a wide spectrum of (both alphabetical and onomasiological) specialist dictionaries by defining norms and setting terminological standards. Also mono- and multilingual language dictionaries containing definitions and explanations figure prominently in the picture (Felber and Budin 1989: 155–177). Terminological work has helped to establish a large number of novel terms and designations – e.g. the fact that we speak of *personenbezogene Daten* ‘personal data/ individual-related data’ in German data processing contexts, or *informations nominatives* in French, is the result of terminological work (Arntz, Picht, and Mayer 2009: 129).

A further important aspect is terminology’s close ties to state-of-the-art electronic data processing and advanced information technology, as is reflected in highly sophisticated term banks and term ontography, which is concerned with computer-implemented ontologies, amongst other things. Special (technical) languages such as *Terminology Markup Framework* (TMF) are used to create terminological networks, which collect the full forms, for instance the German term *Festplatte*, synonyms such as *Harddisk*, short forms (*HD*), as well as various types of colloquial expressions. Also antonyms and preferred designations are filed, as are hierarchical and non-hierarchical conceptual relations (Schmitz 2012: 5).

What practical terminological work clearly shows is this: Despite all terminological efforts and accuracy a high ratio of synonymy and polysemy still persists in specialized communication. Yet until well into the 1990s, little terminological research has been done on the competition of designations and meanings, which finds its expression in these phenomena. Here are just a few examples: in specialized technical dictionaries (electrical engineering) Neubert (1987: 34–38) finds five synonyms for *Fotoemissionseffekt* ‘photoelectric effect’. Loan translations also lead to synonymous expressions, as in: *Beam-lead Technik* – *Balken-Leiter-Technik/Isoliergriff-Technik*. Synonymy often extends even beyond specialized fields and disciplines: “For example, in terminology, *cell* points to quite different domains such as HUMAN BODY, PRISON, ELECTROLYSIS, and SOLAR ENERGY” (Faber and López Rodríguez 2012: 26). Another major standardization issue is that terminological equivalence cannot be assumed between different natural languages – the English term *informatics* is neither equivalent to the German *Informatik* nor to *informatique* in French, as both

must be translated as *computer science* in English; closely connected to this complexity is the phenomenon known as *faux amis* in standardization practice (Arntz, Picht, and Mayer 2009: 179). Furthermore, not all concepts identified as, in principle, relevant for a certain domain, have definitions or designations. Finally, different cultures often develop different conceptual frameworks and concepts – a frequent problem in those areas of the judiciary system with a long-standing (vernacular) tradition. The challenge of terminological variation is thus manifest on many levels but it's still far from clear how traditional terminology could tackle the problem, let alone account for competing terminological systems. Terminological variation is primarily attributed to general language [use]: “The inherent imprecision of natural language as opposed to formal language, and the inherent polysemy of words is a fact that terminological models have to take into account. [...] The dynamic nature of terms and their constant change in meanings require constant human intervention in the form of ‘terminological control’ [...]” (Budin 2003: 75–76).

## 4 Criticism of the traditional theory of terminology

Since the 1990s various terminological approaches have sought to bring the discipline closer to linguistic research: “[...] terms are no longer seen as part of ‘a semi-artificial language deliberately devoid of any of the functions of other lexical items’” (Temmermann 2000: 25). Terms are now considered as multifunctional units to be investigated from a linguistic, cognitive and communicative perspective (Cabr   2003: 189). Criticism is raised in three respects, including:

(1) *Critique of the theoretical understanding of terms and the idealized image of science*: Epistemological, scientific and semantic premises have been critically reviewed including principles resulting from these premises (e.g. the univocity principle) and the positivist view of science linked with them. Essentially, criticism is levelled at the implications of representation theory deemed unsuited as point of departure in the humanities and social sciences, where *a priori* given objects are few (for aesthetic categories in literary studies and art sciences see Gardt 1998: 52–58). These disciplines mostly constitute their subject matter through language in communicative processes, a fact that consequently shifts the focus to the function of language in the constitution of knowledge and reality. Contrary to representation theory, it is assumed that language not merely expresses knowledge but is the essential prerequisite for understanding (Felder and Gardt 2015: 4). This applies for natural sciences and life sciences as well: “For some concepts (e.g. DNA) there is evidence that the phenomena existed before they were understood and named, but others are pure products of human activity and understanding (e.g. biotechnology)” (Temmermann 2000: 5). Various theorists and philosophers of science have argued that also natural sciences are dynamic areas of knowledge rather than static fields. Depending on prevailing par-

adigms, mindsets or *Denkstile* (in the sense of Fleck 2011), the perspective on and perception of scientific objects in these disciplines may vary (see Chapter 6, this volume). Traditional terminology theory tends to overlook the fact that varieties in designation often result from different perspectives on the same subject matter or object. Terminological variation is thus indicative of semantic struggles – a well-known phenomenon for linguistic researchers (Felder 2006). However, polysemy may also be due to the fact that monosemisation frequently is only possible within a specific textual environment. Throughout the text of “Critique of Pure Reason”, Kant, for instance, uses the term *reason* in 23 different meanings (Roelcke 1995: 401) that must be deduced from the context. This does not hamper understanding though, since what Kant meant in each case is clarified by the textual passage in which the linguistic expression occurs. In each case the meaning is unambiguous. Here, univocity is achieved by a term’s embeddedness in a particular syntagmatic context rather than by the term itself.

(2) *Critique of the methodology of traditional terminology*: Taking into consideration competing designations and meanings as undisputable facts in scientific discourse, terminological researchers are increasingly adopting descriptive and corpus-driven methods instead of prescriptive ones: “Their approach is descriptive, linguistic and semasiological and it is based on the study of specialised texts and corpora. The adherents of descriptive terminology question [...] the monosemy ideal [...]” (Bertels 2011: 95). Most studies draw on techniques developed in corpus linguistics (for instance, the retrieval of key words in context) and incorporate co-occurrence analyses. Corpus-linguistic investigations tend to corroborate the existence of polysemy within a specialized subject field and simultaneously provide a basis on which change processes can be identified, particularly on the level of lexicalization and phraseology (e.g. Bertels 2011; Kast-Aigner 2009; Kermes and Teich 2012).

(3) *Critique of a simplistic view of both human cognition and specialized communication*: (Socio-)cognitive approaches are addressing terminology’s oversimplifying view of human cognition and focus on processes of concept formation, prototypical features, the frame-based organization of knowledge systems, as well as creative processes in scientific practices underlying, for instance, the formation of metaphorical analogies (see section 3.1). Other analyses of terms have also dealt with the relationship between knowledge and language, but typically the use of terms is analysed against the background of the overall function of specialized communication, i.e. terms are regarded as conventionalized means of action in the constitution of reality (Beißwenger 2010: 364). Specialized terms are, however, also indicative of scholars’ creative thinking and the freedom to carry out definatory acts of usage-fixing (“definit-orische Gebrauchsfixierungshandlungen”) on the metalinguistic level (Wiegand 1996: 94). Whether a term will stand the test in specialized communication thus not only depends on the successful linguistic labelling of an object, but also on the plausible conceptual structuring of a part or segment of reality accompanied by explanations and arguments established in scientific debate. For lack of a better term, and following Felder and Gardt (2015: 15–18), I propose to subsume this particular line of research

under the heading of “socio-pragmatics”: Science here is regarded as one communicative practice among others, and for this reason their main focus is on exchange patterns, knowledge transfer and relationships with other (social) practices, as well as on speech acts that contribute to the terminologisation of an expression. Specifically the French branch of *socioterminologie* have emphasized the social dimension of language use, including the use of specialized terms as membership markers.

## 5 New approaches to terminology

### 5.1 The socio-cognitive approach

Terminology is, on the one hand, a crystallization of domain-specific knowledge, but this knowledge has developed in dynamic processes. In socio-cognitive approaches a great focus is thus placed on the cognitive processes of interactants, following the assumption that “[m]odern terminology could incorporate the idea that humans do not just perceive the objective world but have the faculty to create categories in mind. Many of these categories of the mind have a prototype structure” (Temmermann 2000: 61). Whenever human beings perceive an object or state of affair, prior knowledge is being activated by means of linguistic signs, which are themselves material artefacts; the object or event is thus always interpreted and understood against the background of existing knowledge.

Cognitive terminology research over recent decades has tried to come to terms with these facts claiming that: 1) in analogy with terminological definitions, also the categorization of objects should be based on prototypical features. This implies that concepts might not always be clearly separated; instead they are classified according to the principle of family resemblance (see, for example, Jahr 1992; Temmermann 2000: 57–67; Zawada and Swandepoel 1994). 2). It is proposed that knowledge associated with a term should be described within the theoretical framework of frame semantics (Faber and López Rodríguez 2012: 17–31; Engberg 2007: 10–21).

Knowledge structures are, of course, not static in nature: as products of communicative processes they are negotiated in social interactions. Yet from the perspective of cognitive semantics it seems doubtful whether term definitions can ensure inter-subjectively comparable, identical understandings. That is because, first, one tends to overlook the cognitive creativity of individual users (Hummel 2009: 121), and, secondly, individual levels of understanding may vary (Shelov and Leitchik 2006: 18). Further, the fact that a term’s embeddedness within a text may trigger different understandings and interpretations must be taken into account.

Socio-cognitive approaches proceed on the assumption that specialized terms are *units of understanding*, which may be described by, for instance, prototype theory. Various studies found that for terms with a limited number of features intensional

definitions apply, as traditional terminology theory assumes. There are, however, other types of terms which exhibit “prototypicality effects” including: (a) “differences of typicality and membership salience”, (b) “clustering into family resemblances”, (c) “fuzziness at the edges, membership uncertainty”, and (d) “absence of necessary-and-sufficient definitions” (Geeraets 2010: 189). This means not only that knowledge structures are no longer conceived as hierarchical concept systems with clearly separated conceptual units. It also implies that, for lack of superordinated concepts, not every term can be defined on an intensional basis with a clear-cut delineation of hyper- and hyponyms; even the extension of a concept might not always be fully clear. Using text examples from the domain of life sciences, Temmermann (2000: 73–124) shows that knowledge building does not necessarily follow the principles of (traditional) terminology: While the usual description of *intron*, a component of DNA, seems to correspond to both intensional and extensional definitions prioritized by terminology theory, scholars do not abide by this rule in definitions of common techniques like *blotting* or collective categories such as *biotechnology*, but instead resort to encyclopaedic knowledge for descriptions (Temmermann 2000: 94). The author describes these terms as propositional ICMs (idealized cognitive models in Lakoff’s sense, see 1987: 68), i. e. as “structural wholes of experience, beliefs and practices constituting a kind of conceptual prerequisite for understanding the meaning of a word. Defining a category will involve describing the relative position this category has in the conceptual structure” (Temmermann 2000: 96). Temmermann goes on to propose a new scheme for collecting and classifying terms which includes the “type of category (e. g. entity, activity), intracategorical information (e. g. is part of, consists of parts, aims, use) and intercategory information (e. g. perspectives, domains, intentions)” (Temmermann 2000: 122).

She also shows that polysemy and synonymy are universal characteristics of science communication and that scientific research has always been closely linked to the use of metaphors, since “[...] metaphorical models link the language system to the world of experience and to the functioning of the mind” (Temmermann 2000: 44). Structuring our understanding, metaphors are credited with leading to new insights. Traditional terminology theory has acknowledged the significant role of metaphors in science communication. In the specialized area of machine parts, for instance, findings by Arntz, Picht, and Mayer (2009: 116–120) point to an abundant use of body-part metaphors such as *Kopf/Nase/Zahn* in German, or *head/nose/tooth* in English. The fact that metaphorical models may encompass an entire field of knowledge and motivate term formation has been confirmed in various studies. Molecular biology is characteristically informed by metaphors of writing and information technology, with the current view of genes as information-transmitting codes having emerged in the 1950s (cf. Kay 2000).

However, introducing prototype theory into terminology research has been repeatedly criticized, because the definition of a prototype crucially depends “on the subjective evaluation of the terminologist. It is impossible to define the exact nature

of the center of prototypical categories or explain how degrees of prototypicality can be objectively measured” (Faber and López Rodríguez 2012: 22). Notwithstanding the fact that Temmermann’s approach is clearly hermeneutic rather than quantitative in nature, the methodological critique seems justified in that the nature of the relationship between the linguistic form expressing the characteristics of an object or state of affair and implied intra- and intercategory information is not readily apparent in prototype analyses. An alternative approach would be frame-based terminology in Fillmore’s tradition (2006). Frames are described as components of long-term memory combining “elements and entities associated with a particular culturally embedded scene, situation or event from human experience. Frames include different sorts of knowledge including attributes, and relations between attributes” (Evans 2007: 85). Frames may be captured through argument structures. Faber and López Rodríguez (2012) proceed on the assumption that the description of a specialized language is predicated on key events relevant to the field, for which they propose a “general frame-based event” as a basis for the description of more specific argument structures. This includes an agent template, a process template and a patient/result template (Faber and López Rodríguez 2012: 28), which are interlinked to describe a term like *erosion* thus:

EROSION is a process that conforms to the process template with the context of a Frame-based Environmental Event. A process takes place over a period of time and can be divided into smaller segments or phases. It can happen at a specific season of the year, and may occur in a certain direction at a given location. It is included by an agent (natural force) and affects a specific geographic place or environmental entity, thus producing a certain result that is often a modification of the affected entity (Faber and López Rodríguez 2012: 28).

In cognitive approaches no fundamental distinction is made between ordinary words and specialized terms. That terms are given special attention is merely owing to the fact that specialized communication has come to be identified with the transmission of knowledge, in which terms figure as key components occurring with high frequency in scientific texts.

To sum up, cognitive approaches are taking into account processes of understanding, shedding light on the fact that concepts, objects or their designations may be subject to change triggered by cognitive processes themselves without regulatory intervention through normative procedures.

## 5.2 Socio-pragmatic approaches

Socio-pragmatic approaches investigate term usage from a functional perspective describing science as a cultural communicative practice. The basic assumption is that language use and verbal action are shaping our reality. *Reality*, for scholars, is usually negotiated in exemplary texts and discussions in which some state of affair or

facts are described from a specific point of view within a communicative frame that presupposes certain socio-communicative relationships: “The central point of culturally determined communication is that actors with culture-specific socializations are selecting signs and symbolic forms in specific contexts of interpretation according to the anticipated expectations of addressees in order to produce certain effects through these speech acts” (Felder and Gardt 2015: 15; translation by Bettina Seifried).

If similar acts are repeatedly performed in comparable contexts, specific expressive patterns evolve, understood as form-function correlations. These patterns, then, function as contextualization cues or *pars-pro-toto* constructions referring back to the action framework and text or discourse types with which they are generally associated (Feilke 2015: 101). For specialized terms it implies, on the one hand, that they are viewed primarily as a means of communicative action and design used for special purposes in specific communication contexts, which are, in turn, associated with specific textual patterns. Here, specialized terms are resources in the constitution of scientific objects (Beißwenger 2010: 351). As such they are embedded in a complex argumentation, description or explanation directed at a specific readership – typically a special part of the scientific community. On the other hand, the capacity of terms to contextualize previous situations of use is often exploited to indicate a certain scientific positioning or refer to a scholarly tradition. Owing to the fact that specialized subject fields are defined as a communication community of experts, specialization thus not only has a factual but also a social dimension. Terms can be understood not only as symbols but also as symptoms and signals (in Bühler’s sense (1965 [1934])). Taking into account the heterogeneous nature of specialized communication, socio-pragmatic approaches call into question traditional terminology’s claim of homogeneity through a fresh view on science as a site of controversies, semantic struggles and different scholarly traditions. A first group of key questions is thus: which types of texts and discourses make use of which terms? How do terms contribute to diasituative variation in a sociological sense? Are terms defined differently in different text types, and how are they defined? Linked to this is the question of diastratic variation, since terms are used by specific speakers.

Research into specialized language suggests that the existence of synonyms is a correlate of varying communicative situations and different specializations within a discipline: Scholarly work in medical science makes frequent use of Greek or Latin terminology, whilst competing linguistic forms are reserved for clinical settings and communication with non-experts. This accounts for the co-existence (in German) of *Eileiter* (German) – *tuba uterina* (Latin) – *tuba* (abbreviated Latin) – *Salpinx* (Greek) and even *Ovidukt* as a derivation from English contexts (Kretzenbacher 1991: 41). These findings point to the need to distinguish between different contexts of use and show that a straightforward equation of term occurrence with specialization is not tenable. Depending on the context, terms may or may not be commented upon and clarified by metalinguistic acts that define or explain them. Explanations are not necessarily required in contexts of specialized communication between scientific experts,



e. g. in specialized papers and research reports. Here, definitions are only provided to introduce new terms or propose a different meaning of an already established terminological unit, for instance in scientific controversies (Schuster 2010: 251–264, for a definition of controversies see Fritz (2010) and the Fritz’s contribution in this volume). As a general rule, the systematic preference of one term over another without further comment (see apparent synonyms like *Referent*, *Designat*, *Denotat*, *Denotation* in German) may signal affiliation with a specific scholarly tradition or school of thought (see also L’Homme 2015: 344–346). Things are different in contexts of teaching and learning, where in text books, introductions and reference books definitions are generally provided. Terms are essential features of scientific secondary socialization and attest to a specific *Denkstil*. In the communication between experts and laypersons in popular science literature terms are also normally explained, often by using comparisons and creating links to familiar concepts of everyday life. As Kalverkämper (1984: 53–57) has noted early on, the use of terms in a scientific paper presupposes a “complex context of explanations, definitions and descriptions” serving as instructions for the recipient to activate previous knowledge. But just as the use of terms presupposes familiarity with preceding texts, it also evokes specific follow-up texts to connect to. In contrast to (socio-)cognitive frameworks, it is assumed that the re-activated knowledge incorporates references to other texts and particular patterns of use, which correspond to a specific register. The capacity for communicative action within a subject field thus not only hinges on knowledge on the subject matter in the narrow sense, but also on knowing when, where and, most of all, in what manner it is to be presented.

Extensive research on terminological linearization in different text types has been carried out by Roelcke (see, inter alia, 2012, 2014) in an attempt to answer the following questions: “Which structure does the terminological system constituted in the text show?”; “What linear sequence definitions resp. defined terms can be observed?” “Which types of definitions are used to constitute the terminological system?” (Roelcke 2014: 87). The studies show that different terminologisation strategies are tailored to address different audiences. Also, there is historical variability in strategies of defining terms as “different LSP-texts pursue different strategies of terminological linearization: a didactic-structural, a discursive-contentual, and a normative-alphabetic” (Roelcke 2014: 98). An early work on German grammar from the 17th century seems to adopt the same didactic strategy as today’s prescriptive *Duden* grammar (Roelcke 2012). By contrast, Kant’s “Critique of Pure Reason” as well as present-day grammars based on scientific findings may be classified as discursive in nature, since hierarchies in terminological systems are avoided and real definitions are assigned a rather marginal role. In fact, it seems that only the DIN standard 2330 on terminological standardization abides by the principles of traditional terminology, as Roelcke has repeatedly shown. On the whole, the findings suggest that argumentative text types adopt different strategies for defining terms than norm-oriented prescriptive texts. Closely linked to this difference is the fact that the frequent use of a term in public discourse

often leads to its de-terminologisation, specifically in the fields of medicine (*virus, incubation, ...*), psychiatry (*depression, schizophrenia, ...*) and psychoanalysis (*super-ego, repression, flight into illness, ...*). The close links between terminology building, writing strategy and scientific understanding are particularly emphasized by Pörksen in an insightful comparison of Linné and Goethe (Pörksen 1986: 71–96).

The wide variety of different communicative situations also illustrates that, particularly with regard to lexis, specialization is not exclusively limited to the use or occurrence of terms in a text. Research by Shelov and Leitchik (2006: 17) has identified further elements: “[...] ‘pragmonyms’, professionalisms, items from professional vernacular, units of scientific and technical substandard language and slang, etc.” It would be erroneous to reduce specialized communication to the use of technical terms, as expert status may also be signalled by professional “lingos” and jargons. Moreover, terms are always embedded in either standard or specialized language (con-)texts, and as a result these environments also contribute significantly to the understanding of specialized terms.

On yet another level, terms may be used to indicate group membership thus facilitating the formation of communicative communities. The use of specialized terms is often tied to a social role (e. g. medical doctor) and associated with prestige. That sociolinguistic aspects such as these are incorporated into the research is the special achievement of the French branch of *socioterminologie* (Gaudin 2005). Its adherents have time and again emphasized that the diversity of contexts and situations of use (“la diversité des leurs usages sociaux”, Gaudin 2005: 81) inevitably leads to cases of polysemy and synonymy. Terminology is investigated from a socio-critical perspective, for example in discourse analyses following Foucault: Here terms are regarded as signs whose social significance – e. g. the ability to control large parts of a society’s knowledge stock – will be revealed in an analysis of the interrelations of the social distribution of knowledge and institutionalized forms of power. The use of terms, it is maintained, is thus not only appropriate for a given communicative context but actually predictable within and characteristic for a particular society. Gaudin also points out hegemonic effects of national and international attempts to establish standard terminologies that exclude regional language cultures, e. g. in Africa: term formation constitutes a form of social standardization, a “contrôle social du sens” (Gaudin 2005: 86) tied up with the notion of rationality and an efficient organization of scientific research to the exclusion of alternative traditions and approaches to human knowledge and experience.

A second group of questions linked to socio-pragmatic issues includes the following: to what extent does the occurrence of terms signal either emergence or establishment of a scientific field? Are there different categories of terms? Variations in meaning and multiple designations are often indicative of different schools of thought. Terms function here as a lexical demarcation line (Schuster 2010: 194). Tracing the genesis of terms, specialist vocabularies typically illustrate the “non-simultaneity of the simultaneous”, or “simultaneity of the non-simultaneous”. A striking example is

(German) linguistics vocabulary, which has assembled layers of a multitude of theoretical traditions. For instance, the influence of the Neogrammarians is still evident in terms like *Stammbaum*, *Morphologie*, *Organismus* and *Assimilation* borrowed from natural sciences (Elsen 2003: 68). Structuralism's influence makes itself felt in the key notions *langue* and *parole* borrowed from ordinary French language. As a general rule, the stock of linguistic expressions is subject to continuous change. Even established terms within a discipline might no longer be deemed appropriate and become obsolete, *cloning* or *social class* are cases in point. As noted earlier, terms, on a pragmatic level, contextualize previous contexts of use, therefore any actual use may signal affinity with a particular theory or tradition (as with the expression *Sprachspiel/language game* in linguistic pragmatics, which inevitably refers to Wittgenstein's theory of meaning). However, traditions may also be rejected by the non-use of terms. A term might even be replaced by a less well-defined one precisely because of its long history and tradition: Replacing *melancholia* with *depression* in clinical psychiatry was not so much due to fresh insights on the nature of the illness but due to the fact that the old term was linked to a history of cultural stereotypes about melancholiacs that could not be confirmed in clinical practice (e. g. the long-held assumption that all melancholic persons are black-haired). Also, the word *depression* seems to make a more sophisticated, medical "impression" when contrasted with *melancholia* (Schuster 2010: 269; 334–355). For a long time, the notion that mental illness is a *brain disease* was a scientific postulate that merely *anticipated* future medical findings. Terms such as these might be called "evocative terms" (in Knobloch's sense (1987: 63)). The fact that terms acquire cultural connotations over time, as in the case of *melancholia*, is also confirmed by Hummel, who, using the French lexeme *cadre* as example, illustrates the career it made in the political vocabulary of (German-speaking) communist contexts:

In summary, we see that the mental prototype of a word like *cadre* may be considered, from an historical point of view, as a crystallization of historical referential experience. In this sense *cadre* has a cultural charge [...] which allows us to consider it a key word linked to an epoch. This implies at the same time that the word and the terms coined out of it will grow older in future in the sense that the mental prototype will be perceived as being a prototype of the past (Hummel 2009: 122; for further examples see L'Homme 2015: 342–343).

On the whole, socio-pragmatic approaches clearly show that any comprehensive characterization of terms must take into consideration the different dimensions of signs. In addition to referential and appellative functions, terms have social symbolic and cultural significance.

Moreover, the synchronic perspective on scientific communication should not blind us to the fact that terms also have a diachronic dimension: first, in the sense that a term's evolution from innovative to accepted usage may be reconstructed, and secondly, in that practices of use enable scholars to connect to certain scientific traditions and schools – or else prevent these connections from becoming apparent. Further, it should be taken into account that even linguistic forms relating to either extremely

vague concepts or to a variety of competing notions – innovative or traditional – may function perfectly well as terms. Cases in point are *irony*, *style* or *meaning*, which do not have one single commonly accepted definition but a myriad of explanations, the plausibility of which depends on the underlying theoretical assumptions – i. e. they must be read in the light of the term's use within a particular text or discourse. In the humanities, especially in cultural studies, terms have occasionally been compared to conglomerates or aggregates (Gardt 1998: 54) coated with several layers of traditions. In my view, fanfold paper (as used by the servant “Leporello” in Mozart's famous opera *Don Giovanni*) would be a more apt comparison: Depending on the communicative purpose, *irony*'s entire centuries-old discourse could be unfolded in one context (e. g. in a doctoral thesis on the subject), whilst in a different context it might suffice to briefly point out that the term *irony* refers to dissimulating verbal behaviour stating the opposite of what is meant. Such a description would, of course, not correspond to the terminological concepts proposed so far.

## 6 Summary

Traditional terminological theory starts out from an idealized image of science communication. In its practical applications, it has doubtless contributed widely to international exchange and scientific communication through terminographical work and the development of translation aids. However, the assumption that clear, unambiguous communication hinges upon the exchange of well-defined, univocal terms, has certainly narrowed the view on the diversity of forms and aspects of scientific communication at the same time. There is no evidence that the understanding of a term amounts to nothing more than memorizing real definitions and terminological systems. Also, no evidence is found that polysemous expressions in a text – if indeed there are any – are hampering understanding or argumentation. Moreover, a rather reductionistic notion of *meaning* seems to prevail in traditional theory that prevents researchers from taking account of the fact that a linguistic expression operates as cognitive “token”, or shorthand symbol, referring to a specific horizon of knowledge, as studies in cognitive semantics have shown. What is also left out of account is that scientists contribute to the shaping of new realities by coining and introducing (new) terms.

However, fresh approaches to both terminological theory and research in applied linguistics have made valid proposals to remedy these shortcomings. What seems sufficiently clear is that the complex nature of terms cannot be exhaustively explained by a simple theory of reference. The knowledge structure of terms need to be explored with the descriptive apparatus and analytic means provided by cognitive semantics. Without a supplemental description of conventionalized use contexts and related functions (e. g. expressive function) any analysis would remain incomplete, though.

Still, there are certain types of terms such as *irony*, which seem to defy linguistic description. Although specialized terms are highly productive linguistic elements, it would not be appropriate to reduce specialized communication in scientific contexts to its terminological dimension. In contrast to traditional terminology theory, descriptive and corpus-based linguistic approaches paint a different picture of science communication where synonymy, polysemy, use of metaphors and fuzzy concepts are not only unavoidable but even essential to the dynamics of scientific discourse, the function of which is to describe and (re-)discover the world in new ways through language. This discourse, however, takes place against the backdrop of a specific communicative space to which scientists are committed to a certain extent, and whose historically developed structures are re-actualized in current uses that in turn contribute to shaping the future. Findings so far suggest that textual traditions play indeed a crucial role in regulating the modalities of the occurrence of terms.

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Thorsten Pohl

## 9 The study of student academic writing

**Abstract:** This chapter examines research conducted on problems students have with academic writing, the changes over time in the institutional framework in which such writing takes place, the acquisition of academic writing skills, and university support measures. In the literature, difficulties in meeting the requirements of producing academic texts are repeatedly noted, both with respect to the writing process and to the written products. However, complaints about the quality of student writing have a long history, and are connected to what has been and is expected of students. In the early 19th century, when German university institutes (*Seminar*) were first created, only a handful of students were required to write texts at all. Only by the early 20th century did academic writing become a compulsory part of university study. Academic writing is interpreted here as “polydimensional”, which helps explain some of the especially challenging aspects of such text production for students. Mastering this skill, this chapter argues, is part of a developmental process students undergo throughout their course of study; secondary school does not fully prepare them for this task. The final section discusses some approaches – oriented to instruction, communication, reception, or curriculum – which have been suggested for supporting the process of acquiring academic writing skills.

**Keywords:** specialized knowledge – writing skills – writing product – writing process – scholarship – research – academic writing – student writing – acquisition – development

### Introduction

In the past, the study of student academic writing was often motivated by the perception that deficits existed. That is, such writing was not a subject of research in and of itself, but instead only became interesting (and relevant from a research point of view) as part of the effort to respond to student writing skills and accomplishments. Initially, the observation of weaknesses arose from the daily practice of reading and correcting term papers, seminar essays, and theses. Subsequently, surveys were conducted among instructors and students so as to empirically identify and focus on student “writing problems”. These eventually led universities to found writing centers and labs, hire writing tutors, and offer courses in academic writing, inasmuch as these had not previously existed. The Anglo-American essay tradition, for example, led to the creation of freshman writing or composition courses at many universities (Nystrand, Greene, and Wiemelt 1993).

What has not drawn sufficient attention in this rather deficiency-oriented perception, even today, is the idea that academic writing skills are only gradually acquired



by students over the course of their studies. Such skills must be acquired through apposite reading and writing experiences, a development which takes time and is embedded in the comprehensive process of academic enculturation (Lea and Street 1998) and socialization into academic scholarship. To this, one needs to add the cognitive acquisition of concepts relevant to scholarly analysis and insight, as well as the continuous accumulation of specialized knowledge (Pohl 2007). It is only in the interplay of these factors that competence in academic writing can develop. This is true even for those already highly literate who bear diplomas from academically-oriented secondary schools. A deficiency-oriented perspective, in other words, needs to be complemented by a developmentally-oriented view.

The oft-expressed critique of student writing skills and accomplishments is broad and applies to aspects of both writing process and written products (Section 1). Yet complaints about the quality of what students produce are by no means new. Student writing in the 19th century, at least in German university seminars, took place in rather different institutional contexts than what we are familiar with today (Section 2). In Section 3, I use “academic writing” to refer to the special requirements that make such writing difficult or challenging for those learning it; specific to it is its polydimensional character. The next section surveys studies which focus particularly on the developmental perspective (Section 4). The paper concludes with a discussion of dissemination and facilitation approaches.

## 1 The critique of student writing and writing skills

In day-to-day academic life, instructors often regard what students write as inadequate, and criticize students for not (or no longer) being able to write “correctly”. This can be with reference to the process involved in academic writing, from the organization of the workflow – which involves literature research, reading, and potentially conducting a survey or investigation – up to formulating and composing a text. Ruhmann (1995), employing a “constructed case study”, provides an incisive picture. In her experience as a writing coach, the most “readily recognizable pattern of problems with writing” was “not being able to start – and not being able to stop”, seen both in the process of reading and of writing. Problems in the writing process were often “closely intertwined [...] with psychological issues and problems of practical life skills” (1995: 86). Additionally, students lacked “cognitive strategies for resolving their writing assignments” (1995: 88), which could even lead to “heightened feelings of shame and anxiety” (1995: 88–89).

Ruhmann’s diagnosis is certainly alarming. Nevertheless, one needs diagnostic tools which allow for a substantiated assessment of when, or in which constellations, such problems go beyond normal levels. Written communication perforce will be challenging in demanding writing contexts of the kind found in academic scholarship.

Even those who write academic texts professionally see it this way (Narr and Stary 1999). The process model most frequently cited (Hayes and Flower 1980) conceptualizes writing as problem-solving, though in the specific context of producing academic texts, delays (such as repeated starts, detours, taking the wrong track) can even be regarded as positive signs of a particularly successful epistemic writing process (see Bereiter 1980).

Feilke and Steinhoff note that problems with the writing *process* could hide problems with the writing *product*:

The basic problem students have in writing academic papers is not a process problem at all. It is a problem of communication, text and language competence [...] which come prior to the actual writing process! Students ask themselves ‘how do I need to write so that my statements in the text make a claim to knowledge, and thus [can] make a claim to be valid in the specialized communication of the discipline?’ (2003: 113–114)

As far as problems with the writing product are concerned, we still lack empirical statistics on errors or the characteristics of flaws which are based on a large body of student texts (but see Deane and Quinlan 2010 or Rödning 2017). Usually, the literature only notes the observations of individual authors and what is striking about the “typical shortcomings of seminar papers” (Ruhmann 1997: 137) is their range. They extend across the levels of the language, with the following shortcomings typically highlighted for German student texts:

- general spelling faults and grammar and orthography errors (Ruhmann 2000: 44)
- general deficiencies, such as overly complex formulations (Kruse 1997: 141)
- general organization defects, such as incoherent or partial texts (Fischer and Moll 2002: 237)
- erroneous citation and references, including misrepresenting or distorting sources (Jakobs 1997: 86)
- poor reasoning, including implicit theses or absent justifications and arguments (Püschel 1994: 131)

What calls for explanation in this list, first, is its broad range. These deficiencies are being identified among student authors far advanced in their literacy, where certain errors ought no longer to exist. Second, two aspects specifically related to academic writing, scientific citation conventions and the nature of scholarly forms of argument, also require explanation.

With respect to the first, Taylor, in his analysis of individual cases (1986, 1988), addressed the connection between content complexity and linguistic ability, focusing on the level of wording as well as on basic skills in using correct grammar and syntax. In the texts of a single student, he showed that these abilities, rather than being mastered as universally applicable competencies, instead vary from one writing task to the next. Thus, numerous errors were evident in this student’s research essay on literature, though they did not occur in texts written in other fields. Taylor’s conclusion is

that students' problems lie less in a simple inability to handle the surface forms of syntactic and other structures themselves than in an inability to control linguistic form in unfamiliar or intellectually taxing contexts of meaning (Taylor 1988: 64)

In his *Errors and Explanations* (Taylor 1986), Taylor points to a variety of content and conceptual problems which give rise to grammatical phenomena (including collocations between verb and preposition, choice of tense, inflectional endings), and concludes that "in some way, grammar enters 'unconsciously' into composition" (1986: 146). It is clear that mistakes at a level presumed to be purely that of formal language can be generated by the complexity of content or through cognitive confusion. Ortner calls this phenomenon "breakdown" (Ortner 1993: 100).

Following Taylor, the danger of committing such errors is particular high in academic writing, for here writers must not only describe or explain an isolated subject,

they must confront the complex relations between authors and their theories, the instruments of evidence, the actual object of enquiry (so far as the latter is separable from the evidence) and the conclusions to be drawn from applying theory, evidence and argument to a problem concerning the object of enquiry. That is to say, the focus is no longer merely on the object of enquiry but on the standpoints and methods of approach that their authors use to draw conclusions about it. (Taylor 1988: 61)

As for scientific citation conventions and the nature of scholarly forms of argument, one analysis of eight surveys conducted among students and/or instructors at German universities showed a clear discrepancy in their assessments of potential writing problems (Pohl 2007: 21–24). In Dittmann et al.'s survey, for example, students regarded scientific citation as of only middling importance (rank 7 and 8 of 15) while instructors regarded it as a major deficiency (Dittmann et al. 2003: 174–175). Quite similar findings resulted from answers to a questionnaire about the "criteria for gaining essay marks" which Branthwaite, Truemann, and Hartley (1980) administered. For students, "originality" was the most highly ranked criterion; it was not even mentioned as a criterion by their instructors (1980: 99–100). So are students themselves even aware of their own writing problems? Or, given the developmental process they are in the middle of, *could* they even be? (Pohl 2007: 21).

The causes of what are today assumed to be writing problems have also been discussed in the German-language literature on higher education. Two main propositions can be discerned. The first is that student writing skills have worsened when compared with the past. This is seen, among other possibilities, as due to social and biographical factors involved in making universities accessible for students from educationally disadvantaged strata (see Ruhmann 1997: 125). The second is that, again as compared with the past, the institutional demands and standards of academic writing have risen (Ehlich 2000: 4). A logical third proposition, however, has not been considered, namely that everything has more or less remained unchanged.

Complaints about, and unhappiness with, student deficiencies in writing can be documented at least back to 1787 (Pohl 2009: 148–149), which, interestingly, is about

the date when student writing at German universities even began. Comparable complaints can also be found in histories of academic writing in the U.S. (Russell 1991: 74) and in France (Bernheim 1912: 25). One explanation could be that competence in academic writing is part of a developmental process that needs to be repeated for every new generation of students. As a result, one always faces students with skills and competencies which are still only partial or not yet fully acquired. Instructors in higher education institutions, however, perceive these as shortcomings (Pohl 2007: 26).

## 2 On the history of student writing

For many centuries, the education of students was strongly oral in nature. This lasted far beyond the scholasticism found in the medieval university, and only gradually began to change by the end of the 18th century (see Pohl 2009). The dominant form until then was the lecture (*lectio*), in which, while students did take notes, they were not themselves conceiving and composing independent texts (Apel 1999). This was even true of the main form of examination, a formalized debate or dispute (*disputatio*) with fixed roles for Proponent, Opponent and (at least in medieval universities) a presiding Master (*praeses*) (Marti 1994a). If the theses or questions were written out in advance, then this “disputation script” functioned into the 18th century as an invitation to the debate itself (Marti 1994b: 880). Even when such a script was written afterwards and submitted, this was not, at least initially, necessarily an independent text. These “bare theses” (*theses nudaе*) only consisted of stringing together sentences that were “simple assertions” and they only “gradually became discourses or treatises” (“adorned theses” or *theses vestitae*) (Marti 1994a: 869).

It was only once the seminar was invented at the end of the 18th century, which Fichte in 1817 called a “plant nursery for academic artists” (*Pflanzschule wissenschaftlicher Künstler*) (Fichte 1956 [1817]: 142), that there was a break with the strongly oral orientation in educating students in German-speaking countries. The seminar founded around 1700 by August Wilhelm Francke (to separate the preparation of pastors from that of teachers) is regarded as a preform, and the founding of the philological seminar in Göttingen in 1737 by Johann Mathias Gesner (1737) had a similar motivation. Gesner’s immediate successor, Christian Gottlob Heyne, already began to neglect the needs of teachers in favor of philological studies, and by the time Friedrich August Wolf founded the philological seminar in Halle in 1786, the orientation was purely to the discipline.

In contrast to the lecture, whose primary intent was to transmit content, insights, and “facts”, instruction in the seminar was focused on methods, procedures and techniques in the particular field of inquiry. The goal was not to transmit knowledge as such but instead provide instruction in scholarly approaches: “it was not just knowledge as such, but also the knowledge about how one arrived at this knowledge”

(Paulsen 1966 [1902]: 266–267). In contrast to the *disputatio*, the introduction of an obligation to craft seminar papers led to a radical change in medium: students began to write in an academic manner and their professor acted as the facilitator of this process, and seminar discussions integrated, if only partly and in a modified form, the *disputatio*. Today, we know the seminar as one type of class, but a *Seminar* used to be a small research institute with its own budget provided by the Prussian state. If one compares its current form with its earlier form, then the differences are as follows:

**Table 1:** Comparison of seminar forms (Pohl 2013: 43)

| <b>Seminars today</b>                                                     | <b><i>Seminar</i> in the 18th–19th centuries</b>                       |
|---------------------------------------------------------------------------|------------------------------------------------------------------------|
| <b>30 to 60</b> (in the worst case, even more) participants               | Limited to around <b>5 to 15</b> participants                          |
| Attended for <b>one semester</b>                                          | Attended for at least <b>three years</b>                               |
| A student attends <b>multiple seminars</b> during their course of study   | A student attends a <b>single seminar</b> during their course of study |
| A student attends seminars in <b>different</b> disciplines                | A student attends the seminar in <b>one</b> discipline                 |
| Students attend seminars taught by <b>different</b> instructors           | Students attend seminars taught by a <b>single</b> professor           |
| <b>One</b> paper per seminar and semester is <b>potentially</b> mandatory | <b>Two</b> papers per seminar and semester are <b>always</b> mandatory |
| Seminar attendance is <b>mandatory</b>                                    | Seminar attendance is <b>optional</b>                                  |

Initially, being accepted into a seminar was *not* the rule when studying at a university. On the contrary: participation meant a high degree of distinction for those students who were granted this honor. Only those studying in (and admitted to) a *Seminar* had to provide written work; other students did not. These full participants in the *Seminar* also received various material and non-material benefits, including scholarships, subsidies for printing their doctoral theses, and even preferential employment in the state’s civil service (Pohl 2013: 45). It would only be in the late 19th and early 20th centuries that the seminar became a standard type of class; with this change, writing became a mandatory part of a students’ course of study.

The early “elitist” form of the *Seminar*, with the production of writing anchored in it, can in hindsight be regarded as an innovative and successful model for academic study. Throughout the 19th century, more and more such *Seminare* were founded. What began in philology, coinciding temporally with the methodological consolidation of the discipline, was increasingly adopted in other disciplines. Thus, natural science and mathematics *Seminare* (such as the one founded in Königsberg in 1834)

were brought to life, and these, too, required their student participants to produce term papers (Pohl 2009: 42–54).

The German neo-humanistic ideal of education (*Bildungsideal*), linking research and instruction, influenced other nations in the 19th century, including those of the United States, Russia, Japan, and France (Jarausch 1991: 314). The adoption of the “German university model” (Turner 1991: 238) into American academe introduced core organization forms, including “lecture course, seminar, and laboratory” (Russell 1991: 71). According to Watt (1964), the seminar was first introduced to the U.S., in Michigan in 1869, by the historian Charles Kendall Adams; he referred to the German *Seminar* paper as a “documented essay (or research paper or term paper)” (Russell 1991: 79). This “text-dependent approach to scholarship” brought with it not only a complex pattern “with extensive textual conventions, such as footnotes and bibliography”, but also posed a problem for its young writers: to whom were they addressing their written efforts?

The new text-based scholarship, [...] changed the nature of the academic game. Oral performance for a local academic community demanded only a display of learning, but the new text-based standards demanded an original contribution to a disciplinary community in written form: a research paper. [...] The shift poses a problem: if the primary forums for the faculty’s scholarly discourse lay outside the local academic community, where should the forum for students’ scholarly discourse lie? (Russell 1991: 80)

Additionally, by the end of the 19th century, the U.S. had developed its own tradition of academic writing, influenced among other things by the composition courses introduced in 1872 by Harvard’s President Charles W. Eliot. Russell argues that by around 1910, the “idealistic experiments” with the (older form) of the German *Seminar* paper came to an end, and the genre then took on a “school-like” aspect in U.S. academe – a process quite similar to what happened in the course of the 19th century in German universities. If one asks what made the mandatory writing students had to do in the *Seminar* a success – certainly true for the first half of the 19th century – then it was owing to an interplay of the following:

- extremely small working groups
- the focus on only a single discipline or specialized area
- ongoing and lengthy or intensive coaching by only one instructor
- the circulating of seminar papers among the ‘seminarians’ (a type of peer review)
- the evaluation of the seminar papers produced in seminar discussions

Overall, the interaction between these elements in the early 19th century *Seminar* led to the emergence of something like a miniature discourse (or even research) community. For student participants, there was no question who they were addressing. It also seems likely that the *Seminar* provided key support for developing skills in composing academic texts – something no longer available in the types of classes called seminars that are available in today’s German universities.

### 3 The definition of academic writing

In terms of the production of academic texts, the specifics can basically be identified for nearly all the structural levels of language: collocations (Gledhill 2000), phraseology (Howarth 1996), nominalizations (Martin 1991), grammatical metaphors (Halliday 1998), personal pronouns (Vassileva 2002), citations (Hübler 1991), introductions (Swales 1990), narrative conventions (Harré 1990), and Introduction, Methods, Results and Discussion (IMRaD) structure (Hill, Soppelsa, and West 1982). In what follows, a functionally-oriented definition will be developed to explain the effects academic writing has on the various structural levels, from specific wordings through text composition.

Though the literature provides many approaches and concepts, space only allows for the presentation of two examples here (for more details, see Gruber 2010); with their help, one can elaborate an understanding sensitive to the process of developmental acquisition. The definition should not only answer the question as to what is specific to academic writing, or what distinguishes academic texts from other text types or writing domains, it should also implicitly answer what makes academic writing particularly difficult for students to master. The focus here is primarily on the characteristics of academic writing products, with the prototypical form taken to be the research paper or article.

In everyday understanding, academic texts are commonly identified by textual features such as footnotes, quotes, source references, and specialist literature, but also by their frequent use of specialized terminology, complex forms of expressed language, and an “impersonal style” of writing. As accurate as these associations might be, they are at odds with formulating a definition specifically meant to characterize the particular demands academic writing makes. Hence, one can ask what is so difficult about quoting a text – which, after all, is just copying – or including a specialized term (inasmuch as it is a term one can assume is known).

Ehlich and Weinrich provide fruitful answers here, with Ehlich pursuing the question of which speech acts are dominant in academic texts, while Weinrich’s interest lies in the (semantic) truth concepts they contain. Ehlich (1993) begins by assuming that it is primarily assertive speech acts which are realized in academic texts, due to their orientation to observable realities and verifiable truths. More precise analysis of academic texts, however, leads Ehlich to a second structure,

one not concerned with a representation of reality in the text but rather with the mapping of a discursive structure onto a textual structure. In the academic texts consulted, the basic discursive structure is one of dispute, which one can regard as an *eristic structure* [...] (Ehlich 1993: 28)

The “eristic structure” Ehlich identifies is “a kind of lattice” which overlays “the purely assertive structure” (1993: 26), so the two structures, or levels, of academic texts stand in a strongly integrative relationship to one another. The level that is objective or con-

tains factual content is filtered through the discursive level. This can be more clearly seen in the formulations chosen. Rather than saying “X is the case” (purely assertive), what characterizes academic texts are formulations such as “A asserts, that X is the case”, or “B refutes A’s assertion that X is the case” (assertive and eristic).

It is precisely this integrative moment in academic writing that is key to Weinrich’s approach. To show the “unity of science” with respect to its communicative and linguistic disposition, Weinrich (1995) deliberately analyzes two academic texts which are quite different in length and by discipline: Watson and Crick’s 1953 paper in molecular biology which led to their Nobel Prize, and historian Frances A. Yates’s 1966 *The Art of Memory*. In Weinrich’s view, both works engage in a process involving four clearly delineated steps, each of which uses its own form of scholarly truth (1995: 160):

1. “Reference truth” (derived from the references used) addresses the state of research.
2. “Protocol truth” (derived from the records or protocols kept) identifies the research results and reports on how they came about.
3. “Dialogue truth” or “Argumentative truth” connects the first two by discussing the research results against the background of other research outcomes or positions.
4. “Orientation truth” provides an outlook on potential future research (Weinrich 1995: 159–164).

Weinrich regards these four steps as the “general model of the scientific process”, and places special emphasis on their discursive intertwining. With this discourse, “a researcher places himself within the communication context of his discipline”, and is thus also “a link in the chain of this field” (Weinrich 1995: 160).

There are clear parallels here to Ehlich’s conceptualization: Ehlich’s assertive structure is roughly related to Weinrich’s protocol truth, and reference and dialogue truth form the discursive structure Ehlich discerns. Above all, the asserted components in both conceptualizations stand in an integrative relationship to one another. The particular nature of academic text production can be recognized in this special form of *multiperspectivity* or *polydimensionality*.

Following Ehlich and Weinrich, three central dimensions of academic writing can be identified here. As in any other text, academic texts have a *subject* or a topic. However, this subject – already here making it different from many other text types – never appears in isolation but is already established by the scholarly *discourse*. Hence, the writer not only “immediately encounters” the subject, but finds it textually present as well (including in canonical texts, articles in handbooks, and research reports) in the respective discipline. Owing to shared research interests and scholarly convictions, the disciplinary discourse itself is shaped in particular ways by controversies, schools of thought, approaches, and paradigms. It is in this constellation of subject and scholarly discourse that something “happens” in an academic text, which we can broadly call the *line of argument dimension*. This encompasses the examination and analysis of the scholarly discourse in a narrower sense (e. g. Weinrich’s dialogue truth)



as well as the inclusion or application of a particular method (e. g. Weinrich's protocol truth), which at first refers exclusively to the subject but then, in its acquisition of insight, is used in argument vis-à-vis the discourse.

These three dimensions – *subject*, *discourse*, and *line of argument* – form the epistemic profile of academic texts (see Fig. 1):

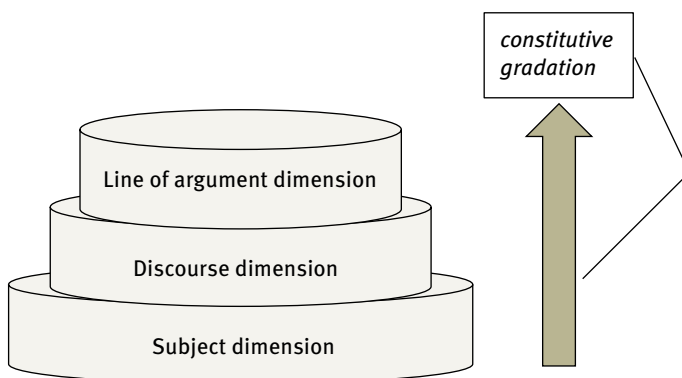


**Fig. 1:** The epistemic profile of academic texts (Pohl 2010: 100)

Although there are types of academic writing in which the line of argument is less pronounced and which largely make use of a combination of subject and discourse dimensions (e. g. text types which compile information, such as reports of previous research or the handbook article), even here one finds traces of arguments and of positions taken. These three dimensions in fact lie at the core of, and can be particularly clearly seen in, the text types which drive progress and yield insight in academic contexts: academic journal articles, chapters in edited volumes, scientific papers, dissertations, postdoctoral qualification studies (*Habilitation*), and so forth. The situation is somewhat different with respect to essay writing, in which one largely finds a combination of subject and line of argument dimensions, though such essays can vary greatly by academic discipline and context (van Peer 1990).

That we are dealing with a *constitutive gradation* is of particular relevance to the demands of academic writing, because it is precisely in the interaction between the three dimensions that the special challenges – or potential for writing output – arise for students just beginning their studies. These dimensions and interactions are often unknown and can lead to the corresponding “problems with academic writing”.

Establishing the three dimensions takes place at nearly all the relevant levels of textual and linguistic structure. “Realization effects” occur, beginning with giving a title to a paper through certain forms of structuring the text and extending to the level of formulation. Even morphological and syntagmatic levels are not unaffected. This does not mean, though, that all three dimensions always or constantly need to be addressed in an academic text; this is more the task performed by introduction and

conclusion, as well as at particular transition points in the text which refer to the argument being made.

## 4 The development of skills in academic writing, with models

In English-language research, one finds scattered approaches which add a developmental perspective complementing the deficiency-oriented perspective noted above. In addition to works by Taylor (1986) and Taylor et al. (*Literacy by Degrees*, 1988), one can cite, among others, Ballard and Clanchy (1988), Bock (1988), Knudsen (2014), Negretti (2012), and Shaw (2001). The work undertaken by Bartholomae (1985), which began already in the 1980s, is particularly noteworthy, and is based on assumptions made by Bizzell (1982).

Bizzell criticized “inner-directed theorists” such as Hayes and Flower for taking the writing process not only to be universal but as the “outgrowths of individual capacities” (1982: 215). This needed to be augmented by including the perspective of the “outer-directed theorists”. Following Fish, Bizzell regards the “discourse community” not just as a linguistic community which shares some “language-using rules” but also as an “interpretive community” (Fish 1980: 304). This assumes that “the discourse gives meaning to the words and not vice versa” (Bizzell 1982: 225). The students’ problem is then not just cognitive, affecting the organization of the writing process:

Producing text within a discourse community [...] cannot take place unless the writer can define her goals in terms of the community’s interpretative conventions. Writing is always already writing for some purposes that can only be understood in its community context. (Bizzell 1982: 227)

In his *Inventing the University*, Bartholomae analyzed and interpreted 500 “expository essays of first-year college students” with reference to “stylistic resources that enabled writers to locate themselves within an ‘academic’ discourse” (1985: 148). He concludes that there are three levels of development, or perhaps better, convergence: “primary discourse”, “approximate discourse” and “official literary criticism” (1985: 146). Each provide a different access to the writing tasks, or different strategies for establishing discursive authority in the text: “At [the] first level, a student might establish his authority by simply stating his own presence within the field of a subject” (Bartholomae 1985: 158). It is typical of such texts that they strongly emphasize the self (in the “I”-form), and that they almost necessarily are narrative in form.

It is characteristic of the second level that its authors “establish their authority by mimicking the rhythm and texture, the ‘sound’ of academic prose, without there being any recognizable interpretive or academic project underway” (1985: 158). In these texts, therefore, one finds utterances which are approximations or imitations

that do not yet show the methods or approaches used in an “interpretive or academic project”. It is only at the third level that expressive and context levels converge (1985: 158). Overall, Bartholomae sees it as highly likely that the second, approximating, stage is – at least for some students – a necessary transitional state:

It may very well be that some students will need to learn to crudely mimic the “distinctive register” of academic discourse before they are prepared to actually and legitimately do the work of the discourse, and before they are sophisticated enough with the refinements of tone and gesture to do it with grace or elegance. (Bartholomae 1985: 162)

If one takes Bizzell’s thesis that knowledge of the “interpretative conventions” in a discourse community makes scholarly goals communicable, then the transitional stage Bartholomae assumes seems relatively likely.

Hounsell, using a similar method, also discerns three types in his *Conceptions of Essay-Writing* (1984: 108–111). To this end, he examines texts of second-year undergraduates studying history. The “most sophisticated” variant was the “essay as argument”, texts with an “ordered presentation of an argument well-supported by evidence” (1984: 109). By contrast, the “essay as viewpoint” only had an “ordered presentation of a distinctive viewpoint on a problem or issue” (1984: 111). The least developed variant was the “essay as arrangement”, described as “an ordered presentation embracing facts and ideas” (1984: 111). However, Hounsell does not explicitly see these three variants as developmental differences. In contrast to the work of Bartholomae and Hounsell, Flower et al. explicitly argue against assuming there are “staged developmental model(s)” (1990: 222) and instead see the socialization process into specific linguistic conventions as one of “adaptation and negotiation” (1990: 227).

In German-speaking research, one finds two comprehensive studies on the acquisition of academic writing skills (Pohl 2007; Steinhoff 2007). The two are based on different empirical material from the humanities and social sciences, and use different categories for evaluation. Though they employ differing models of skill acquisition, they are complementary. Steinhoff, using 296 student seminar papers, analyzes formulation-level phenomena, comparing them with works produced by experts and by journalists, Pohl, using a longitudinal corpus of only twelve seminar and final papers crafted by selected students, investigates excerpts of academic writing, and analyzes them at the level of linguistic and textual structure. The results obtained from the analysis of these latter cases were empirically tested using additional writing samples (85 cloze texts and 56 introductory texts).

Steinhoff’s developmental model distinguishes between three acquisition phases, using a theory derived initially from Piaget (Steinhoff 2007: 130–135) before later confirming it in the course of his empirical analysis (see Fig. 2).

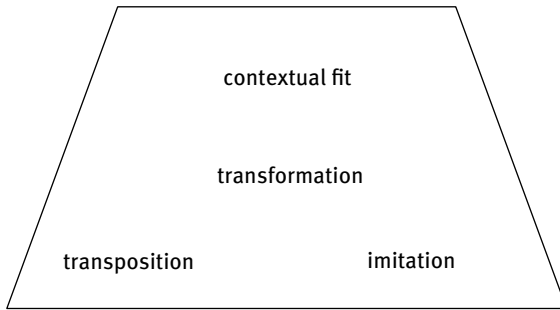


**Fig. 2:** Developmental model following Steinhoff (2007: 138; abbreviated)

At the outset, Steinhoff sees two types of problem-solving strategies among novices to academic writing: transposition and imitation. In the case of transposition, students try to solve new problems using old means, in particular with the help of linguistic competencies acquired before entering the university (2007: 139). “The influence of various non-academic practices” is particularly large here, whether from journalistic and popular science formulations or from patterns taught for composing school essays or in more colloquial speech (Steinhoff 2007: 423). In the case of imitation, students try to mimic what they believe to be academic language, but they “are not yet in full control of the repertoire they use, and don’t use it appropriately but instead exaggerate”. Characteristic is “the use of over-strained phrases”, “the creation of highly elongated compound sentences”, and the “use of stilted, elaborate written formulations” (Steinhoff 2007: 423).

Acquisition of the full range of expression only properly begins in the developmental stage which follows. “Transformation” is marked by a growing “understanding of the surface features and the functional specifics of the expressions” (Steinhoff 2007: 423), though this is still an “intermediate stage” in the development of full written competence in academic writing. On the one hand, this can be seen in characteristic breaks in formulations, and on the other in the overuse of what is still a limited repertoire of expressions.

The preliminary end of this development is reached at the “contextual fit” stage. At this level of proficiency, there is an “ability to use context-adequate language suited to scholarship” (Steinhoff 2007: 424), and writers control the use of the relevant linguistic means and use them consciously and deliberately. Compared with the previous stage, there is a significant increase in the repertoire so that “the student is capable of variable, differentiated usage” (2007: 424). Steinhoff can even show that there are discipline-specific effects, for example with respect to how often, and in which manner, the self-referential “I” is used in the text. In other words, students adjust to the linguistic and textual habitus of the discipline for which they are writing their term papers.

In Pohl’s model, the development follows the dimensions of academic writing described above. An initial stage, when students focus largely on the subject, is sup-

planted by an acquisition phase in which the focus is on the academic discourse in the discipline. Only after this do students also succeed in including a line of argument in their texts. Unlike Steinhoff's model, Pohl's sees an integrative, developmental succession in which prior stages are not transcended as much as they are integrated into the newly acquired skills. Moving into a higher stage of acquisition also means further development of partial competencies at the lower levels (see Fig. 3).

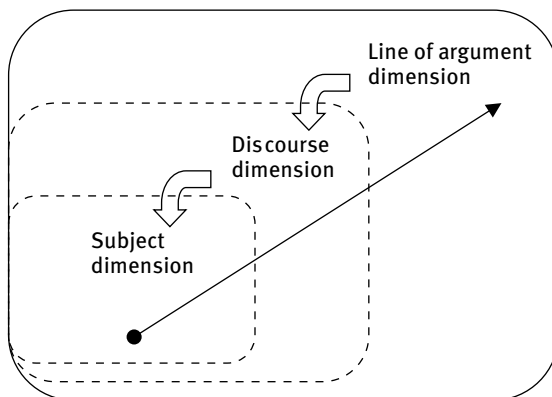


Fig. 3: The evolution of academic writing (Pohl 2007: 448)

At the first, developmental, level (subject), in the absence of an appropriate inventory of expressions, students make use – as Steinhoff also sees it – of everyday or imitative formulations often insufficient for the phrasing specific to the particular domain. The result is grammatically defective text or infelicitous wording. The components of an everyday yet scholarly language (Ehlich 1993) are only rudimentarily evident, and often are not used by students in an epistemic manner. Reference to, and citation of, the research literature is highly selective. One often finds students using ‘relief citations’ (*Textentlastungszitate*) in which, by inserting quotes into their own texts, students try to incorporate complex content relationships without going into detail. The result can be breaks in coherence, or in extreme cases, simply a collage of quotes. More specifically, the selective attention paid to the research discourse comes at the cost of attention being paid to epistemic modifications and scholarly arguments. The subject under scrutiny is, as it were, freed from this additional “ballast” – and it is thus becomes relatively easy to turn *theses* into asserted *facts*.

Isolating the dimension of the subject is further reflected in the formats used for organizing the text. The structures are often systematic or purely additive, which in turn can mean that a term paper ends with an evaluative appendix in order to still include a students’ “own position” or “personal opinion” in the text. Such an appendix is either weakly or not at all connected to the main text, and does not form a conclusion in the narrower sense. Correspondingly, the introduction is either very

subject-oriented or there is a preface which addresses the personal relationship of the author to the subject of the text – something which is not relevant in the case of an academic text.

At the second, discourse-related level, students have a basic stock of variant wordings which indicate an understanding of the context of the domain, or in Swales' sense (1990), are appropriate to the discourse community. Focusing on the discourse dimension – in addition to the subject dimension – is synonymous with learning a first inventory of expressions used in the everyday discourse of a discipline. However, fuller reference made to disciplinary discourse can lead to employing over-complex syntax in German, in the form of extremely nested sentences filled with sub-clauses. Intertextual reference to the academic discourse also increasingly distances itself from the referenced texts, since citing and quoting are realized by an external representation of that external text.

Student learners now also connect the content of quotes more strongly with their own, independent formulations, and in that manner explicate their understanding. At the meso level, authors can identify diverging positions, reproduce them as such, and address them through argument. However, this still lacks macro-structural effects which would be relevant to the overall architecture of the paper, and instead occurs only at local sites in the text. The overall structure is explanatory, not so much a coherent structure as oriented to the understanding of the reader. In this phase of development, accordingly, one still finds evaluative appendices.

At the third, line of argument level, learners have an expanded range of tools, or routines for formulating in the appropriate style, at their disposal. The everyday language of the discipline no longer only serves as a means for presenting the research discourse but also for an analysis and discussion of positions taken in this discourse. At the syntactic level, authors are increasingly able to work with complex groups of compound nouns in order to address the three complexity dimensions, while at the same time avoiding excessively hypotactic structures. Reference to the research literature is no longer selective, and the references cited are appropriately contextualized. Argument, as the general constituting principle of the academic text, no longer only occurs at the meso-level but now also at the macro-structural level. Student authors arrange the structure of their texts so that its parts converge on a final, concluding section. The three dimensions of academic writing are also fully presented in the introductory material.

It should be noted that both developmental models (Steinhoff 2007, Pohl 2007) also pursue purely descriptive and explanatory research interests. On the one hand, the models try to describe what is contained in the student texts. On the other hand, they also try to understand why the acquisition of writing skills is ordered in the manner presented. Both models do not posit that the acquisition of competence in academic writing proceeds automatically or that every student reaches the highest level of development by the end of their studies – which, in the empirical data, was in fact not always the case.

## 5 Dissemination and facilitation

The literature suggests numerous ways to facilitate student academic writing, some of which have been empirically tested (see Rakedzon and Baram-Tsabari 2017). Consensus seems to have been reached that interdisciplinary or overarching approaches (“writing across the curriculum”) are insufficient and need to be augmented by discipline-specific orientations (“writing in the curriculum”). One can identify the following approaches:

1. **Instruction-oriented:** writing seminars, tutorials, exercises (e.g. Beaufort 2012 on developing a system of courses)
2. **Communication-oriented:** counseling centers and offices, learning alliances (e.g. Pargman, Hedin, and Hrastinski 2013 for “group supervision” and other approaches)
3. **Reception-oriented:** the reception and analysis of academic texts (e.g. Rienecker 1999 on the use of “model-examples”)
4. **Curriculum-oriented:** suggestions for changing the academic writing curriculum, the types of texts used in exercises or the writing conditions (e.g. Irawati 2015 on project-oriented writing)
5. **Mixed:** integrating 1–4 (e.g. Lehnen, Schüler, and Steinseifer 2014)

At a higher level of abstraction, these approaches fall into two groups: those which are instruction-based (1–3, possibly 5) and production-based (4, possibly 5). All the instruction-based approaches – they dominate the literature – are strongly presuppositional, which is often not reflected upon. For all of these concepts, including those with feedback or reflective elements, need to be communicated to the student learner through more or less specific instructions, and in that sense are instruction-based. Instructional measures function according to the motto: *If the student learners cannot do it by themselves, you need to tell or explain to them how it works (and then it will work)*. Understandable as such optimism is – and it is widespread in the rich literature about teaching academic writing – the business of instruction is rich with presuppositions.

Among other things, it presupposes that the relevant content (knowledge, skills) to be transmitted are known to the instructors and that they can be communicated in a practicable fashion. An instructor must be able to understand the relevant communicative offerings, and the individuals to be instructed must be able to derive guidelines for action from the communicated instructions. Student learners need to be able to transfer what was learned in an exercise or a particular situation to other contexts, and if possible, even craft routines or habits of action out of the instructions. Only then is there a chance of coping with particularly complex writing requirements, as is the case for academic writing. Against this background, it is not surprising that critical voices have been raised about introductory courses in academic writing or composition (Davidson and Tomic 1999: 168), about remedial writing programs (Nightingale

1988: 263), or about particular forms of commentary such as “feedback sheets” (Lea and Street 1998).

Much speaks for the need to combine instruction-based with production-based approaches. From the studies noted above, one can identify the necessary (if not sufficient) conditions for acquiring adequate competencies (Pohl 2007: 526):

- the ongoing acquisition of specialized knowledge
- regularly reading the specialized literature
- repeated opportunities for writing, including different types of written products
- overall, enough time to develop writing skills

Such conditions could, in addition to individual instructional measures, be embedded in a disciplinary writing curriculum adequate to the complex demands of academic writing. This could be organized to last throughout a student’s course of study and proceed step-by-step from 1) subject-oriented writing (analysis of subject, protocols) to 2) discourse-oriented writing (excerpts, reviews, research reports) to 3) line of argument writing (fully developed academic writing, with argument, that is used in term or seminar papers).

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## **II Text types, media, and practices of science communication**



Thomas Gloning

## 10 Epistemic genres

**Abstract:** The production, organization, dissemination and joint examination of “knowledge” is one of the central tasks of scientists. This complex of epistemic tasks is closely linked to the use of language and other communicative resources that are organized by epistemic genres. Genres are products of communicative evolution, their development is steered or guided by their respective functions and available media among other factors. Newer forms of scientific communication are characterized by an increasing use of digital tools and multimodal arrangements. Epistemic genres are tools that are used by scientists to produce, formulate, publish, and discuss their findings. In this article, the interrelation between scientific knowledge production, organization and transmission with communicative genres in the sciences is discussed from a linguistic perspective.

**Keywords:** scientific communication – knowledge production – knowledge organization – scientific genres – scientific text types – visualization – multimodality – scientific word usage – scientific terminology – epistemic genres

### 1 Introduction

The main aim of modern sciences (including the humanities, arts, life sciences, etc.) is the production of “knowledge”, its systematic organization, publication and joint examination. On the one hand, the search for knowledge is a value in itself, it is an anthropological constituent of man, the “knowledge-seeking animal”. Knowledge helps humans to make sense of and to understand the natural, social, economic, etc. world they live in. On the other hand, scientific knowledge is also directed at various practical functions, be that in areas like medical therapy and rehabilitation, the construction of houses, bridges or machines, the production of new chemical substances for industrial purposes, business management or blasting engineering, to name but a few. Science is one of the cultural and social ways of dealing with knowledge and coming to terms with life. But there are others (Winch 1964).

“Knowledge” is not an absolute term. What counts as scientific knowledge in a given time is at least partially determined by contemporary scientific practices and standards. In a reflexive perspective, today’s scientific knowledge can be seen as “the

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best candidate” available, which is subject to discussion and debate, testing, improvement, falsification, modification and all kinds of practices and stages of quality management. The conception(s) of “knowledge” and its near relatives like “certainty”, “truth”, “evidence” and several others are important subjects both in the history of science, the theory of science (‘Wissenschaftstheorie’) and in more specific reflections on different disciplines, like, for example, literary criticism. The search for knowledge is what connects modern science to its historical predecessors. Gaining and systematizing knowledge is a very ancient aim and practice, even if its role in former societies and forms of life may have been quite different. The Assyrian king Ashurbanipal, famous both for the foundation of a library and for his political cruelty, wore a sword and a pen side by side.

Knowledge is dependent on forms of representation. In most cases, knowledge is *constituted* by way of representation (e. g. Antos 1997). This does not mean that there is no knowledge without representation: if a child happens to touch a hot oven, gets hurt and screams out loud, the child “knows” that touching a hot oven can be painful, even if it cannot verbally represent the results of this experience. One could think about a child’s theatrical representation of the experience: playing “getting hurt by inadvertently touching a hot oven”. In respect of scientific knowledge, we may say that knowledge is dependent on forms of (verbal, visual, performative) representations.

The core of producing, representing and systematically organizing scientific knowledge is intimately connected to “epistemic” text types and multimodal genres, though there are a few related concepts that we will deal with in section 2. Epistemic genres like scientific monographs, journal articles, handbooks, etc. have in common that they are a means to represent knowledge and to systematically contribute to discipline-specific knowledge organization, production and publication. They are the result of historical evolution and they suggest ways how authors can solve their specific tasks. From the reader’s perspective, they equally produce expectations, for example with respect to content, structure, linguistic form or knowledge organization.

Not all texts or multimodal arrangements in science and academia are related to epistemic text types or genres. To order a new computer, to write an invitation for a committee session, to write the minutes of such a session, and many others do not have the function to produce and organize scientific knowledge. Rather they serve or contribute to organize the work and the social infrastructure of scientists.

In modern times, scientific knowledge is supposed to be publicly available. As a consequence, the forms of representation have to allow for public distribution, for example by way of specific media like books, journals or websites, which have a considerably wider outreach than, say, a manuscript. This close connection between scientific genres and media with a wide reach is a historical achievement, which, however, is still not trivial in the light of language barriers, information overflow, problems of findability, commercial restrictions of access to relevant literature and several others.

This article introduces the notion of text type and genre (section 2), then gives an overview of epistemic genres (section 3), it characterizes the role of word usage and terminology in scientific texts (section 4), the last section deals with forms of quality control, e. g. in reviews and controversies (section 5).

## 2 Text types, genres and related concepts

The concepts of text type and genre have produced a huge amount of literature and I am not going to trace the various developments here. For our purposes the two notions share properties that are relevant with respect to the epistemic functions of texts and multimodal arrangements in the field of internal science communication.

First comes the assumption that texts and multimodal arrangements are organized along patterns that have evolved historically. Only in some cases were they a product of intentional design. They provide authors with guidelines for text production, and they help readers to understand texts and semiotically enriched scientific products. Such patterns of “expressing things” follow functional needs and they may be seen as instruments for fulfilling specific tasks, for example reporting on an experimental setting and the results of its use (Bazerman 1988).

Secondly, the communicative patterns in question may be characterized by a number of core aspects of organization. From a linguistic-pragmatic point of view, the most important aspects are: the function of a text, linguistic actions and patterns of their sequencing (e. g. describing, explaining, classifying), structures and practices of topical organization and progression, the use of linguistic means (for example syntactic patterns, specific lexical means), communication principles like precision, the forms of knowledge organization and progression and others. These parameters of organization may be complemented by aspects of institutional embedding in processes of science communication (e. g. peer comments) and by aspects of the use of multimodal resources like images, diagrams, colours, typography, spatial arrangement and others. These principles of organization are in part mutually dependent of each other.

Thirdly, the aforementioned parameters or principles of textual organization are a powerful tool for the description of scientific text types and multimodal arrangements. To characterize a specific text type or multimodal arrangement requires a description of the way basic parameters of organization are typically set. In a scientific review, for example, the core function is to inform readers about new publications and to evaluate them. Hence, there are both informative and evaluative parts (action structure). With respect to topic management, there is a range of relevant aspects that can be addressed (for example the aims of a new publication, its structure, the pros and cons, the contribution to a field of research, specific flaws, the price, the book binding, etc). According to the core functions (information, evaluation) we often find specific



lexical material. The communicative principles of reviews are frequently referred to in rejoinders to reviews (“Reply to ...”; Khosravi and Babaii 2017). For example, the concluding sentence of a rejoinder by Robert S. Westman in response to a review by Michael Shank is: “A reviewer is supposed to appraise the claims an author actually makes, not the inventions of his or her own imagination” (Westman 2014: 184). This is a general statement (“A reviewer”, “his or her”), which expresses a principle of scientific reviews, it is, however, addressed at the reviewer of Westman’s book.

Fourthly, an action-based, pragmatic methodology of analysis can also account for multimodal arrangements, which nowadays are the standard case of scientific publications. Here we may ask what each resource contributes to the communicative function, how different resources are “orchestrated” and whether or not there is a conventional basis for the contribution of a specific resource and the way the resources are combined (Bucher 2017; Kress 2009; Bateman 2008).

Fifth comes the dynamics of knowledge organization with texts and multimodal arrangements. While this aspect is important for all texts, kinds of communication and questions of understanding (Fritz 2017: ch. 3.3, 3.5 and 6), it is especially important and vital with respect to the epistemic function of scientific texts. Since epistemic genres are closely tied to knowledge production, the linguistic and textual aspects of knowledge management are central to scientific texts.

Knowledge production and communication are dynamic processes that go hand in hand in the scientific life cycle. Hence, there are different stages and phases of research as well as all kinds of communication like jotting down a first idea of a new research topic, the drafting of a preliminary table of contents of a future publication, taking notes while reading research literature, filling out specific information positions in lab books, discussing questions with colleagues, etc. In some cases, the stages of knowledge production and its activity types follow specific time schemes in the use of different text types or communicative activities, e. g. the following sequence:

- reading a call for papers (and possibly discussing the question whether or not to contribute),
- providing a submission, e. g. an abstract or extended abstract,
- producing a set of slides (and in some cases a manuscript for the spoken text of the presentation),
- testing the presentation with respect to coherence and the time frame,
- performing the presentation along the sequence of slides in a conference,
- discussing the presentation and taking notes about various comments,
- formulating a manuscript for publication,
- revising the manuscript according to peer review comments,
- submitting the final manuscript and publication of the article.

As can be seen from this example the published article is only the final stage of a long sequence in the use of different communicative activities (texts, dialogues, spoken and written polylogues) with specific epistemic functions.

### 3 The core repertoire of epistemic genres

Monographs, journal articles, scientific handbooks and textbooks, presentations, review articles, bibliographic surveys, to name but a few, each fulfil specific functions. They have in common that they are related in one way or another to knowledge generation, knowledge organization, knowledge testing and knowledge dissemination. These text types or genres may be dubbed “epistemic genres”.

There are other forms of communication in the sciences which do not primarily serve the organization of knowledge, they have other functions such as personnel management (job offer), the constitution of scientific role models (eulogies, commemorative speeches), administration (minutes of faculty meetings) or infrastructure (ordering a new computer). An intermediate position can be ascribed to forms of communication that support knowledge production indirectly, e.g. specialist bibliographies, publisher catalogues, references to new publications on mailing lists or personal hints to relevant publications.

The core repertoire is small: Basically, it consists of monographs, original articles, handbooks and textbooks (together with their oral counterparts). In the following sections, I characterize this core repertoire of epistemic genres (3.1, 3.2) together with communicative aspects that are important for their epistemic function (3.3–3.6).

#### 3.1 Monographs and original articles

Monographs, so-called original articles and other types of texts are associated with the claim to offer “new” insights relative to the current state of research. The underlying figure of thought is based on the principle of reception (Weinrich 1995), according to which scientists must have read the relevant literature on the subject at hand. Secondly there is the idea that there is something like a current state of research which can be derived from relevant (older and contemporary) work and which in any case can be determined in principle. Both ideas are not trivial: in times of information overflow, it is sometimes no longer possible to find and process all of the relevant literature (see Chapter 31, this volume). This problem is addressed by specific text types such as literature reports and overviews (e.g. metastudies on clinical investigations). One can also mention the possibly obstructive influence of the principle of reception on scientific originality (Merton 1981, 51–56): creative new ideas may be prevented by reading too much of the “old stuff”.

Different subject areas have developed their own textual and multimodal patterns for the presentation of new research results in monographs and original articles. The five-part scheme for empirically-based contributions in the natural sciences is particularly prominent, comprising sections for research questions, literature report, material and methods, results and discussion (Bazerman 1988; Gross, Harmon, and Reidy 2002; Ylönen 2001). The wide range of forms of representation that are functionally

adapted to discipline-specific goals becomes apparent when one compares this five-part scheme with completely different forms of monographic representation in other disciplines, for example with the practice of critical editions in the historical-philological sciences. Critical editions usually have components such as the so-called praefatio, in which different research questions concerning the respective text (e.g. author, tradition, sources) are systematically dealt with, the critically constituted text itself, different types of apparatuses, indices, glossaries, commentary, etc. These components can be combined in a variable and problem-related way (cf. Martens and Zeller 1971; Severyns 1962; Plachta 1997; Editio 1987 ff.).

If monographs or journal articles have oral counterparts (e.g. a lecture or a series of lectures) these are usually only a step on the way to the written document. The spoken word is ephemeral. This changes with the advent of new technologies for conserving and disseminating speech events and multimodal performances. Conference talks, lecture series, etc. are increasingly videotaped and made accessible via streaming services. Nevertheless, the bulk of scientific information still comes from books and journals.

Knowledge organization in monographs and original articles is closely related to communicative aspects, most importantly with topic organization, word usage and terminology, forms of visualization and techniques of multimodal arrangement (see sections 3.3–3.6).

## 3.2 Handbooks, textbooks and their oral counterparts

The primary function of scientific handbooks is to document and to organize the state of knowledge available at a certain point in time for the scientific peers in a systematic and up-to-date manner. Handbooks are important milestones in the development of young scientific disciplines: if handbooks can be written, a mature and systematically well-rounded state of research has been achieved. The revisions of subsequent editions of a handbook accordingly reflect the progress in knowledge generation. For example, between 1902 and 1904 a six-volume handbook in the field of bacteriology (*Handbuch der pathogenen Mikroorganismen*) was published as one of the milestones in bacteriology, which was still a young discipline at that time. Its size and differentiation of content steadily increased in the two subsequent editions of 1913 and of the late 1920s. The thematic arrangement of such multi-volume handbooks reflects a specific view of the systematics of the field in question: thematic organization and knowledge organization are particularly closely related. The target audience of handbooks are scientists who can be expected to meet the discipline-specific requirements. Compared with textbooks, no didactic considerations have to be taken into account.

In contrast to the thematic principle of organization, there are handbooks that are organized according to lexical criteria, e.g. the *Handwörterbuch der Sexualwissenschaft* (1923; lit. 'Hand-dictionary of the science of sexuality'), whose subtitle *Enzyklo-*

*pädie der natur- und kulturwissenschaftlichen Sexualkunde des Menschen* ('Encyclopedia of the natural and cultural science of human sexuality') nevertheless confirmed the systematic claim of this book for the then young sexual science. In the foreword, the editor, Max Marcuse, writes:

What would otherwise be to the detriment of scientific dictionaries – the unsystematic arrangement of the material, following only the external guideline of the alphabet – should in this case mean a gain for the discipline, since the heterogeneity and the richness of relationships of the sexual-scientific material do for the time being not allow to organize the material coherently. (Marcuse 1923, III; transl. TG)

Projects such as the *Historisches Wörterbuch der Philosophie* ('Historical Dictionary of Philosophy') show that terms like "Dictionary" or "Handwörterbuch" are also used for forms of presentation that offer not only information on the use of technical terms, but also on the discipline-specific content, which is closely tied to word usage. Beyond alphabetical access, cross-reference systems can be used to increase the degree of systematic organization and integration. The decomposition of discipline-specific content along central terms requires different strategies for designing textual components and different strategies for organization and systematic integration.

Scientific textbooks differ from handbooks mainly in their didactic orientation: they are targeted at newcomers to a field in a specific knowledge constellation, to teaching situations such as lectures, and to specific objectives and forms of examination. However, like handbooks, textbooks aim at systematically structuring a field. In addition, technical terminology and its place in a system is introduced and explained. In most cases and depending on the subject area, scientific textbooks today are characterized by a highly multimodal presentation, using text, different kinds of images, spatial arrangement, colour, icons, etc. in a coordinated manner (cf. Bezemer and Kress 2016). A good example is the biology textbook by Campbell et al. (2018), in which multimodal resources are used in a sophisticated way. Another particularly interesting example is the *Duale Reihe* ('Dual Series') published by Thieme-Verlag: in addition to the ample use of multimodal resources, the medical textbooks of this series integrate two components: a standard textbook, which occupies about  $\frac{2}{3}$  of each page, and a condensed textbook, which is contained in a parallel column, which makes up the remaining third of the page. Depending on the study situation, users can jump between the standard and the condensed version or use only one of the two.

In contrast to their enormous importance, scientific textbooks have so far not attracted intensive research. Examples are case studies like Schlösser (2012) on textbooks on economy and the handbook article by Bezemer and Kress (2016). From a historical perspective, the works of Fuhrmann (1960) and Stükelberger (1994) on ancient textbooks can be mentioned. Further work is devoted to individual aspects or elements of representation (e. g. Freyer 1998 and 2000 on the textbook picture in medicine, Keil 2007 on the transfer of specialist knowledge) and questions of linguistic and multimodal design (Guo 2004; Swales 1990; Lundgren and Bensaude-Vincent

2000). Of course, there is research from other perspectives, for example on the social role of textbooks in the scientific community (e. g. Myers 1992). Overall, however, it must be said that the connections between text organization, knowledge transfer and specific textual and communicative procedures have not yet been investigated on a broad basis.

Among the oral forms of result-oriented knowledge organization and transfer the scientific lecture (see Chapters 12 and 26, this volume) and, more recently, the scientific presentation are prominent (cf. Lobin 2009; Dynkowska, Lobin, and Ermakova 2012; Schnettler and Knoblauch 2007; Bucher and Niemann 2012). Compared to written forms, the scientific lecture also shows aspects of body-mediated performativity; depending on the degree of preparation, typical phenomena of spoken language can occur. If lectures are supported by visual means of presentation, questions of the functional connection between what is expressed verbally and what is shown visually arise, as well as questions of the procedures of coordination. They include pointing gestures, explicit verbal reference to what is shown, parallelizing elements mentioned and shown on slides, direction of gaze, etc.

Lectures and presentations are also an important means of communicating scientific content to a wider public (see Chapter 27, this volume). In addition to the performances intended for the attending public, it is possible to make them accessible in medialized form via general or specific Internet portals such as YouTube or Slideshare. I wish Alexander von Humboldt's Kosmos Lectures in Berlin were available on YouTube, they would, like many outstanding Science Slam contributions or lectures of the 21st century, be usable beyond the moment of their performance.

The (instances of the) epistemic genres discussed so far are used publicly and result-oriented. For the generation of knowledge, however, numerous other forms of communication, which are used in the communicative background, must also be mentioned. These include laboratory protocols, reading excerpts, notes on ideas or observations, e-mail exchanges with colleagues or personal conversations in various, sometimes informal constellations. Texts and communication events of this kind are difficult to document and to evaluate in their role for scientific work. Indications of their role were given, for example, in the context of *Laboratory Studies* (e. g. Latour and Woolgar 1986; Knorr-Cetina 1999). But also in correspondences or prefaces there are sometimes references to the important role of such informal types of communication in the background.

Many forms of discussion that take place in the background are central to the work on knowledge. These include the critical discussion of early stages of publications and discussions that serve the development of project ideas. Semi-public forms include scientific panel discussions. They often do not aim at presenting results, but rather at the development of perspectives or the exchange of points of view in a controversial field. Equally important are epistemic forms of discussion that characterize everyday academic life, for example forms of teaching and counselling, but also examinations and communication in working groups (cf. Fandrych, Meißner, and Slavcheva 2014;

Redder, Heller, and Thielmann 2014; GeWiss o. J.; Fandrych, Meißner, and Wallner 2017).

With the digitization of science new tendencies have emerged, for example the open science movement, which advocates that not only scientific results but also the underlying research data should be accessible, controllable and reusable. In the field of scientific publishing the open access movement is gaining momentum. Some of the uses of new media (portals, Twitter, mailing lists) equally serve epistemic functions, for example when research results are summarized on mailing lists and, if necessary, critically discussed. Other uses of social media contribute more indirectly to scientific tasks, for example by providing information on new work, new projects, or new publications in a field of research (Bader 2018).

### 3.3 Knowledge organization, communicative tasks, and functional text units

In scientific texts specific communicative tasks have to be fulfilled, some of which are particularly closely related to the epistemic aspects of knowledge generation and organization. These include:

- to formulate a research question and to explain its relevance;
- to define a terminological expression;
- to describe a scientific object in its relevant aspects (e. g. a type of cell tissue);
- to describe a process and explain how the parts of the process interact (e. g. in cell division);
- to announce that a sub-topic of the text is now finished, and then announce the following sub-topic;
- to specify the evidence or source of a statement;
- to explain which method is used and why;
- to indicate where gaps in knowledge exist, where uncertainty exists or where contradictory findings may exist, etc. (cf. Janich, Nordmann, and Schebek 2012).

For all these activities there are typical units of realization in various scientific domains, which can be dubbed “functional text units/modules” (Fritz 2017, ch. 2.1), “text routines” (Feilke 2010) or “constructions”, among others. Functional text units can be of different size and complexity. The spectrum ranges from elementary units (e. g. the citation of a source) to large units that can extend over several paragraphs (e. g. describing a plant). These units make up a modular system, in which larger functional units can be assembled from smaller ones.

The examples show that the individual activities and textual units are related in very different ways to questions of knowledge generation, organization and transfer: while the scientific description of an object such as the genome sequence of *Mycobacterium lepromatosis* directly represents the knowledge of the object, information on

the chosen analytical methods, for example, contributes to a critical assessment of the knowledge presented and the investigation methods used. In many cases, however, the separation of objects and analytical procedures is not neatly feasible, because scientific objects are at least in part co-constituted by theoretical assumptions, scientific practices and associated tools.

### 3.4 Knowledge organization and thematic organization

In addition to the functional structure of scientific texts and communicative arrangements, the thematic organization is closely linked to knowledge generation and organization. Four aspects are particularly important.

(1) As a rule, different types of scientific objects require specific forms of thematic decomposition. A historical event such as the Röhm Putsch, a newly discovered type of bacterium, black holes in the cosmos, the structure of the noun phrase in English, all these are examples of scientific objects from different domains, each of which requires specific thematic decisions. With the term “thematic decomposition” (Schröder 2003) we refer to the question of which sub-topics a global or superordinate topic requires or permits. The term “thematic decision” implies that writers generally have alternatives in the selection, delimitation, weighting and sequencing of sub-topics, for which a choice must be made, which must be implemented linguistically and, if necessary, justified. In many cases, a specific perspective on the subject is associated with a certain type of thematic organization. Reviews and other forms of commenting on scientific works are the communicative domain where thematic decisions and forms of thematic organization can be discussed and, if necessary, criticized. In addition, there are often reflexive passages where the authors themselves discuss and openly address thematic alternatives, textual needs or aspects that speak in favour of one or the other thematic alternative.

(2) Scientific forms of representation (types of text, types of multimodal communication, oral forms) can be regarded as more or less standardized or schematized forms of the accomplishment of communicative tasks of knowledge organization and topic management. Anyone submitting a paper for the *Proceedings of the National Academy of Sciences (PNAS)* can rely on proven and traditional patterns of representation, which include aspects of thematic development depending on the subject matter. In addition, there are also creative, novel solutions for knowledge and topic management, for example in the field of new media and textbooks. The aforementioned dual strategy in the Thieme medical textbooks (standard textbook plus condensed textbook on one page) is quite obviously a specific development that responds to the needs of medical education in different phases.

(3) Forms of thematic organization and progression in scientific texts are, with regards to knowledge dynamics, co-determined by different target audiences and by communicative purposes related to them. Types of target audiences can be derived, for

example, from educational levels (e. g. first-year students, examination candidates), professional constellations (e. g. biochemistry *for* physicians), constellations of being affected (e. g. scientific information units on blood cancer for patients) and other aspects such as assumptions about the linguistic and professional prerequisites of a readership. The central aspects of topic management for specific user groups include first and foremost the coordination of topic progression and knowledge requirements, but also the calculation of what can be assumed with regard to word usage by one or more target audiences. Thematic organization, systematic knowledge building and controlled use and introduction of word usage are therefore very closely related.

(4) If one assumes a close connection between knowledge organization and topic management, then the question of the textual procedures of topic organization arises, e. g. forms of thematic labelling of sections (for a micro-analysis of thematic labelling in Rudolf Virchow's *Cellulopathologie* [1858] cf. Gloning 2012). Procedures of thematic labelling at the textual surface include:

- the use of structuring and enumeration means (e. g. *on the one hand – on the other hand, firstly, secondly, further, in addition, finally, ...*);
- the use of connectors that can be used to indicate the kind of connection between parts of the text (e. g. *of course, however, therefore, to conclude, to sum up, ...*);
- forms of indicating sub-topics, e. g. by placing prominent noun phrases at the beginning of paragraphs, e. g. (*As for/Regarding*) *The Structure*, or by typographically highlighting thematic signal words, e. g. by boldface or italics.

In addition, traditional paratexts, e. g. tables of contents, headings, headers, living column titles, spoken or visually supported topic overviews in lectures or presentations as well as navigation devices in digital documents are equally important means of global topic organization. Aspects of word usage and terminological elements in their function as a means of topic access and retrieval also play an important role (cf. section 4).

### 3.5 Forms of visualization and epistemic functions

The use of illustrations and other forms of visualization is one of the most important developments in science communication (see Chapter 11, this volume). Texts are often functionally coordinated with illustrations. Different procedures have evolved for the spatial arrangement of texts and images on pages or double pages. There are also specific traditions of using and coordinating spoken text and images. For specific purposes, different types of images (photos, infographics, techno images, etc.) can be used in different disciplines. All these developments are closely related to objectives and tasks of knowledge organization.



### 3.5.1 Images: types and functions

With regard to forms of multimodal knowledge organization, one can first distinguish several types of illustrations together with their functional potential (“reach”). The most important types of illustrations include:

- photographs or drawings of objects (e. g. plants, organs),
- infographics for the structure of complex objects, the course of temporal events and for the explanation of complex connections (Blum and Bucher 1998: ch. 8; Tufte 1998a, 1998b, 2000),
- the products of imaging procedures in the broadest sense, e. g. X-ray or ultrasound images,
- forms of data visualization, for which specific research and teaching areas were developed (example: Brath and Banissi 2016).

In printed media only static images can be used for display on a spatial surface, whereas in audio-visual media (e. g. educational films, digital media) moving images can be used. Here the dimension of space is combined with the dimension of time. In addition, there are forms of interactivity which allow for personal “epistemic paths” while using a document space.

Illustrations can be classified, among other things, according to the type of production, the underlying technical background and the associated usage potential. In their time, newly available techniques such as photography, film technology, (electron-)microscopic photography, imaging processes, e. g. with ultrasound or X-rays, had considerable effects on the processes of knowledge generation, transfer and representation both in research and teaching. I will illustrate this point with two examples:

(1) In early bacteriology of the late 19th century, the identification of pathogens was one of the most difficult problems. Robert Koch succeeded in producing ‘photograms from nature’ (1877; “Photogramme nach der Natur”) of bacteria for the first time by combining dyeing techniques, microscopy and photography. He used these photograms as colour reproductions in his scientific treatises. Together with forms of proof for the connection between pathogen types and certain diseases, these visualizations contributed to the constitution of the new research object (“bacteria”) at that time.

(2) For a long time, the representation of surgical techniques depended on textual descriptions, some of which were supplemented by illustrations (woodcuts, copper engravings, drawings, photographs). With the availability of film technology, specific instructional films could be produced, for example films of a prototypical operation in which an off-voice explains the individual steps and provides further information on how each step must be executed. The spoken text provides information which moving images alone cannot convey and vice versa. Today, such materials are available in portals and on companion CDs or websites to textbooks.

The types of functions that can be fulfilled with illustrations in scientific contexts show great variety. Nevertheless, there are prototypical uses in specific fields of science and in different forms of communication. These include, for example, images of persons in biographical articles or lectures. Maps or topo-graphics can be used to illustrate spatial relationships. Timeline information graphics in history and cultural studies can be used to illustrate historical events and phases in their chronology. Reproductions of medical techno images (images that are the results of specific technologies like medical ultrasound) in textbooks can be used to prepare medical students for the use of such images in medical practice, etc. In different fields, specific repertoires of illustration types and forms of use have historically developed (e.g. Holländer 2000; Siegel 2009; Schneider and Nocke 2014; see also Chapter 25, this volume).

### 3.5.2 Forms and methods of text/image coordination

One of the basic methods of coordinating text units and images or parts of images is explicit referencing by means of image numbers and sigla, which can be found both in the text and in or at the bottom of an image. In a more complex form, an image caption provides a link between the main text and image elements, whereby the same expressions are usually used in the caption and in the main text. Another method coordinates picture elements and text parts using arrows or connecting lines. There is a broad spectrum of coordination techniques, from the aforementioned basic procedures up to the modern possibilities of digital linking of textual units and visual elements, which often work in both directions. The history of all these coordination procedures has not yet been written.

In the field of spoken texts, forms of coordination with illustrations are very common too, for example in the context of scientific presentations (Lobin 2009). Different ways of designing and coordinating presentation slides, spoken text and bodily performance yield different and surprising results with respect to comprehension and retention (Dynkowska, Lobin, and Ermakova 2012). Historically related to the use of illustrations are demonstrations, where speaking and showing are orchestrated, for example in medical corpse dissections, chemical experiments or the showing of objects together with spoken explanations in biological lectures.

### 3.5.3 Scientific fields and specific forms of visualization

Forms of visualization and their coordination with textual elements have a long tradition in almost all branches of scientific communication. Many types of visualization are closely tied to specific epistemic tasks, for example showing the network structure of a social group or Twitter-interaction, demonstrating the typical properties of an

object (e. g. a kind of plant), illustrating the structure of a complex machine (e. g. the Large Hadron Collider) or the phases of a process (e. g. an election), proving the existence of an object (e. g. a remote star) and many others, including topics with political implications like climate change (Schneider and Nocke 2014).

These traditions include, to name but a few examples, representations of plants from the early plant pictures of the Viennese Dioscorides manuscript of the 6th century up to the Early Modern herbals. In the field of medicine there is a long tradition and a broad variety of visualizations of objects (e. g. organs, birth positions), in technology there is a long tradition of picturing machines (Lefèvre 2004). Manufacturing and reproduction techniques (woodcuts, copperplate engraving, X-rays, modern imaging techniques like microscopic photography) both enable and constrain the representational potential of visualizations. In many scientific fields there are reflexive discussions about the benefits, dangers and the functional reach of image types. In addition, there is a specific educational literature that is oriented towards the use and the principles of “reading” images, e. g. sonographic images in medicine.

Similarly, other scientific disciplines can be examined with respect to the epistemic role of specific visualization practices (e. g. tree representations in syntax) and the question of how they have evolved: What role do practices of illustration play in early anthropological representations of the late 19th and early 20th centuries? What role did different types of images and visualizations play in astronomy and cosmology from Ptolemy to Regiomontanus and to the times of high-performance telescopes? What practical and epistemic role do methods of visualization in experimental settings have? As far as I can see, a comprehensive history of forms, functions, technical foundations and uses of visualization in the sciences has not yet been written. Valuable special studies, surveys and collective works are devoted, e. g., to the use of illustrations in individual disciplines (e. g. Herrlinger and Putscher 1967–1972), in relation to central periods (Holländer 2000) or in relation to specific forms, means or areas of use of illustrations (e. g. Freyer 1998, 2000; Oswalt 2015; Liebert 2007; cf. also Chapters 11 and 25, this volume).

Forms of visualization in knowledge generation and organization is a topic in its own right in the reflexive scientific discussion of visualization techniques. Current developments include discussions about big data and forms of visualization (e. g. Bubenhofer 2014) as well as reflections on the role of visualization in specific disciplines such as history, literature (e. g. Moretti 2007) or fields in which geodata and network structures play an important role.

### 3.6 Multimodality and multimediality

Today, scientific communication is organized more or less multimodally depending on the subject area. Even text-heavy books such as John Searle’s *Speech acts* or *Conven-*

tion by David Lewis use aspects of spatial arrangement (footnotes, indents, headers, lists), typographic means and a modest number of visualizations (e.g. tables, schemata). If, on the other hand, one looks at a modern biology textbook (e.g. Campbell et al. 2018) or the articles in scientific periodicals, it becomes clear that there is a considerable difference in the complexity of multimodal organization, both with regard to the number of resources used and the complexity of its organization as well as with regard to the procedures of orchestration.

If we look (again) at the website of the *Proceedings of the National Academy of Sciences of the United States of America* ([www.pnas.org](http://www.pnas.org)) as an example, this site is multimodally structured in a highly complex manner, which includes interactive elements and intermediality. The focus of this website is on access to the contributions of the *Proceedings*. The resource “text” still bears the main thematic burden. On the other hand, numerous topic-specific forms of visualization are used. Colour markings, forms of spatial arrangement and quotations-as-links further contribute to the multimodal structure. Images can be downloaded separately in order to facilitate their use in teaching. The site also offers a wide range of podcasts (sound files with transcriptions), a video library, links to press resonance, blogs, Twitter, Facebook, etc., as well as services such as various email alerts to subscribe to news and information. This example is only one among many; it shows how multimodal forms of design shape not only traditional epistemic genres like journal articles, but also digital systems with which information transfer is organized. If one compares these multimodal and digital systems with the card catalogues of the 1980s, it becomes clear what profound changes have taken place in one single generation.

Although multimodal forms of design have dramatically gained importance, it is worth noting that they were also available in earlier centuries (see Chapter 25, this volume).

The communicative processes and patterns of knowledge organization in the sciences are closely connected to the available media and the underlying technologies. In the age of handwritten dissemination of knowledge in antiquity and the Middle Ages, many semiotic resources of representation were already available, which we today call multimodal (e.g. font face, spatial arrangement, colour, text/image coordination), but the communicative reach of manuscripts was limited, even though there were well-organized systems of manuscript duplication in those times. The history of science communication and its varieties of knowledge organization is deeply influenced by new media. These changes include:

- the emergence of scientific journals from the second half of the 17th century onwards with consequences for the repertoire of genres and the publication dynamics in scholarly communication (cf. Habel 2007; see Chapters 14 and 25, this volume);
- the possibility of producing and reproducing increasingly complex and dynamic images, ranging from schematic woodcuts or painted illustrations to complex, multimodal, interactive infographics;

- technological changes that open up new possibilities for presentation, documentation, distribution and access (e. g. book printing, photography, colour printing, digital storage, access and publication technologies);
- Communication and cooperation technologies (letters, telephone, e-mail, video conferencing, mailing lists, digital data exchange, digital learning platforms, etc.).

The emergence of new technologies and their uses follows distribution patterns that are guided by discipline-specific differences: for example, digital publication platforms like ArXiv in the natural sciences were used much earlier than in the humanities. A further example: Reading a printed manuscript at conferences without any visual support still exists today in some disciplines of the humanities, while in other areas the freely spoken lecture supported by presentation slides is common. New media and technologies are often used conservatively without exhausting their epistemic potential. For a long time, for example, reviews on online platforms were equivalent to their printed counterparts, and the potential of new media remained and remains unused to some extent to this day: only text, no interaction, no hyper-linking. On the other hand, there are innovative uses of the multimodal and interactive potential of new media for open peer review (see Chapter 14, this volume).

## 4 Epistemic genres, knowledge organization, and terminology

Terminologically used expressions are an essential instrument for producing and organizing knowledge in different scientific fields. With regard to the relationship between knowledge organization and terminology, three main questions arise: What role do terminological units and the terminological systems in which they are embedded play in the organization of scientific knowledge and knowledge transfer in different disciplines (section 4.1)? Which communicative methods are applied for work on terminological units and their use in scientific texts and discussions (section 4.2)? What do terminological units contribute to the constitution of scientific objects (4.3)?

### 4.1 Fields of knowledge and terminological systems

In a widespread spatial metaphor, one speaks of knowledge areas, thematic areas or fields. This metaphor captures the ideas, that knowledge fields have a border and show an internal organization. Scientific disciplines and other technical fields (e. g. types of craftsmanship) are subject to high requirements of systematization and explicitness. The discipline-specific system of knowledge organization has its counterpart in a structured technical terminology, the organization of which is closely related to the

knowledge system. Epistemic genres organize the mapping of fields of knowledge and terminological systems.

For the purpose of illustration, let us take the biology textbook of Campbell et al. (2018) as an example. With respect to the terminological profile of such a work, one first recognizes the close connection between the thematic structure of the textbook, the systematics of the subject field it represents, and the architecture of the terminology. For example, genetics, the study of cells or the history of the development of living beings (phylogenetics) are sub-areas of biology with their own terminological sectors that have developed historically.

The assumption that positions in a system of ideas can be mapped to a system of word usage and corresponding vocabulary sectors is a powerful tool for the analysis of terminological systems and their architecture. Tables of contents and the hierarchical organization of their terminological units can be used in order to reconstruct terminological systems. Registers, indices, glossaries or terminological dictionaries and thesauri list terminological units for different purposes, including navigation or didactic purposes.

If someone works through a textbook, then she or he will at the same time acquire knowledge about scientific topics and knowledge about the meaning of expressions. If, for example, someone works through Campbell's textbook mentioned above, he or she will not only learn a lot about basic assumptions and essential results of the evolutionary history of living beings, but will also acquire many items of the specific technical vocabulary and their meanings. In respect of scientific texts, there is a close connection between representation of encyclopaedic knowledge and knowledge of meaning, even if one cannot simply equate the two forms (cf. Gloning 1996, 344 f.; Dieckmann 1988).

The systematic architecture of a terminology with its manifold interrelations, dependencies and presuppositions is one of the most difficult and important tasks in writing a textbook with its sequential textual organization. In the event that a (digital) textbook provides different reading paths, the complexity of this task still increases because there is not a single reading path with its sequential aspects of knowledge and terminology management, but a network-like structure, which can be quite complex for works of several hundred pages and which requires, for example, digital hyperlinking and cross-referencing.

## 4.2 Terminology management and textual procedures

In epistemic texts, terminology work is closely linked to specific textual procedures (Roelcke 2013: 2). These include definitions of new terms or new ways of using them, definitions of already established technical terms, the introduction and explanation of conceptual distinctions, the introduction and explanation of technical terms in textbooks and other introductory works, the presentation of discipline-specific terminol-

ogy systems and the principles of their organization. Moreover, we find proposals for new terminological units and the discussion of their advantages and disadvantages.

Terminological units can also be the target of criticism; the communicative place for this is, among other things, the critical parts of publications (e. g. literature discussions in monographs, reviews) or oral discussions following lectures. From a historical perspective, criticism of terminological units was often associated with a change in scientific views or with aspects of competing theories.

Terminologies, thesauri and so-called ontologies are important means of organizing access to technical knowledge, be it with registers or indices to scientific contributions, be it in library catalogues or other documentation systems, be it in websites such as Wikipedia. From a communicative perspective, the connection between knowledge systems and terminological systems is used to make resources findable. For example, a terminological entry like *turn-taking* (from the field of conversation analysis) can be used to organize access to publications related to the topic in question. “Findability” is one of the FAIR principles in designing a new digital environment for scientific research: findability, accessibility, interoperability, reusability.

The use of words of everyday language can be a resource for the establishment of technical usages. Examples are expressions such as *point* (mathematics), *resistance* (psychoanalysis, physics) or German *bösartig* (‘malignant’, medicine). Conversely, technical usage can become common usage, for example when technical topics also become the subject of public discussion, such as in the case of HIV, nuclear energy or climate change. The works of Pörksen (1986) and the contributions in the volume *Kontroverse Begriffe* (Stötzel and Wengeler 1995) offer numerous examples and communicative contexts. Definitions, word formations, forms of metaphor and other procedures are important resources of concept formation in the sciences. However, the perspective of terminology development should always be tied back to communicative procedures in texts and conversations in which either explicit terminology work is carried out or in which established ways of using words continue to stabilize or change in small steps.

### 4.3 Theoretical objects and their constitution

If one chooses a *prima vista* unspectacular expression such as *infection* as a starting point, it becomes clear that its medical significance is shaped by changing medical views and by scientific work in the relevant field. If, for example, one reads Fleck’s article *The Modern Concept of Infection and of Infectious Disease* (1930), one can see how the work on concepts such as *infection*, *virulence* or *immunity* is closely linked to textual processes of representation, to changing stocks of knowledge and to competing scientific views (cf. Fleck 2011: 70–90).

Scientific objects are constituted by the theories in which they are treated, even if everyday phenomena can be a starting point. Communicative procedures in texts

and conversations are the place where work on the constitution of scientific objects is carried out in a collaborative manner. Various approaches to the history of science have made it plausible that scientific contexts in laboratories, styles of thinking (*Denkstile*), experimental environments and other factors have a bearing on the way in which scientific findings are made and thus “constituted” (e.g. Rheinberger 1992, 2007; Fleck 2011; Hull 1988; Shapin 1994; Latour and Woolgar 1986). On the other hand, detailed studies on the building up of conceptual worlds in texts and on the constitution of terminological systems along sequential text still belong to the desiderata in this field.

## 5 Epistemic genres and quality control: criticism and controversy

In many everyday situations, one can put forward views that do not stand up to strict standards of verification and proof. For example, narratives in a sociable environment are intended primarily for entertainment, therefore precision and faithfulness to facts are not high-ranking principles. In the sciences and their sub-areas, on the other hand, specific quality requirements and verification principles apply, which can be enforced in certain communicative contexts and for certain genres. However, there is no overriding scientific authority to monitor compliance to these principles. Rather, there are specific forms of communication within science that are used to discuss and to assure quality of scientific texts. The notion and relevant aspects of “quality” itself can be a matter of communicative deliberation.

Quality assurance in the sciences and humanities is served, for example,

- by reviews,
- by critical contributions or by parts of contributions (e.g. reports on previous research in the context of monographs),
- written or oral controversies,
- critical questions and contributions to discussions following lectures,
- various forms of critical commentary on manuscripts through formalized procedures of (open) peer reviews or by way of personal communication.

In addition, individual disciplines and journals have developed specialized arrangements that serve the critical examination of theses, methodological procedures or new concepts: in the journals *Behavioral and Brain Sciences* or *Language and Cognition*, for example, thematically dedicated issues with a target article have been published for many years. Target articles are critically commented on by several colleagues and the authors of the target article then have the opportunity to comment on the comments. This format allows for a close examination and collaborative discussion of new ideas and proposals in a short time frame.



The available media also determine the spectrum of critical activities: with the printing of books, scientific controversies were given a wider scope and with the availability of scientific journals from the late 17th century onwards, a new review system emerged, which both allowed for timely information about new publications and for their critical examination (cf. Chapter 14, this volume). In addition, the exchange of letters between scholars in the Early Modern period was a widespread medium for exchange, scientific discussion and controversy (Fritz 2010; Dascal 1998a, 1998b). In digital science communication, some of the established forms of criticism have been adopted and adapted in new media, e.g. varieties of reviews. There were experiments with other formats and format constellations, such as electronic roundtables on mailing lists (see Gloning and Fritz 2011 for this and other formats).

The communicative procedures and the media of scientific quality control were repeatedly the subject of discussion, as can be seen from public complaints about the peer review procedure, from criticism of review cartels or reports on forms of scientific misconduct and other forms of failure of scientific quality control.

There are approaches in which the use of scientific language and forms of scientific communication were the subject of epistemic criticism, linguistic criticism and linguistic scepticism. Large parts of the theory of science deal with linguistic-communicative questions, including questions concerning the nature of scientific genres: What counts as an explanation? What types of explanation (for what types of objects) are there? What role does narration play in the historical sciences? How must theories be formulated and constructed so that essential criteria such as systematicity, coherence, freedom from contradiction, etc. are fulfilled? Parts of the discussions on an ideal language (Eco 1994; Sinnreich 1972; Maat and Cram 2000) addressed the shortcomings of everyday language in relation to the stricter requirements of scientific knowledge: Leibniz, Newton (Elliott 1957) or Frege (1879) are prominent examples of authors who pursued the plan of a universal language of thought or an ideal language as an instrument of knowledge management.

As for controversies as an environment of scientific quality control, there are numerous contributions that originate from different disciplinary roots including the history of science, the history of ideas, (historical) linguistics, argumentation theory to name but a few (e.g. Rudwick 1985; Lakatos and Musgrave 1970; Engelhardt and Caplan 1987; Dascal 1998c; Fritz 2016, ch. 6, 9, and 10; cf. the book series *Controversies*, published with Benjamins; see also Chapter 15, this volume).

## 6 Further perspectives

So far, I have focused on the connection between knowledge organization and specific communicative procedures, terminology issues and aspects of quality assurance in the sciences, which are specific for the organization of epistemic genres. It has

become clear that science communication is multifaceted. There are, however, aspects of variation in science communication that can not only be explained by epistemic differences between disciplines and their communicative repertoire, but by political, economic and socio-economic factors, which are not the focus here.

Yet, political and socio-economic factors do have linguistic and communicative ties, ranging from forms of justification for the use of public funds, questions of unequal supply of literature, the suppression of scientific findings for economic reasons to public images of science. These images range from beliefs in the authority of science to openly anti-scientific positions, e. g. in the field of creationism debates. Educational discourses are related to the institution of the university, its mission, tasks and problems in a rapidly changing world (e. g. Hahn 1995; Collini 2017).

Furthermore, looking at aspects of variation in an epistemic perspective, the points of view mentioned in the previous sections offer starting points for a more differentiated disciplinary picture, which already exists in some places (e. g. Ylönen 2001 on the original works in the field of medicine). Nevertheless, it would be desirable to further investigate the specific characteristics of different disciplines and how they are related to the repertoire of genres, forms of representation, strategies of visualization and multimodality.

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# 11 On the nature and role of visual representations in knowledge production and science communication

**Abstract:** This chapter presents a conceptual framework for a more thorough and conscious investigation of visual representational practices within the different discourses of scientific data representation, conceptualization, and scholarly and public communication. While several scholars have pointed at the great diversity of visual representations and their uses, few systematic attempts have been made at devising a typology of uses or at producing an encompassing framework for increasing insight in this complex domain. Such a taxonomic attempt however may form the basis or starting point of a more conscious practice and an essential part of a program aimed at heightening both social and natural scientists' visual literacy skills as well as those of science communicators.

**Keywords:** visual representations – scientific visualization – visual typology – visual literacy – visual competencies

## 1 Introduction

The multifaceted issue of visualization in knowledge production and dissemination involves the complex processes through which scientists and science communicators develop or produce (and communicate with) imagery, schemes and graphical representations, computer renderings or the like, using various means (ranging from a simple pencil on paper to advanced computers or optical devices). Therefore, not just the result, but also how it was attained (i. e., the implicit or explicit methodology in the broad sense of the word) and the subsequent uses to which the result is put, should all be scrutinized as to their impact on the nature of what is visually represented and the ways in which this representation can be employed. Visual representations in science differ significantly in terms of how they relate to what they purport to represent (i. e., their representational and “ontological” status), the means, processes, and methods by which they are produced, the normative contexts involved, the purposes served, and the many ways in which they are used and combined, to name but some of the more crucial aspects.

This chapter will discuss a number of key aspects and intricacies of the production and transfer of knowledge of a highly varied nature to a range of distinct audiences and equally diverse purposes, using a variety of visual instruments. It will look at the role of visuals in scientific discourses, or in the process of knowledge production and dissemination in a broad sense.



As such it eschews any narrow definition of science communication as the “popularization” of science for general audiences. “Science communication” or the communication of knowledge, in this broader view, occurs at different levels: starting at the “intrapersonal” (scholars trying to record their thoughts, findings, or insights in a specific material form), to the “interpersonal” (exchange of views or data between specialized peers in journals and during conferences or with individual actors) to the “group” level and “mass media” (including larger groups of potential stakeholders such as students, the media, sponsors, and the general public). All of the levels do share a collection of common principles, opportunities, and intricacies in regards to the usage of visual materials in an intelligible and appropriate way.

## 2 The varied nature of the referent: what is being depicted?

The array of objects or referents of visual representations in science is very broad and of a highly heterogeneous nature. Visual representations in science may “refer” to objects that are believed to have some kind of material or physical existence, but may equally refer to purely mental, conceptual, theoretical, abstract constructs and/or immaterial “entities”.

Material or physical referents may have visual characteristics that are *directly observable* to the human eye (e.g. various types of human interaction, the external structure of animals, trees, etc.). On the other hand, there are objects and phenomena with aspects that *only become visible with special representational means and devices* (e.g. they can only be observed using special techniques or instruments such as high-speed photography, satellite image transmission, a telescope, a microscope, or an endoscope). The reason is that either these aspects are too fast (e.g. an explosion, eye movements), too slow (e.g. transformations in a living organism), too big (e.g. stellar configurations), too small (e.g. microscopic organisms), too similar to each other (e.g. colors of vegetation), too far away (e.g. planets) for the human eye to discern, or they are hidden (e.g. organs of a living body) or inaccessible unless a destructive course of action is taken (e.g. the dissection of an organism, the creation of a cross section of an object, the excavation of remains). Furthermore, physical objects or phenomena may not have visual characteristics as such and still be *translated from a non-visible state* (e.g. sound waves, thermal radiation) *into visual representations* using special devices.

Representational practices in science often do not seek merely to “reproduce” visual or non-visual phenomena, but also to provide *visual data representations* (e.g. charts) of aspects of these phenomena based on measurements of some kind (length, weight, thickness, resistance, quantity, temperature, verbal responses, etc.). In the latter cases, “data” are derived from or constructed on the basis of an observed reality

and subsequently represented in a visual form that allows one to discern changes or see relationships more clearly. While the resulting representations are based upon empirical observations or interrogations in the field, they are not “reflections” of visual natural phenomena. They are rather visual representations of observations in the physical world that are not necessarily visual in nature. In other words, what is represented are not physical objects or phenomena, but data that are constructed by observing aspects of the physical world. The relationships among the data and their representation is much more abstract/arbitrary and conventional, though some aspects may be also be motivated or iconic (i. e., they may bear some resemblance to the referent). For example, graphical representations of the evolution of the birth rate within a particular population over a certain period of time, temperature fluctuations during one month in summer, or the number of murders per state do not necessarily entertain a visual iconic or indexical relationship (in the Peircian sense) with a physical or material referent, as often there is none. Instead, these data representations may have a mental referent as far as the source is concerned, since the representations are not so much depictions of phenomena in the real world as conceptual translations of aspects of it. Yet, they are based at least in part on quantifiable or qualifiable aspects of an observed “reality” of some kind and thus are not purely invented or products of the imagination. The referent of a representation may be even more *immaterial and abstract* in nature. Representations that primarily seek to visualize relations between observed phenomena, visualize hypothetical relationships, postulated phenomena or effects, and even purely abstract concepts. The referent of such representations may become an almost purely mental or theoretical construct that has no “pre-existence” in the physical, historical world whatsoever. Nonetheless, representations of these kinds of referents may play an important role in understanding or influencing that world.

Finally, it should be noted that many representations for scientific and informational purposes combine several of the abovementioned aspects and thus have *multiple referents and thus a hybrid semiotic status*. Certain aspects of the representation may, for example, refer to an observed visual reality in an iconic way (e. g. it might mimic its shape or color) and include conceptual structures (such as metaphors) or symbolic elements (arrows, markers, colors, shapes). A typical example here are most cartographic maps: their contours and some of the shapes included within them (like the trajectory of waterways and roads) refer in an iconic way to existing (national, natural or man-made) boundaries (some of them could indeed be observed in the same way from an aerial view), and some of the colors are also “motivated” to some extent (e. g. blue for water, green for woods), but many other aspects of elements on the map like the colors and thickness of the roads have symbolic properties: roads indicated by thick red lines may refer to the main roads or to highways with special traffic regulations, while in actual fact they will not necessarily be wider than other roads let alone painted red. The many textual parts and arrows then are purely symbolic types information, based on convention (driving directions, signs for landmarks, etc.).

### 3. Production processes: social, technological, and cultural aspects

#### 3.1 Inscription, transcription, invention, and fabrication

Every “representational” process involves a translation or conversion of some kind; a process of inscription (e. g. light that hits a light-sensitive surface and makes a permanent mark on it), transcription (e. g. analogue data which is transcribed into a digital notation), and/or fabrication (what the technology or the involved actors “add” to it) whereby the initial source (phenomenon, concept) is captured, transformed, or even (re-)created through a chain of decisions that involves several actors (scientists, artists, technicians), technological devices, and normative settings. This complex process of meaning-making has an important impact on what and how it can be known, on what is revealed or obscured, and on what is included or excluded.

As I have argued in the previous section, the divergent nature of the referent in science prefigures the crucial importance of the equally divergent processes of producing a visual representation. These processes not only involve technical issues but also encompass important social and cultural aspects. Obviously, technology and each of its products are part and parcel of culture (i. e., they are both a cultural product or “result” and a cultural actor or “force”), both in a broad cultural and a more restricted sub-cultural sense, and thus they embody specific norms and values (Pauwels 2006). Apart from the characteristics of the instrumentation, which are to some degree a result of cultural processes as well, a host of other social and cultural influences at the moment of choosing and selecting the objects, samples, etc., also have an important impact on how the representation will appear as well as on the purposes it may subsequently serve.

#### 3.2 Analyzing the social and cultural setting: division of labor and normative contexts

Rosenblum’s (1978) sociological study of photographic styles demonstrates how the “look of things”, particularly the appearance of press, art, and advertising photographs, is to a significant degree a function of various social, technological, and cultural factors and constraints that are connected with their creation. The division and standardization of labor, technological constraints, professional ethics, time pressures, as well as economic factors, all play a significant role in their creation, look, and value.

Sociologists of science, on the other hand, have studied the complex interactions in a laboratory setting where science is being “produced” (Latour and Woolgar 1979; Lynch 1985a), an approach that yields insight into how an object of inquiry is selected,

delineated, and “prepared” to fulfill its role. Lynch has looked at the laboratory setting and the processes by which natural objects are visualized and analyzed. Preparatory procedures that tend to turn the object of investigation into what Lynch calls a “docile object” fit to be studied according to the established methods and mores of science, as well as various aspects of the instrumentation and the laboratory set-up challenge the idea that scientific visualization provides an unproblematic or uncompromising “window” onto the natural world (Lynch 1985b: 43–44).

Similar processes are at work when scientists make observations in the “field”, as objects are here too selected and prepared to be subjected to scientific practices or made to participate in data-generating procedures. Furthermore, the issues of research funding (e. g. cost of using or updating equipment), academic recognition (e. g. by adhering to established traditions or certain schools of thought), and societal trends (e. g. with respect to technologies and ways of representing data), must all be taken into account if one endeavors to reveal and explain the processes that lie at the heart of particular visual representations of facts or ideas. They likewise may influence what is selected and how it is selected, and the way in which it is processed.

### 3.3 The varied nature of visual and non-visual transcription

There is a fairly significant, though not exclusive or unconditional relation between the nature of the referent and the processes through which a representation is or ought to be produced.

Obviously, *conceptual constructions* that have no material, let alone visual substance, cannot be recorded automatically or according to standardized and repeatable processes (e. g. mental images cannot be photographed or scanned electronically), as they are the result of multiple intentional acts that, first and foremost, require a suitable production technique for such highly intentional activity (e. g. pencil and paper or a computer drawing package). The involvement of the originator of the idea is paramount, and a demanding process of translating a mental image or an emerging idea into an inter-subjective visible representation is required. Aspects or dimensions that cannot in any way be visualized or verbally described are in fact lost to science.

Objects or phenomena that are *visible to the human eye* through direct observation, on the other hand, can be captured by representational devices such as a photographic camera that will produce detailed representations characterized by uniform time and continuous space. This may result in a kind of “indifference” (some might say “objectivity”, though this may be too burdened a term to use), since all elements and details are treated equally (even though photographers have ways of foregrounding or emphasizing certain aspects at the expense of others, such as through the choice of lens, film, filters, lighting, framing, viewpoint, etc.). However, directly observable phenomena also can be represented through more manual techniques, using simpler media, such as pencils and brushes, which require a more *intentional* series of acts by

humans (draftsmen, illustrators). These techniques produce imagery that do not have a uniform time (in fact quite some time may pass during the creation of the different parts of the representation) and that are not bound by continuous space or a uniform use of scale.

The process whereby one works from a *directly visible referent to a visual representation of it* would appear to be the most straightforward, but even then, a great variety of techniques are available. Moreover, even the commonly applied techniques have their intricacies, which are easily overlooked. This is true of relatively simple and ubiquitous techniques, including photography of directly observable phenomena, where one often has the advantage of being able to compare the referent (the object or phenomenon with a material existence) and the depiction (a drawing or photograph). However, as much such devices may differ in terms of the manner in which they “translate” an object or phenomenon into a record of it (a photograph clearly entertains a much stronger indexical relation with the referent than a drawing, and is thus more likely to be accepted as “proof” of its existence), it is important to note that both the source or the referent (the natural object or phenomenon) and its representation are “visual” in nature and are respectively captured and constructed by methods or processes that are essentially visual as well. In such instances, there is at least the theoretical option of comparing the source and its representation in order to assess to what degree and in which respects they resemble one another. Thus, a “check of correspondence” can be performed, albeit only to a certain degree.

A much more complex translation process occurs when the referent is visual and physical in nature (though often hidden from direct observation), while the *intermediate steps are not based on reflected visible light waves*. This is the case, for example, when ultrasound scans or X-rays are used. In these instances it is not light that is reflected by the object that is recorded, but a reaction of other types of “invisible” waves to some characteristic or aspect (e.g. density) of the structure of the referent. These translations, while equally “indexical” in nature, typically require a more cumbersome process of decoding and calibration (see for example Pasveer 1992); they do not allow a simple check of “visual correspondence”. Radiologists, for instance, need to learn how to “read” these images, and even then, they may differ on how a particular one should be interpreted.

If the translation process is not visual or if the referent is inaccessible or invisible to the unaided human eye, one has to rely on – and thus transfer authority to – the “machine” (Snijder 1989) in order to chart often unknown territory. In such cases, one has to be particularly aware of the possibility that one is looking at *artifacts of the instrumentation*, that is the “objects” and effects that are generated by the representational processes themselves and that do not refer to anything in the “outside world” or at least not to the phenomenon that is under scrutiny. In many data-generating processes, it is not always easy to differentiate “noise” from “data”. Artifacts or effects thus may be attributed erroneously to the outside world, while in fact they are produced standardly by the instruments or as a result of technical failure. Moreover, an

atypical representation also may result from an unexpected and unaccounted event or coincidence in the physical world.

So, especially if the referent is of an uncertain nature, the problem of artifacts of instrumentation may arise. This may be the case when the existence of the referent is postulated rather than confirmed by fact and the process of representation serves the purpose of providing such evidence; or when complex instruments are being used; or when aspects of reality can only be seen through the instruments, that is to say, as a “representation”. But even with very realistic renderings of directly visible objects (e. g. simple camera images of directly observable phenomena), one should be wary of the possibility of “effects” induced by the instrumentation. Such effects can present themselves to the uninitiated eye as qualities or traits of depicted objects (color, shape, spatiality) while in fact they are merely properties of the instrumentation (e. g. the extremely foreshortened perspective when using telephoto lenses makes objects appear much closer to one another than they are in reality; internal reflections may produce flare and ghosting, etc.). In a similar way, scientists should be aware of the possibility that important aspects of the referent might not be captured by the instrumentation (e. g. because of an inadequate resolution or insensitivity caused by a limited spectral range) or might mistakenly be weeded out as noise. Instruments, in addition to capturing or recording data, invariably both reduce (or lose) data and tend to mold (and add) data in a particular way. These two phenomena in themselves should already warn against a naïvely realistic view of the merely technical aspect of representation.

### 3.4 Algorithmic versus non-algorithmic processes

Every representation requires some kind of device or medium. Yet, it is useful to make a distinction between mediation processes that are highly automated, or *algorithmic* processes (e. g. photography), and more manually and intentionally performed – *non-algorithmic* – activities (e. g. hand-drawn or driven representations). However, these are not absolute categories and it is better to think about this useful distinction as two extremes of a continuum. Moreover, current digital technologies have blurred the dichotomy between “machine-generated” and “hand-made” imagery and increasingly have allowed for more complex combinations of the two (for instance digital photographs that can be manipulated at will with the aid of sophisticated software).

Technically sophisticated instruments that produce representations or images in a highly automated and standardized way (such as cameras and scanning devices) are generally thought of as the most suitable for scientific purposes, as they produce coherent, reliable, and repeatable representations with a predetermined level of detail. Moreover, they tend not to rely too much on personal judgment or skills in the process of image generation, unlike manual techniques such as drawing (though the interpretation of such representations may still require a lot of personal judgment and experience!).

However, in some cases more intentional processes and products may be far more convenient. This is true, for instance, if the depiction is *too detailed* for the intended purpose. This may be the case when using a highly automated and “indifferent” process such as a camera recording. Such a recording can be indifferent in the sense that all visible elements in front of the lens receive the same treatment, irrespective of whether they are relevant to the researcher. Thus, the essence of the recording may be obscured by unneeded, distracting, or irrelevant detail that can impede comprehension. Furthermore, intentional processes allow a much swifter combination of *different types of signs (iconic, indexical, and symbolic) and levels of signification*. Consequently, they may yield a more functional expressive presentation of fact and vision. A third important consideration is that intentional processes may provide a much needed *synthesis of features* rather than a simple transcript of a particular (snapshot-like) instance of a phenomenon.

For instance, ornithologists who use imagery to determine the species of a particular bird encountered in the field may be better off with well-crafted illustrations of a number of similar-looking species – such as a colored drawing that contrasts a heron (*Ardea cinerea* L.) and a purple heron (*Ardea purpurea* L.). After all, they can derive from such a drawing how the two birds differ “in general”. Color photographs, on the other hand, unavoidably show a particular specimen of each type of heron in a particular stage of its development and photographed against a particular background, in particular light conditions, from a particular angle, etc. This photographic “particularity” may be less helpful in determining the species of an individual bird in the wild.

On the other hand, purposefully simplified representations and abstractions may instill some misconceptions in people’s minds if they are not duly communicated or if they are used for other than the initially intended purpose. For example, medical students may be baffled by the visual differences between stylized and simplified anatomical drawings of heart, lungs, and vascular system in their introductory courses and the “real thing”. Similarly, engineering students may be surprised by the differences between a highly stylized drawing of engine wiring and the three-dimensional reality of a dismantled engine that needs reassembling.

*Scientific illustration* as a sub-discipline of science is an interesting example of a specialty that has evolved in recognition of the fact that both scientists and artists generally lack the skills to produce renderings of birds, human anatomy, or complex technical artifacts with the required level of detail and generic faculties. Using artists who are very skilled in drawing, but largely unaware of the exact purpose of the illustration, inadvertently will produce imagery that may thwart that purpose. Scientific illustrators, on the other hand, need to be well-versed in both the art of illustration and in specialized fields of science. They are trained to have a thorough and fully integrated knowledge of the subject matter or concepts that they are asked to draw and of the exact scientific and didactic purposes their products need to serve.

## 4 The visual product: the impact of medium and execution/style

### 4.1 Cultural impact on style and use of media

Visualization obviously results in a product that can be “seen”: a graphic representation, a photograph, a computer rendering. The products of a visualization process emanate the characteristics of the (final) medium or successive operations as well as the features of the particular application or instance: the selections and choices of what and how to depict.

The end medium or medium of presentation has an important impact on the final appearance of a visual representation. Although each medium has a number of preset characteristics, within each medium there is almost always a great variety in the manner in which a particular referent may be represented (mimetically and expressively). This choice and combination of specific formal options henceforth will be referred to as the “style of execution”. The style of execution is only partly determined by the medium.

The notion of a wide variety of styles within the same medium is illustrated easily by divergent painterly traditions such as Cubism and Hyperrealism. Similarly, scientists may choose a variety of methods and techniques (ranging from realist to extremely stylized, to metaphorical, or even phantasmagoric) for depicting a particular subject or idea. These variations in style have to do with genre conventions, cultural schemata, scientific traditions, specific circumstances of the production process, skill, preferences, and idiosyncrasies of the maker, as well as the specific purposes the representations need to serve. To complicate matters further, various media and styles may be combined in a particular representation, lending it a highly hybrid character.

Even if the referent is a phenomenon that is accessible through direct observation, this is still not a guarantee for a “faithful” or reliable reproduction, especially if a non-mechanical process, such as hand-drawing or painting, is involved. This is particularly true if the phenomena are drawn from memory after a brief and perhaps exciting encounter (for instance the early drawings of newly discovered animals). For representations based on first encounters or limited study, even the scientists may not know to what extent their representations have a rule-like (general) as opposed to an exception-like (deviant) quality. Even if memory is not the major obstacle, perception is always colored by prior knowledge of other phenomena, drawing conventions, cultural representational schemata, matters of skill, and mental processes. The human mind, as Gestalt psychologists revealed, seems very eager to fill in the gaps and to make us see what we want to see or what we expect to see.

Art historian Gombrich (1994 [1960]) provided a textbook example of this when he commented on Dürer’s famous woodcut of a rhinoceros (1515): “he had to rely on second-hand evidence which he filled in from his own imagination, colored, no



doubt, by what he had learned of the most famous of exotic beasts, the dragon with its armoured body” (Gombrich 1994 [1960]: 70–71). But even drawings that are claimed to have been made “from life” (“sur vif”), such as Villard de Honnecourt’s *Lion and Porcupine* (about 1235), may not provide us with depictions that are as faithful as the medium allows but highly idiosyncratic or artistic renderings, which in de Honnecourt’s case included a quirky stylized lion that would better serve heraldic purposes than (naturalistic) representational ones. Gombrich concluded that the claim that something was made “from life” clearly must have had a different meaning at that time: “He can have meant only that he had drawn his schema in the presence of a real lion” (Gombrich 1994 [1960]: 68).

## 4.2 Visual representational latitude: coping with variation in the depicted and the depiction

Though visual media and techniques provide many unique advantages in representing the physical world and in expressing scientific ways of thinking, as soon as a certain level of abstraction or generalization is needed – an essential facet and phase of many scientific undertakings – some distinctive problems may arise. Verbally, for instance, one can state that a certain bird species may have three to seven spots on its wings. However, when producing a visual representation, one inevitably must draw a definite number of spots. Visuals, unlike oral descriptions, do not offer the option of indicating a range, say “from three to seven”. Instead, a choice needs to be made out of the five possibilities when representing in a single drawing a species that exhibits that amount of variation. Moreover, if a photograph is used, one is even forced to show a particular specimen of the species (or a series of photographs of different specimen), of a particular age and sex, in specific circumstances (habitat, weather, time of day, season, etc.).

Neither intentional nor more automated (algorithmic) visual images can by themselves express in a simple way the variation (in shape, color, amount, etc.) one may expect to encounter in the real world. Nor can visual depictions fully explain the connections among the particularities of the representation (the variation in the depiction) and what they seek to refer to (the phenomenon and the different forms it can assume in reality).

This multifaceted problem of different types of justified or unjustified variation in visual representations, combined with both the variation that exists within the species or phenomenon that is depicted and the variation in the depiction of certain phenomena or ideas, could be coined “visual representational latitude”. This latitude will be determined partly by the capacities of the medium applied (e.g. intentional versus algorithmic media) in coping with the variation observed within the depicted phenomenon or process, but more importantly by the *manner* in which that medium is used, including the stylistic options it offers, the scientifically motivated choices, and

the various “liberties” that producers allow themselves. The “room for maneuver” or representational margins may or may not be purposeful, functional, and understood.

Visual representational latitude, therefore, is not just a producer’s (or sender’s) problem; that is, it is not just a matter of deciding how to express variation, of choosing the right level of iconicity or abstraction for a specific purpose. It is also a user’s (or receiver’s) problem: what kind of variation is to be expected in the real world, and which elements in this particular representation are ‘motivated’ by a perceived reality, and which others are due to specific, intentional or unintentional choices of the producer, limitations of the medium, or larger production context? To what extent is every choice to be interpreted as “necessarily so” or as just “one way of putting it”? If, for instance, a physical phenomenon is depicted as consisting of a core with, say, 23 particles revolving around it, one is still uncertain whether this exact number of particles is a unique and thus determining trait of the phenomenon, or whether the person who produced the diagram merely meant to indicate that “many” particles are revolving around the core. Similar questions could be raised with respect to the relative distance of the constituting parts of the drawing, their scale, color, shape, etc.

Verbal comments (e.g. in the form of an extended “legend” and various other ways to add symbolic information – e.g. graphic markers; colors – to the visuals) are one way of making sure that users know what they are looking at, what codes are being used, what semiotic variation is being employed, and what representational claims are put in effect by the representation. Another way is to develop further a visual language of scientific representation, which in a sense restricts the ways in which visual elements may be employed, but at the same time enables a more visual and less ambiguous form of information transfer and expression.

## 5 Types and contexts of use: matters of encoding and decoding

### 5.1 Representational constraints

Representations cannot serve adequately just any purpose or intent. Various significant relationships exist between the type of referent, the production process, the medium, and the types of uses and claims that can be attached to them. Visual representations must have the necessary “properties” to comply with certain functions or uses. These properties denote not only the characteristics of the medium that is employed but also imply the broader contexts of both production and use.

Mitchell (1992) distinguished between two types of representational “constraints” or, put differently, two factors that both the producer and user will have to take into account when trying to apply visuals successfully in a communication and cogni-

tive process. First, there is what he called *representational commitment*, by which he meant that certain techniques are (more) appropriate for recording certain things and less suited or even totally unsuited for recording others: “different medical-imaging techniques – CT, ultrasound, PET, MRI, and so on – are committed to acquiring different types of data about bony and soft tissue diseases and physiological activities, and so are used for different diagnostic purposes” (Mitchell 1992: 221). Similarly, black-and-white photography may offer the right kind of detail to study naturally occurring phenomena in a social context and thus may be an ideal tool for anthropologists and sociologists; but in some instances this representational choice will be less than adequate. This could be the case when documenting trends in fashion, home decoration, and the like, where the use of color embodies essential information; or when a detailed account of processes is required, which can only be achieved by means of a continuous record of moving images. A second requirement that Mitchell puts forward is that a visual representation “must have the correct type of *intentional relationship to its subject matter*” (Mitchell 1992: 221). Some examples may help illustrate the importance of this requirement: the picture of an escaped convict may help police track down that particular individual, but his facial characteristics cannot be used to identify other individuals with criminal tendencies before they can actually commit a crime. Likewise, a scan of a pathogenic heart may serve as a diagnostic tool to help one particular patient, but that is not to say that it is the most appropriate representation for use in a general medical textbook.

However, the same medium types of representation may serve many purposes and entertain widely divergent relations with the depicted matter. Furthermore, a particular visual representation that was made for a specific purpose may be suitable for other purposes, even for some that were not envisioned at the time of production. However, in most cases one needs to know exactly how the images or visual representations came about and what their broader context of production was before one can assess their validity for those other purposes. The use one can make of a representation is determined, to a considerable extent, by its generative process (choice of visual medium and broader production aspects: choices regarding style, selection, and preparation of subject, normative systems) vis-à-vis its intended use. So, insofar as this is possible, a predetermined purpose should guide the production process. Some purposes, such as the exploration of a naturally occurring phenomenon, may require an indifferent, detailed account of particularistic data in their specific context, whereas others, such as educational aims, may better be served by highly stylized and synthetic representations highlighting only the essence of a more general phenomenon. So, the medium and the techniques in part will determine the uses that can be made of a representation, but even representations produced with the same medium or technique may be used for widely divergent intents and embody divergent representational positions.

## 5.2 Kinds of intents and purposes

The intents and purposes for using visual representations in scientific discourses are manifold. For one thing, natural phenomena might be visualized for the purpose of *further analysis*: to make a diagnosis, to compare, to describe, to preserve for future study, to verify, to explore new territory, to generate new data, etc. Representations that serve these primary purposes often will be algorithmic in nature and they may have an only “intermediate” function, since they are primary “data”. Visual representations that have no material referent may serve primarily to *facilitate concept development* or to uncover relationships, evolutions (e. g. through charts of all kinds) and, in general, to make the *abstract more concrete* and thus more accessible for further inquiry. Forms of externalized thinking (conceptual graphs) may be useful both on an intra-personal level (for example to guide researchers in a dialogue with themselves) and an inter-personal/inter-specialist level (e. g. to exchange ideas in an early stage, to invite feedback or to prompt co-operation from peers). Visual representations not only serve analytical and intermediate purposes, but they are also often used to *summarize or synthesize* empirical findings or a theoretical line of thought. Thus, they may provide an overview, display results in their spatial organization or conceptual relations, or clarify the textual or numerical part. In science, more synthesized or purposefully assembled visual representations generally serve to facilitate knowledge transfer in a variety of ways and seek to communicate with diverse audiences. They can illustrate, demonstrate, or exemplify features, relations, and processes, or provide mediated experiences in ways that are adapted to the audience (which may vary from highly specialized to lay audiences).

Many visual representations intentionally or inadvertently will embody an implicit or more explicit view on or argument about what is being presented visually, through the many elements and choices that make up the representation. This expressive function of scientific visualizations need not be a problem as long as it is duly acknowledged and, if required, further explained. As intentional forms of communication and through the selection and formal execution of the representations as well as by their thoughtful arrangement in the broader context of an article – a presentation or a multimedia product – visual representations will be powerful aids in the attempt to exert a certain amount of persuasion. Often, receivers or users of the representation will, in subtle ways, be invited, seduced, or even compelled to adopt the views of the sender and to perform the preferred actions (to believe, give approval, appreciate, change opinions, donate money, or support morally). For those reasons, but also for the more acclaimed function of cognitive transfer and education, a visual representation may perform the function of an eye catcher or of a topic signal, a means to arouse and maintain attention and interest, or even to entertain the reader/spectator (and thus bring them into the right mood for acceptance). Some aspects of a visual representation in science may even perform no other function than to appeal to the aesthetic feelings of the receivers or just be an expression of the personal aesthetic preferences

of the maker. These latter functions, though not readily associated with a scientific discourse, are not necessarily detrimental to the mission of a scientific undertaking, as long as these traits do not interfere with the more fundamental functions of data or cognitive transfer, and on condition that transparency is provided.

While we can never be complete in the listing of possible functions and intents of a scientific visual representation, this brief discussion of functions demonstrates that the idea that scientific visualizations and representations are solely meant to generate and present “objective” data or to facilitate pure cognition should be abandoned. It should be clear that most functions and intents that are found in human communication also will be found in scientific representation, though some functions and intents obviously will serve a more central role, whereas others will not feature prominently or may be intended to perform an auxiliary function. Moreover, it should be clear that any visual representation used as part of a scientific discourse will serve and combine different functions at the same time, whether intentionally or unintentionally. These purposes may be scientific in a narrow sense, but they may also have to do with intents that lie outside the realm of the acknowledged scientific purposes, such as to serve vested interests of persons and institutions. Finally, it should be stressed that the different functions that are embodied by aspects of the visual representation may be read or “decoded” in many different ways by different receivers (based on their intents, experience, knowledge, formal background, etc.) in different contexts and over time.

## 6 Developing visual scientific competencies

The basic premise of this chapter is that visual representations and representational practices may be extremely helpful in developing, clarifying, or transmitting scientific knowledge. However, when not produced and used with extreme care and competence, they may create at least as much confusion and misunderstandings. If one considers scientific representations and the ways in which they can foster or thwart our understanding, it is clear that a mere “object approach”, which would devote all attention to the “representation” as a free-standing product of scientific labor, is inadequate. What is needed is a process approach: each visual representation should be linked with its context of production. Moreover, it cannot be understood sensibly outside a particular and dynamic context of use, re-use, and reception. However, given the great many types of referents, representational techniques, purposes, and uses, it seems fair to assume that the vast consequences of this requirement are hardly grasped by the growing number of people who produce and use visual representations on a daily basis.

Scientists and science communicators should more actively develop a sensitivity for the wide variety of visual representational practices and products and the many

ways in which they can be deployed in scientific discourse. Furthermore, a real set of skills is needed in order to be able to *assess* the usability of given representations based on a thorough knowledge of their generic processes, and to be able to *produce* visual representations with the required representational and expressive properties in relation to their purpose(s). Visual representations invariably have a strong communicative function, certainly with regard to the originator (e. g. to guide his or her thinking, or to serve as data for further analysis), but often also toward a variety of specialized and non-specialized audiences (to prove a point, to convince, to facilitate understanding ...). Unconsciously applied and/or unmotivated use of aesthetics and unexplained use of certain conventions are a potential hazard, whereas well thought-out and reflexive use of aesthetics, formal choices, and well-explicated representational codes and conventions may create hitherto not fully exploited opportunities to further scientific knowledge building and communication.

Modern technology offers many complex ways of generating images, but few users have a clear understanding of all the steps involved. To counter this emerging “black box syndrome”, it is clear that scientists need to keep track of new media technologies to the extent that they offer new ways of looking and (not) knowing.

This complex set of requirements involving specific knowledge attitudes and skills may be understood as a specific kind of visual literacy or competence for scientists. Visual competence for scientists can therefore be defined as a reflexive attitude (throughout the production process), a specific body of knowledge, and even a certain level of proficiency or skill in assessing and applying specific characteristics (strengths and limitations) of a particular medium, and awareness of cultural practices (codified uses, expectations) and the actual context of use (including the “cultural repertoire” of the intended audience). In other words, a visually competent scholar should be aware of the impact of the social, cultural, and technological aspects involved in the production and handling of representations, as well as the different normative systems that may be at work and how they exert a determining influence on the eventual appearance and the usefulness of representations.

Visual scientific competency (or “visual science literacy”, see Bucchi and Saracino 2016; Lemke 2000) shouldn’t just imply establishing a clear division of labor (every person keeping to his trade) and then linking together those various types of expertise, as in fact they need to be merged rather than developed and applied according to a separate logic for each specialized aspect. The different normative systems (e. g. scientific, technical, creative, cultural ...) that are consciously or unconsciously employed need to be skillfully combined with a view to the ultimate purpose of the representation. While expertise obviously cannot be accumulated endlessly in one and the same person, a serious effort should at least be made at providing a unifying framework whereby each contributor should develop a knowledge about and sensitivity for the bigger whole. What they should not do is lock themselves up in their own area of expertise, as hardly any choice that is made along the way is without epistemological consequence. A central concern is to develop a critical awareness and a set

of both generic and specific (discipline-specific) competencies among scholars about the nature of visualization practices and their results as products of technology, social organization, traditions, contextual constraints, competencies, etc. and with respect to the uses one can make of them, e. g. the amount of certainty when using visual representation to make a diagnosis, to illustrate a point, to sell an idea, etc. Such (meta-) knowledge about the intricacies of visual representational practices should facilitate a more rapid, transparent, and effective adoption of new/future technologies and uses. While highlighting the visual aspects of knowledge development and dissemination in this chapter it should be clear that they do not exist in isolation from other expressive systems. Therefore this domain of study and practice also should embrace *multimodality* (Tang, Delgado, and Moje 2014; Bateman 2008; Guo 2004; Jewitt 2009; Kress 2010; Lemke 1998) as a key component of its further development.

The aspects and issues that have been discussed so far in this chapter may serve as a theoretical framework for the thoughtful production of visual representations in science or they may be used as a tool to assess critically the appropriateness of different aspects of particular representations. Such a framework may prove useful in examining the complex interdependencies that exist among the nature of the referent, the social, technological, and cultural context of production, the choices with respect to medium and style of representation, and the purposes and uses that need to be achieved. Figure 1, then, is an attempt to summarize and – be it in a rather limited way – visualize the elements and arguments of this framework as gradually developed from section to section. Visual representations will always be used to enlighten and broaden our understanding, but at the same time, they will continue to obscure it. Concerted and integrated efforts in delineating and developing visual competencies will considerably help scholars to optimize the production and uses of visual representations in various types of research and communication.

## 7 Further perspectives and readings

Scholars from very diverse disciplinary backgrounds (e.g. sociology of science, medical imaging, philosophy of science, history of science, geographical information systems, geology, biology, physics, visual social science, business sciences, information design, mathematics, communication studies, anthropological linguistics) have gradually taken an interest in the complex issue of visualization in science. They have studied a broad range of types, aspects, and uses of visual representations in the sciences, and each of those research traditions have contributed to considerably to clarifying the huge potential as well as the many tribulations visual representational practices may implicate (Lynch and Woolgar 1990; Pauwels 2006; Coopmans et al. 2014; Carusi et al. 2015). Many aspects of the technical and social development



**Fig. 1:** Integrated framework for producing and assessing visuals in science and science communication

of visual representations and the ways in which they are being employed have been approached from distinct theoretical paradigms and a variety of research methodologies (including: ethnomethodology, phenomenology, semiotics, social constructivism, conversation analysis, interaction studies, ethnography, semiotic analysis, experiments, surveys, interviews, video-recordings, field notes, ...). Researchers have scrutinized processes of perception and knowledge acquisition and negotiation with representations through detailed studies of practices and discourses of groups



of people in different social and professional settings such as those of fieldworkers (Roth and Bowen 1999; Lynch 1985a), laboratory scientists (Latour and Woolgar 1979; Knorr-Cetina 1981; Lynch 1985b), teachers, engineers, students, publishers, navigators, and lawyers (Goodwin 1994, 1995, 1996; Pea 1994) and science journal editors (Frow 2012) to name just a few.

A variety of products and media of visualization have been studied in great detail such as diagrams, photographs, drawings, various scanning techniques. In particular graphs and the social and technical processes that accompany their creation and their use received much attention (Roth, Bowen, and Masciotra 2002; Roth, Bowen, and McGinn 1999; Roth and McGinn 1997; Arsenault, Smith, and Beauchamp 2006). Particularly influential are Tufte's books (1983, 1990, 1997) on the analysis and visual display of data and information and Monmonier's work (1993, 1996, 2010, 2014) on cartography and mapping, thus on the representation and use of visual representations in diverse sectors of society (see also Grady 2006; Welhausen 2015).

Scientific visualization – in a broad sense – has been studied in view of its practicability in fostering educational processes and in bridging theory and practice (Gordin and Pea 1995), pointing at both unique opportunities and issues/obstacles. It may be seen as an enculturation device in a community of practitioners or scientists-in-process (Roth and Bowen 2001), but also as an evolving means of scientific expression (Pauwels 2006, 2015) and a prime tool in the development of scientific literacy (Gordin and Pea 1995; Priest 2013; Gigante 2014) among a diversity of audiences.

The history of visual representations in science (Baigrie 1996; Bredekamp, Schneider, and Dünkel 2008; Knight 2009), and that of the scientific illustration in particular (De Bray 1989; Ford 1992; Givens, Reeds, and Touwaide 2006; Groß 2007; Kusakawa 2012; Jones and Gallison 1998), continues to be a prime area of interest, as is medical imaging (Cartwright 1995; Joyce 2005, 2006; Burri 2013). But education (Gilbert 2010; Rohrdantz et al. 2013), instruction (Cook 2006; Doran 2018; Krause 2017; Wolfe 2015; Rodríguez Estrada and Davis 2015; Stafford 1996) and public engagement and issues of science journalism, popularizing science (Gruber and Dryickerson 2012; Hilgartner 1990; Meyers 2003), and public engagement in science (Allen 2018; Bauer and Bucchi 2007; Brechman, Lee, and Cappella 2009; Bucher and Niemann 2012; Schäfer et al. 2018; Hüppauf 2009; Knight 2006; Smith et al. 2011) too, are key domains in this expanding, be it highly dispersed and subdivided, field of inquiry and professional practice.

The many and highly divergent studies of scientific visualization add up to an impressive body of knowledge that occasionally comes together in themed journal issues, readers and conferences, next to occupying a niche in the different disciplines and specialized journals. Synthesizing the many contributions could, as Cambrosio et al. (1993: 663) called it many years ago already, be a “hopeless task”. Yet working towards integrating at least part of this knowledge and translating it into generic and more customized modules for use in many, if not most, academic curricula and science communication programs and initiatives would be a significant step forward.

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Henning Lobin

## 12 The lecture and the presentation – rhetorics and technology

**Abstract:** For a long time, the lecture dominated performatively presented scientific communication. Given academic traditions, it is possible to make a connection between the lecture and classical rhetoric, a highly differentiated instrument of analysis. The tradition of the lecture has been perpetuated in the presentation of research results, first in the use of transparencies and subsequently through computer-based projections. Yet the use of media technology has also allowed new practices to emerge, including mediation practices hitherto neglected in the theory of rhetoric.

**Keywords:** lecture – presentation – rhetoric – scientific communication – media technology – form of communication

### 1 From the lecture to the presentation

Until recently, the predominant form for communicating scientific findings has been the lecture. Its origins lie in the medieval university practice of instructors reading texts out loud to students. This practice of literally citing the works of an acknowledged authority in a given field was gradually augmented by notes and commentaries an instructor added as glosses to the text. By around 1800, the word “lecture” (*Vortrag*) referred to the manner in which a text and its accompanying commentary were presented, or in other words to what was called *actio* in classical rhetoric and which is now called performance (Peters 2005a: 200). Changes which began in this era to the process of how scientific insights were gained also affected the understanding of how these new insights were to be imparted. A lecturer was not simply supposed to present results but also discuss how he or she arrived at them, which is to say to “always let the whole of the research process arise in the eyes of the apprentice” (Schelling, cited in Peters 2005a: 202).

Peters (2005a; 2005b; 2011) promotes the interesting thesis that the rise of the scientific lecture format after this time is related to the “scientific figuration of evidence”, meaning the recognition of methods-based justifications for scientific insights; this seamlessly made a transition “into other, non-scientific techniques of evidence”. These latter techniques used in the natural sciences included a lecturer showing or demonstrating, as well as using persuasive rhetorical techniques that could blossom independent of a particular discipline.

The scientific lecture can thus be understood as a form of communication which is performatively influenced, shaped not only by its disciplinary content but also by basic aspects of rhetoric. At the same time, the transitory nature of this form of com-

munication creates a problem in how it can be set out in writing and hence made archivable. In the 19th century, this was largely accomplished by having listeners transcribe the spoken text as accurately as possible. With the rise of academic publishing in the 20th century, the responsibility for setting out the text has shifted to the lecturer himself or herself (cf. Peters 2005b: 323). If a lecture is regularly associated with the publication of a related essay, then this will affect the lecture itself (see Chapter 13, this volume).

An efficient way of doing so is to have essay and lecture be closely related, such that the fully formulated lecture can be used, with only minor changes, as a (lecture) manuscript. This practice prevailed internationally, in the 20th century, in nearly every discipline, and is still practiced in fields such as philosophy or law. Before the emergence of the scientific presentation, the communication form of the lecture, which is in fact performative and as such has a function independent of script-based forms used for communicating scientific insights, has become a shell for written publication processes. As such, the lecture has become more of a ritual rather than serving actual communicative functions. However, the systematic driving out of these performative elements from the classical lecture has made room for presentations which contain new and original performative means for dissemination.

Presentations using transparencies are technologically inseparable from the rise in the availability of overhead projectors. These were first used in the 1940s in the U.S. for military and police briefings. The technology spread during the next decades to schools and universities, partly supported by government programs, and to businesses (Schnettler, Knoblauch, and Pötzsch 2007: 11–14 provide details about the history of transparency presentations and the early stages of software for presentations which developed out of it).

The main characteristic of overhead projectors is the use of transparent (usually acetate) foil onto which one can write or draw; this foil is available as individual sheets or as a roll of continuous foil. By shining light through it and using lenses and mirrors in the projector, it is possible without much loss of brightness to project text or images on the transparent foil onto a wall or a screen, making them visible to a larger audience.

Visualization of this kind then becomes the focus of attention during the presentation, and in the context of this communication situation, helps constitute meaning. An important advantage of overhead projectors, as compared with other forms of visualization, is that it makes the medium openly accessible. That is, the presenter, using a suitable pen, can write or draw directly onto the transparency and thus can manipulate what is being shown. It is possible for the presenter, while looking at the foil or writing, to remain facing the audience. He or she can thus maintain eye contact, allowing for a more pronounced social interaction between himself, as presenter, and audience than would be possible when using a blackboard.

To some extent when using a transparency, a presenter therefore can already monitor his projection, which is also the case in presentations using a beamer and a

laptop computer. In both cases, the projected materials, which also lie in the presenter's field of view, serve as a framework for the lecture. This feature of presentation situations remains relevant in fields such as mathematics, even when implemented using digital techniques.

A final feature (if not advantage) of transparencies employed in presentations is that the materials used can be archived or distributed. Unlike a diagram drawn on a blackboard, transparencies are portable, are of small size, and can be duplicated on a copier. Collaborative work using an overhead projector can also be integrated into a more comprehensive, medium-supported workflow – a feature crucial, in the early days of this technology, for the police and the military.

If one looks at the relationship between scientific presentations and these two precursors, then it is clear that in both cases there are pronounced forms of performativity. Thus, the scientific lecture stands in the tradition of classical rhetoric and employs its basic features. The presentation using transparencies, by contrast, is shaped by the element of demonstration; the ability to manipulate the item(s) being demonstrated becomes part of the interaction between presenter and audience. Against this background, scientific presentations are thus a mix of these two precursors. With respect to the scientific lecture, there is a stronger situationally embedded aspect of performativity and interactivity due to the common visual reference shared by presenter and audience. With respect to the transparency presentation, more pronounced planning and language implementation takes place in terms of structuring the lecture. As both precursors “bring along” their own conditions for archiving – the lecture in the form of the written essay or direct transcription of what was orally presented, the transparency presentation in the form of copies of what was projected onto the screen – a particular archiving problem arises here.

Rhetoric itself influences the structure of scientific presentations in two ways. For some time now, practical rhetoric, in the guise of guides, has intensively addressed the conditions favoring effective lectures. These mostly address graphic design as well as the personal demeanor of the speaker. Those seeking advice are provided a multitude of phrases and tricks aimed directly at optimizing the lecture's effect. Practical rhetoric largely reflects the wisdom experienced speakers have gained rather than the results of specific scientific insights. While not directly relevant to research on presentations, such guides are nevertheless interesting sources of information that can inform and justify the study of lecture rhetoric.

The popularity of practical guides to rhetoric can be understood as a reaction to the development of classical rhetoric. In recent eras, this has developed into an interpretive field of study, one whose orientation is influenced by literary theory. Nevertheless, rhetoric in antiquity was quite practically oriented. The grand rhetorical systems of Cicero and Quintilian, in addition to content-related aspects and rhetorical means, also describe the stages in producing a speech. Such systems made universal claims, including a speaker's education and his virtuous way of life, both of which were regarded as indispensable prerequisites for delivering a good oration.



The shift to a more theoretically-oriented understanding of rhetoric took place during the Renaissance, when commentaries on examples of classical orations began to appear. These were phrased in terms of an inventory of rhetorical categories – if at a time when such orations were no longer primarily being used in a productive sense. Additionally, classical rhetoric refers to the design and delivery of the speech itself, and only marginally notes the integration of other media. Hence, Liebert regards presentation rhetoric “as communicative, medial, but in particular as linguistic processes which serve to deliver the information to be transmitted in a presentation in an effective manner” (2005: 33). By the same token, the comprehensive classifications and taxonomies crafted in classical rhetoric can be usefully employed when developing a rhetoric of, and for, scientific presentations.

## 2 Presentation and classical rhetoric

The central question classical rhetoric wishes to answer can be put succinctly: “What conditions for achievement is a communicator who is committed to effectiveness and success subjected to?” (Knape 2007: 53). Classical rhetoric distinguished between three different speech genres in answer to this question, each of which was connected to different communication situations. The production of a speech was additionally divided into defined phases, reflecting a methodical instrument. Finally, the structure of a speech was also taken into account.

### 2.1 Speech genres, structure, and production stages

Classical rhetoric distinguishes between three speech genres: deliberative (*genus deliberativum*), judicial or forensic (*genus iudicale*), and ceremonial or epideictic (*genus demonstrativum*). A fourth speech genre was established during the adoption of classical rhetoric in emerging Christendom. The sermon (*ars praedicandi*) deals with the mediating of Christian beliefs, predominantly in the form of the immutable truth of the Bible, using the tools of rhetoric. In so doing, a speech took on an entirely different function: “its basic problem is not determining truth but relaying it” (Götttert 1991: 129).

A core area in classical rhetoric concerns the systematization of the five stages in producing a speech. The method for the discovery of arguments (*inventio*) is “the term for finding the thoughts and material possibilities which can be developed out of a topic or from a question” (Ueding and Steinbrink 1994: 209). *Inventio* does not refer to an arbitrary invention of a topic but instead to the analysis of an existing topic in terms of the requirements of a speech. From the outset, this phase thus refers to the purpose of a speech, and as such constitutes an evaluative activity.

In the organization of arguments (*dispositio*) phase, the speaker must structure his topic with respect to the intention to speak, and needs in particular, to distribute his persuasive means, both rational and emotional, throughout his entire speech. The third, central phase devoted to style (as well as its level, correctness, clarity, appropriateness, and ornaments – the *elocutio*), is devoted to formulating the terms noted in the *dispositio*. Clearly, the effect and success of the speech as a whole depends to a large extent on the outcome of this phase.

According to Quintilian, the apt expression derives from the subject of the speech, so the linguistic form cannot be separated from its content. The appropriateness of the speech (*aptum*) serves as the “superordinate regulator” (Ueding and Steinbrink 1994: 216). Appropriateness can refer to the relationship of parts of the speech to one another (interior *aptum*) or to the time and place it occurs and to those who listen to it (exterior *aptum*), or in more modern terms, to external communication factors.

Classical rhetoric was based on the principle that an oration should be held freely, though it should correspond exactly to its previously drafted version, including with respect to quotes and particular phrasing to be employed rhetorically. As a result, the key fourth phase (*memoria*) involves (re)calling previously formulated argument or discourse. It is thus a type of memorization.

The fifth and final phase in producing a speech is its actual delivery. Delivery using spoken language (*pronuntiatio*) is differentiated from all non-linguistic elements (*actio*) involved in its enactment. Along with gestures and facial expressions, these could include the staging (or even the “set design”) as well as the objects employed. In the case of court proceedings, these are used as evidence in support of an argument.

In classical rhetoric, an oration is linearly divided into four parts. The task of the introduction (*exordium*) is to generate interest and quickly make listeners receptive to the speaker’s argument. Its function was primarily affective, and was used to evoke understanding, sympathy, and attention for speaker and topic. The second part (*narratio*) states the case, narrating the facts or subject of the oration from a subjective point of view. By definition, this part was meant to win over listeners, and it could therefore omit or exaggerate aspects of the subject.

The proof (*argumentatio*) given is the most important part of the speech, and as such had to be taken into account in the planning phase. Here the central question which arose from the facts at the core was explicated, though the formulation of this question itself would reflect the biases of the speaker. The conclusion of the oration (*peroratio*) has the task of summarizing all the previous parts in a memorable way. It also tried to summarize the train of thought using pointed aphorisms, as well as using emotional means to persuade listeners of the orator’s point of view.

## 2.2 Are presentations “mediatized” speeches?

So what can classical rhetoric tell us about scientific presentations? If we regard the scientific lecture or presentation as a communicative technique for disseminating research results previously arrived at (and hence regarded as valid or validated from the lecturer’s point of view), then this communicative situation seems closest in form to that of the sermon. Both the sermon and the scholarly lecture, at least in terms of medieval theories of rhetoric, are about “secured content”, the stock of beliefs which is to be passed on in the appropriate form.

This analogy is less curious than it may first appear. European universities, when first founded in the Middle Ages, emerged from Christian cultural traditions; for centuries, the study of theology was regarded as the culmination of an academic education (Rüegg 1993: 359–363). For many years, university instruction was based on the reading and exegesis of the writings of ancient authors, interpreted as part of the Christian tradition and imparted in a manner similar to how the Bible or Christian authors were taught. The academic lecture, from which the scientific presentation later emerged, is structurally inspired – at least in part – by the same rhetorical tradition as the sermon.

If one looks at lectures given in the humanities and social sciences, on the other hand, then dialectic and hermeneutic types of argument are relevant. Here the lecture should not be understood as a mediating instrument for insights or knowledge previously generated but itself instead as a method of gaining knowledge (Peters 2005a, 2005b). This form is also closely connected to the other, older form of communication in academic contexts, namely the debate (*disputatio*). In medieval scholasticism, statement and objection were set against one another until a victorious side could be determined. The communicative success in such a disputation was equated with the process of gaining insight, as the disputation was seen as a heuristic instrument.

An intention to present one side as the “correct” interpretation (for example, so as to influence an imminent decision) of course does not correspond either to the *modus operandi* of modern scientific communication or to hermeneutic reasoning processes concerned with the process of argument itself and synthesis. The scientific lecture, in sum, does not (at least ostensibly) mean to influence a decision but rather (at least in principle) wants to convey an insight or reflect on the process of knowledge generation.

In classical rhetoric, the relationship between listeners and the subject of a speech also functioned as a classificatory characteristic, and there are certain parallels here to modern presentation practice. Many modern presentations begin with a statement about what brought the speaker to the topic or subject. This is meant to evoke interest and make connections to other, perhaps better-known questions (see *genus humile*, plain or humble style). Presenters often want to gain the goodwill of listeners by starting with a humorous introduction, or they want to exhibit competency (see *genus dubium*, ambivalent or conflicting style). However, it is not possible

in scientific presentations to make, as classical rhetoric postulates, a clean separation of genres at this level.

The level of theoretical reflection possible with regard to the effect of scientific presentations must be regarded as rather low when compared to classical rhetoric theory. There is no doubt, as is generally the case when presenting academic research, that intellectual operating principles stand in the foreground. These can be well characterized by the didactic techniques of instruction (*docere*) and argumentative proof (*probare*).

Emotional and affective modes are ordinarily not openly used, though a scientific presentation undoubtedly is effective at these levels as well. This applies above all to the “moderate” affective mode. A presenter can, as was already true in antiquity, win over (*conciliare*) his listeners through his demeanor – even though this ability is rarely displayed in scientific environments nowadays. The exception is the humorous talk, a mode accepted to some degree in scientific presentations.

The visual modality also gives a presenter considerable latitude to achieve additional effects at the affective level, among which one can note particularly attractive graphic design evident on transparencies and slides, or the use of the logos of well-known institutions. Elements of this kind have a non-intellectual effect which can reinforce the scientific information being conveyed, and presentations of this kind are more open to such effects than other types of formalized scientific communication such as the essay or a specialized text.

The five stages in the production of a speech noted in classical rhetoric show clear parallels to the usual procedures employed in preparing a scientific presentation or lecture (on this, see Liebert 2005: 34–37). Obviously, the classic *inventio* should not be equated with original research activity today. Instead, scientific presentations are based on a selection of results already obtained that are presented in a form structured in a customary manner (*dispositio*).

However, in humanities disciplines, where the process of writing coincides with the research process, it is conceivable that the structure itself emerges as part of the process of drafting a text for delivery – a variant of the factual unity of *inventio* and *dispositio* as it conceived in classical rhetoric texts. Modern-day lectures follow the classical structure of an oration, in which one or more main parts are framed by an introduction and a conclusion.

Ostensibly, all emotionalized means of persuasion are deliberately suppressed; unlike the classical oration, scientific lectures and presentations are supposed to use dissemination procedures that are exclusively fact-oriented. That this is even possible is, of course, an illusion. The sequence and formulation of argument alone opens up an emotional, if more subtle, dimension (Dynkowska, Lobin, and Ermakova 2012). Knappe (2007: 57–58) has raised the question to what extent using formulaic representations of content in bullet point lists, for example, influences *inventio* in the sense of creating a novel *topos*. *Topoi*, as Aristotle already noted, are basic patterns of argument. While bullet point lists put their stamp on the representation of content, they cannot be seen

as actually specifying content. However, the “PowerPoint is evil” debate (Tufte 2003) begins at exactly this point, its advocates claiming that the medium itself has an effect on the contents.

At the same time, the attention to style found in the classical *elocutio* phase, is largely dispensed with in the modern presentation. This is in part because text written on a slide contains elaborated formulations, even if shown as keywords, which the presenter points to, paraphrases, and supplements.

This partial renunciation of fully formulating the text of a lecture has its advantages and disadvantages. It can be regarded as advantageous if – in the ideal case – thinking and speaking coalesce and the listener is witness to the emergence of scientific insight as the lecture is being given (Peters 2007, 2011). The other end of the spectrum are lectures in which a speaker struggles with formulations inadequate to the task, and where it is evident that an *elocutio* phase could have helped. Most presentations, though, lie somewhere between these poles: a speaker, though somewhat fluent, takes his or her cues from the text on the transparency or slide, but is not able to come up with particularly trenchant or pointed formulations, as these would have required more intensive preparation.

The virtues which underpin *elocutio* (other than *ornatus*, the literary flourishes) also have their counterparts in modern presentations. Inner and outer appropriateness and fitting oneself into existing communication structures is essential in a scientific community which negotiates over subjects, topics, positions, and research money. The virtue of linguistic correctness appears thereby in the form of the correct use of the terminology commonly used in a given discipline. This also functions as a signal or mark of identification among colleagues. Clarity (*puritas*), in the sense of comprehensibility, also is expected of every scientific text. However, it is precisely in scientific presentations that clarity interacts with obfuscation – about further results, about methods, about remaining uncertainties, and about counter-arguments. To what extent lucidity or perspicuity (*perspicuitas*) should be regarded as a virtue remains open to discussion. The presentation of complex subjects is often dominated by the topic itself, not the intent behind the dissemination. Avoiding lucidity may even be intended, particularly when it is a matter of demonstrating virtuosity in handling methods and formalisms in front of an audience drawn from divergent fields.

There are also considerable differences between modern presentation practices and the principle of *memoria* in classical rhetoric. In the latter, a speech had to be memorized so as to be able to be given “freely” – a meaning of the adjective rather different than its current meaning as a “spontaneously formulated” lecture. What is nowadays called a “free lecture” also did not have such spontaneity in mind. It instead meant addressing a topic in a manner that contrasted it with a recognized textbook, hence this sense of “free” means “free of an older academic tradition”.

By contrast, scientific presentations or lectures today are almost always held in linguistically relatively unprepared forms. “Free” thus does not mean “free of a manuscript” (e. g. by heart) or “free of thematic restrictions” (yet preformulated) but rather

“free of pre-produced text”. This naturally has an enormous effect on the linguistic and rhetorical structure of the lecture.

In classical rhetoric, an oration was optimized for effect through a targeted selection of words and phrases. Spontaneous speech, in the context of modern presentations, instead primarily conveys the authenticity of the contents – inasmuch as the presenter has internalized the contents to such an extent that talking about them comes across as spontaneous. In so doing, he or she both documents the scientific impetus which lay behind his presentation of the topic and demonstrates his mastery of the subject.

Recitation from memory, or even the reading out of a text, would therefore not fit this romantic image of the research scientist. However, because the demands made on a presenter often enough exceed his abilities, text-oriented transparencies or slides are a welcome aid; they are notes which can be seen and consulted by speaker and audience alike. This helps explain why so many presentations nowadays are so focused on the slide or transparency text and include only minor, periodic digressions. *Memoria* makes manifest the essential difference between the classical oration and the modern presentation: in the first, one pursued the ideal of the optimal effect in a given situation, while in the second, one pursues the image of scientific authenticity.

On the other hand, the presentation performance itself bears similarities to its ancient prototype. As just noted, an impression of authenticity is conveyed which certainly corresponds to the ideal in classical rhetoric: a speaker is not to behave like an actor but instead show his own personality. Finally, visual elements of a presentation fall into the realm of *actio*, though in a system of rhetoric which branches widely, as such attract little attention.

Classical rhetoric proposes a sequence of parts to an oration, and this finds its analogy in modern scientific presentations. These of course include an introduction and a conclusion, with the introduction often understood as a statement of the “motivation” which led to an examination of the topic, which thereby situates it in terms of its relevance. Here, too, this is about a connection to known facts. But it also performs an affective function through which the interest of listeners is meant to be heightened by ascribing relevance to the particular topic. The rhetorical technique of winning the goodwill of the audience (*captatio benevolentiae*) known in political and juridical contexts, or the use of rhetoric to nevertheless win over a skeptical or disinterested audience (*insinuatio*) at the outset of a speech, are not found in scientific lectures.

As a rule, the conclusion of a presentation is usually a recapitulation, a verdict, or a list of questions which remain open, and in doing so, it reflects the principle of peroration in classical rhetoric. Direct techniques for increasing affective excitement are usually avoided, though mentioning possible applications, insights, or successes achieved in the concluding section of a scientific lecture can increase the positive effect it has.

In the theory of classical rhetoric, narration and proof are the core parts of an oration, and there is clear parallel here to presenting a research problem, in the

context of the current state of research, and the inductive or deductive argument subsequently presented. Often, one does not find a *narratio* openly crafted with an eye to persuade, but one does frequently hear mention of inadequacies or gaps in the research, and these serve a presenter's own line of argument. Scientific lines of argument in a presentation need to be based on the methodology and standards used in a field, and at least in formal terms, the usual demands of objectivity in science need to be adhered to. Here as well, rhetorical devices such as adding features to a statement (*amplificatio*) are used, as when the advantages of one's own results are contrasted, in tabular comparison, to the deficiencies found in other results and the differences thereby highlighted.

Generally speaking, one can conclude that classical rhetoric provides a differentiated inventory of categories which can in large part also be applied to modern presentations. Even if, as Knape (2007) argues, one regards presentations only as an extension of the speech using new media or methods, and that it can terminologically be wholly subsumed under the terms used in classical rhetoric – and one certainly can discern clear parallels in some areas – a number of systematic differences remain in others.

These are found above all in the different function that a scientific presentation performs when compared with classical forms of speech or oration. This is also one reason the use of persuasive means remains relatively small or indirect. Another area which classical rhetoric does not take sufficiently into account is the existence in modern times of a virtual stage created by the projection of a series of transparencies or PowerPoint slides. This stage makes available an independent and dynamic inventory of signs, one with considerable overall influence on the presentation. In conjunction with the linguistic modality, this visual modality leads to an expansion in the performative modality available for and in a presentation.

### 3 Presentations as a form of communication in science

The presentation of research results differs from other types of presentations particularly in terms of characteristics external to their texts. They should be no means be understood as the basic form: "PowerPoint presentations are *not* specifically *scientific or research-oriented forms* of knowledge production and distribution" (Schnettler and Knoblauch 2007: 277). Yet how should scientific presentations be regarded as a communicative genre? The following aspects provide hint about possible answers:

The tendency to use imagery has also not stopped at scientific communication (Peters 2008). Imaging techniques and visualizations of what is difficult to represent purely verbally have a long tradition in the natural sciences, and are increasingly employed in the humanities and social sciences as well. Furthermore, the use of evi-

dence-based techniques taken from the natural sciences has led to a shift away from hermeneutic discourse and towards *demonstratum*, which as such possesses persuasiveness and needs only limited support from forms of argument based on discursive logic.

Labelling presentations generally as the “simplified basic idiom of globalized knowledge societies” (Knoblauch and Schnettler 2007: 279) also applies to scientific presentations. In the scientific community as well, forms of organization involving a division of labor – both within a research institution and between them – are steadily increasing, creating increased communicative needs. Concurrently, owing to ever-increasing specialization, the stock of commonly-held knowledge among specialists is declining, which is answered through communication formats lying below the level of research-oriented specialist publications in terms of information density. Presentations allow this need to be satisfied in science in an adequate manner.

A point one should not underestimate in this context is the use of English as a lingua franca. The simultaneous dissemination of content at both spoken and written levels or channels helps ensure its success in conveying insight, particularly to a heterogeneous audience with differing language needs. Presentations, in this respect, can thus count as a simplified and simplifying basic idiom, especially for globalized communities of scientists (Knoblauch 2013).

Due to their intermediary position between medial and conceptual orality and textuality, presentations ideally fit into an information workflow which transcends specific media – a situation which today influences scientific research activity to an extraordinary degree. Presentations, as the result of a single process of compilation or creation, can on the one hand be bound and transmitted in a performative and situative manner, while on the other hand they can also be sent in the form of a file (of transparencies or slides), and be reviewed independently and archived. Newer Internet-based forms, where presentations are preserved as performative video sequences which can also be archived and searched, use this indifference to the medium in still more subtle ways. Differentiated use of media goes hand-in-hand with a more efficient use of resources, as parts of presentations can be repeatedly changed, adapted, or reconfigured (Liebert 2007).

Due to their reduced formality and usually quite limited publicity, presentations make it possible to publicize or publish scientific results under less rigid conditions than apply to more established forms of sustainable scientific communication (articles in disciplinary journals, edited volumes, books). They thus form an intermediary level in scientific publishing, with attendant connections to wholly informal forms such as the discussion and to highly formalized and recognized publication forms. In this fashion, scientific presentations above all contribute to an acceleration of and in scientific communication, as official paths to publication remain slow and the dissemination of results delayed, hindering quick responses to ongoing developments.

Historically speaking, scientific presentations fill a performative gap which opened up once the traditional scientific lecture was perverted and became only mar-



ginally performative and physical, largely supplanted by draft versions of essays in which written text predominated. Having long practiced a purely text-based rhetorical style, one which survived with a very low degree of steered performativity, the presentation pendulum has now swung in the other direction and allows performativity, while conveying content, to be the center of attention and renouncing the use of controlled rhetoric. The shift to performativity puts the person presenting back in the center of attention, using his or her body as well as interacting with the audience; this thereby increases the space for adopting strategies of persuasion. These unfold beyond the logic-based discursive structures of argument, and through the communicative genre of the presentation, allow for greater influence on the process of gaining scientific insights.

## 4 Concluding remarks

Although presentations represent a unique form of scientific communication, one should not ignore that currently observable presentation practices should also be critically evaluated. One point of critique lies in the low degree of interactivity that is open to a presenter, both relative to the projected contents as well as vis-à-vis the listeners (Lobin 2009; 2012). A presenter finds it difficult to respond to questions or comments as long as these have not already been taken into account in preparing the presentation. This distinguishes them from text written on a blackboard or from an overhead projection using transparencies, as these are designed to be occasions for working together on commonly viewed materials. By contrast, presentation programs are to this day fundamentally designed to be advanced sequentially (using individual keyboard clicks), reproducing prefabricated units of the projection which are difficult to change.

A second serious point of criticism is the tendency to prioritize visualization at the expense of (and reduction in) textual complexity. If text is written on transparencies or slides, then it employs a simplified structure relative to other manifestations in science. Contents conveyed by bullet point list seldom use connectors which reflect the semantic–pragmatic relationships between the assertions, and are usually considerably simplified in terms of topic structure.

Finally, one needs to ask whether presentations themselves bring about changes in the process of reaching scientific insights. Every form of communication shapes the contents which are coded within it. So when we consider what the main features of presentations are as a form of communication, one has the suspicion that the contents which are shaped by the presentation are, from the start, adapted to this particular form of dissemination. It will therefore be interesting to observe whether the ubiquity of scientific presentations will have the effect that those topics and analyses which can be better visualized, as well as be more convincingly embellished performatively, will (demonstratively) prevail over topics less easy to present.

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Sylvia Jaworska

## 13 Spoken language in science and the humanities

**Abstract:** Although a great deal of communication in science and the humanities is conducted through the medium of spoken language, “talk” had long led a shadowy existence in research in science communication and only recently begun to receive scholarly attention. The purpose of this chapter is to offer an overview of this slowly growing body of research. By foregrounding the role and status of participants, this overview focuses on communication 1) between experts, 2) between experts and novices, and 3) experts and lay audiences. In doing so, this chapter provides a comprehensive understanding of the critical role of spoken language in communicating scientific and academic matters across contexts. It shows that spoken language is not just a tool of information exchange but a dynamic and indispensable resource used to interactively co-construct and share knowledge, expertise and evidence. It also raises awareness of the challenges that the different participant constellations pose for effective communication in science and the humanities.

**Keywords:** spoken language – audience – interaction – involvement – lecture – seminar – doctor–patient communication – broadcasting

### 1 Introduction

Traditionally, written texts have been the most privileged domain of communication in science and the humanities. The written word has always been elevated above the oral leading to the development of writing as the ultimate tool of communicating science and a convenient gate keeping mechanism. Although some exceptions might exist, the rule is that writing is the proof of expertise, while speaking plays a less important role. For example, academic degrees and titles are mostly awarded on the basis of a successfully completed larger piece of written text such as BA dissertation or PhD thesis and not through communication by word of mouth. Promotion and prestige are measured by the number of published research articles and monographs, and not by the number of conversations that one had with colleagues and students in research seminars or supervisions.

The superiority of writing in sciences and the humanities reflects wider societal and rather prejudiced beliefs that assume writing to be a sign of erudition and the source of knowledge, while speaking is often seen as fragmented and ordinary (cf. Milroy and Milroy 2012). This led to the perception of writing and speaking as two essentially opposite types of skills with writing having a symbolic significance as virtue and regarded as a complex cognitive task (Cook-Gumperz 2006). It is hence

not surprising that most research on aspects of communication in science and the humanities has been dedicated to written language, the relevance of which has also been justified on pedagogical grounds.

Undoubtedly, writing is an important tool creating permanent records of knowledge that can be disseminated, critiqued, developed and so forth. Yet, writing presents in most cases a final polished product created following strict conventions, which “hide” the multiple ways in which knowledge and meanings are co-produced and negotiated in the process of (academic) interactions (Mauranen 2006). The now vast body of research on spoken language in interactional sociolinguistics (e.g. Coupland and Jaworski 2009) and psychology (e.g. Wertsch 1991) has illuminated the crucial role of speaking either with others (collaborative dialogue) or with oneself (thinking out loud, repetition) in the development of meanings and abstract concepts. This research has also shown the complexity of speaking which requires from the speaker (and the listener) a much broader range of skills than writing (e.g. Biber, Conrad, and Cortes 2004). Above all, writing only reflects a small part of professional life in sciences and the humanities, which is mostly spent on talking. In labs, lecture rooms, supervisions and office hours, lecturers, professors and students use spoken language throughout the day to accomplish a range of individual and common goals. Some of the most important avenues of knowledge dissemination such as conferences and research seminars are oral and increasingly shared on digital channels such as YouTube or TED (see also Chapter 30, this volume). While this is not to undermine the significance of the written word, it is through the use of spoken language that we reproduce and enhance the everyday practices and structures of communication in science and the humanities, and simultaneously constitute these practices (cf. Mauranen 2012). If we want to better understand communicative practices in these domains, we ought to pay more attention to the use of spoken language.

Unfortunately, for a long time, spoken language has not been given the due recognition which it deserves and only recently begun to receive scholarly attention. This was often prompted by methodological innovations, for example, the availability of large corpora of spoken academic discourse or by debates around English as a *Lingua Franca* (ELF) of academic communication, and pedagogical needs of growing numbers of students and academics who are non-native users of English (Mauranen 2006).

The purpose of this chapter is to offer an overview of the recent developments in research on spoken language in science and the humanities. Since spoken language is the ultimate domain of (applied) linguistics, this chapter focuses mostly on linguistic research but when relevant, studies conducted in related fields, for example, health and science communication are considered. Given the international status of English as the language of academic discourse, mostly studies concerned with English as L1 or L2 are discussed but when possible links to studies on other languages and cross-cultural perspectives are offered.

Different classifications of speech and spoken language have been proposed in linguistics, but most of them are based on structural properties and phonetic features

of speech. Since spoken language in sciences and the humanities is used by people to construct and disseminate scientific and academic knowledge, this chapter takes a functional perspective on spoken language foregrounding the speaker and the listener, and their role in the academic community. Thus, the classification which this overview proposes is based on common participant constellations including: 1) communication between experts, 2) communication between experts and novices, and 3) communication between experts and lay audiences. The first two categories are the classic domains of internal academic communication within institutional settings, while the third category encompasses types of external expert talk produced for lay audiences and the media. Using this classification, this overview hopes to offer a comprehensive understanding of the role of spoken language in communicating scientific and academic matters across contexts and raise awareness of the challenges that the different participant constellations pose for effective communication in science and the humanities.

## 2 Spoken language in expert to expert communication

The area of expert to expert communication in science and the humanities has received a great deal of attention in linguistic research, though the most widely studied genres were academic written texts. There is now an impressive body of research on dissertations, published research articles and textbooks in many scientific disciplines. Considerably less attention has been paid to spoken genres and research in this area is rather sparse (Nesi 2003).

Given the importance of teamwork in scientific communities, Monteiro and Keating (2009) explore communicative strategies adopted by scientists from various scientific fields during weekly team meetings. The analysis reveals a variety of common everyday communicative practices in which the scientists use to foster communication including retranslation, redefinition, asking direct questions and humour to manage misunderstandings and partial knowledge.

Given the implications of health communication, there are several studies dedicated to aspects of expert communication in medical settings focusing in particular on the role of language in constructing clinical knowledge. For example, Loewea et al. (1998) study physicians' talk about diabetes showing, contrary to common assumptions, a very evocative and personal language use in the construction of the disease. Måseide (2006) studies construction of evidence in medical meetings demonstrating that evidence is constructed interactively through talk bringing together different "voices" including the voice of institution, scientific discourse and personal experiences. In a similar vein, Nilsen and Ludvigsen (2010) explore physicians' daily interactions about patients and medical problems. The authors show how diagnosis and

treatment are reached through interactive knowledge exchanges, in which the lens of a biomedical model is complemented by making references to experiential knowledge and local circumstances.

Turning to clinical meetings with surgeons at two large Norwegian university hospitals, Underland (2010) studies verbal interactions in the process of the development and sharing of clinical knowledge. The study is a good example demonstrating the role of spoken language in the co-construction of clinical knowledge and establishment of trust. Sampson and Atkinson (2013) study personal narratives of a group of scientists who were involved in a major genetic discovery. Contrary to the public perception of scientific work as factual and rational, this research shows that scientists use a wide range of emotional lexis and metaphors in describing everyday scientific work, specifically uncertainties and confusions.

Closer to home (Applied Linguistics), there have been several studies dedicated to spoken language use at conferences. Conference and research presentations are important avenues for knowledge dissemination (see Chapter 12, this volume). They are also central part of professional life being a mechanism of socialisation into academic communities (Ventola, Shalom, and Thompson 2002). Conference presentations are an interesting genre to explore from an interactional and intercultural perspectives; given their heavy information load that needs to be disseminated in a relatively short space of time (normally 20 minutes), there is a pressure on the speaker to deliver content in a clear and concise manner. In English-speaking academic contexts, in which involvement of the audience is given priority, long monologues based on read-out material are generally dispreferred because they are seen as less engaging (Clyne 1981; Schlee 2009). In other contexts, e. g. in (certain disciplines of) German-speaking countries and in Eastern Europe, a presentation is more likely to be based on written material to be read out, as presenting is considered to be the first step in the publishing process and having written script is considered more serious (Galtung 1985; Schlee 2009). Hence, in English-speaking academic literature, the question of involvement and keeping listeners engaged has been frequently addressed. Rowley-Jolivet and Carter-Thomas (2005) study the introduction of scientific conference presentations in geology, medicine and physics. The authors identify a range of structural and interactional features of conferencing in those fields. In contrast to the written research paper, conference presenters reduce the literature review to a minimum and instead emphasise the novelty of the arguments. Audience needs of processing a heavy factual load are facilitated by using shorter sentences and interactive evaluation; engagement with listeners is attempted through the use of personal pronouns including *I*, *we* and *you*. Similar findings were obtained by Webber (2005) who examined a corpus of medical conference presentations, mostly plenary talks, and compared it to a corpus of research articles from medical journals. She too identifies a high use of interactive features including personal references, hedges (*I think*) and time deictics to build a rapport with the audiences.

In his most recent study, Fernández Polo (2018) investigates the use of *you* in conference presentations given in English by native and non-native speakers. This study

shows that conference presenters employ *you* strategically to enhance the persuasiveness of their talk, to direct the audiences to visual materials and to establish a shared understanding. Some differences between native and non-native speakers have been identified with non-native speakers following at times a “pedagogical impulse” and using *you* for the purpose of negative politeness (Fernández Polo 2018: 24).

Turning to the humanities and social sciences, Reershemius (2012) examines the role of humour in conference presentations in English and German. Interrogating a corpus of conference presentations collected as part of the GeWiss project (*Gesprochene Wissenschaftssprache kontrastiv* ‘Spoken Academic Language in Contrast’, Fandrych, Meißner, and Slavcheva 2012), Reershemius (2012) shows that humour is adopted by speakers to signal in-group membership and to self-present as a skilful rhetorician. Differences were identified between presentations given in German and English; generally, more humour was used in English presentations suggesting a higher level of informality, whereas German equivalents were more formal and monologic in style. This reflects distinctive cultural traditions in the academic communities posing challenges for non-native speakers of English who might not always be familiar with such requirements. This study has also shown that the use of humour depends not just on the country of origin but also on the professional status within the academic hierarchy with higher status scholars being more informal and using more humour than early-career researchers.

### 3 Spoken language in interactions between experts and novices

Whereas spoken language in interactions between experts has received less attention in applied linguistics, a great deal of research has been dedicated to interactions between experts and novices. On the one hand, this strand of research has been motivated by the widely assumed claim that academic but specifically scientific subject matters are inherently abstract, complex and difficult to acquire and thus in need of pedagogical interventions. On the other hand, the need for the development of good academic communication skills prompted an interest in interactions between experts and novices. By far, the most investigated domains are medicine and science teaching.

Although conference presentations and journal articles are important avenues for knowledge dissemination and professional proliferation, academics spend most of their day-to-day activities engaged in educational speech events, of which the academic lecture is the most prominent (Fortanet Gómez and Bellés Fortuño 2005). Hence, most research in linguistics has been dedicated to this particular genre. Fortanet Gómez and Bellés Fortuño (2005) offer a detailed overview of research on academic lectures going back to the 1970s. Here, I will only discuss the most recent studies and highlight the major trends.



Although traditionally academic lecture is conceived as a monologic event whose main goal is to impart facts and knowledge, research has shown that lecturers do not speak in the way they write. Instead, they use a variety of interactive devices typical of spoken everyday conversations such as discourse markers and personal deictics (Fortanet 2004). This is not only typical for lectures delivered in English. German lecturers too draw on a range of interactive features including discourse-structuring devices, first person pronouns, summarisers and repetitions (Grütz 2002).

Using large corpora of spoken and written academic language sampled from six major academic fields of inquiry including business, education, engineering, humanities, natural sciences, and social science, Biber, Conrad, and Cortes (2004) study the use of multi-word sequences defined as lexical bundles across four genres including classroom teaching, academic textbooks, academic prose and everyday interactions. Lexical bundles are understood as recurrent word combinations retrieved automatically from a corpus. They can include fixed expressions as well as more flexible structures with a greater morphological and/or lexical and syntactical variability, for example collocations such as *exert/wield influence* or phrase-frames such as *if you look at*. They are not necessarily complete linguistic structures but rather lexico-grammatical fragments, which “function as basic building blocks of discourse” (Biber, Conrad, and Cortes 2004: 371) ensuring a smooth flow of communication in speech and writing. Biber, Conrad and Cortes’s (2004) study shows that academic classroom teaching emerged as the most diverse genre regarding the use of lexical bundles; it contains more stance and discourse organising bundles than everyday interactions and more referential bundles than academic prose. This study reveals the complexity of academic educational speech events in that they combine elements of both orality and literacy.

Similar findings were obtained by Nesi and Basturkmen (2006) who examined the use of lexical bundles in the British Academic Spoken English (BASE) corpus of 160 university lectures and identified discourse signalling function as the main function of bundles. Utilising the same data set, Thompson (2006) investigates vocabulary use in lectures across four academic fields of knowledge: arts and humanities, social sciences, life sciences and physical sciences. Not surprisingly, he identifies disciplinary differences in word families with lectures in arts and humanities using more words from the domain of culture, argumentation and interpretation, while physical sciences contain more vocabulary centred on processes, causation and relations of size.

In a similar vein, Simpson-Vlach (2006) explores the use of keywords in the Michigan Corpus of Academic Spoken English (MICASE). Her analysis shows a considerable variation across disciplines in the use of hedging devices, discourse markers and deictics. Lecturers in arts and humanities seem to make a greater use of hedging devices (*sort of, kind of*) and fillers (*um, hm*), whereas scientists seem to use more discourse markers (*okay, right, well*) and deictics (*this, these, those*).

The main purpose of educational speech events is to impart knowledge and hence there is, despite the orality, still a heavy focus on informational load. Lectures are

therefore seen as an inherently difficult listening activity posing high demands on real-time processing. Taking this as a starting point, several scholars investigate the ways in which academics facilitate comprehension in lectures and seminars. Thompson (2003) examines the role of text-structuring metadiscourse and intonation in helping the audience to form a coherent mental map of the talk. Crawford Camiciotoli (2004) shows the importance of interactive discourse-structuring devices in academic lectures. Interestingly, her study reveals that non-native speakers of English rely more on such devices possibly due to their heightened awareness of the needs of L2 learners. Focusing specifically on the relevance markers, Deroey (2013) examines the use of such devices in the BASE corpus. The analysis shows that most of the relevance markers were oriented towards the content or the listeners. Zare and Keivanloo-Shahrestanaki (2017) show that relevance markers are used extensively across academic disciplines and lecturers use them primarily to direct students' attention to topics that need extensive coverage or items that are likely to appear in the assessment.

Turning to the opening sequences of academic speech events, Evison (2013) identifies a set of core turn-openers including minimal responses (*mhm, yes, right and okay*) and textual turn-openers (*and, but, so, because/cos, or*). Focusing on the other end of the event – the closings – Cheng (2012) explores strategies used to end academic lectures. An analysis of 56 closings of lectures conducted across disciplines at American universities and included in the MICASE corpus reveals a range of pre- and post-ending strategies. The use of the strategies appears to depend on the class size with smaller classes having a more interactive style of closings.

Markers of involvement in university lectures are of interest to Barbieri (2015). Involvement is part of the larger notion of stance and is defined as speaker's emotions and participation in the interaction. Eighteen linguistic features were identified as markers of involvement including discourse markers, questions, stance verbs and minimal responses and systematically investigated in a 1.3-million-word corpus of classroom discourse that includes university class sessions from different disciplines, levels of instruction and sizes. Barbieri's (2015) analysis shows that the linguistic features of involvement are used extensively across all teaching contexts but are particularly frequent in the humanities and social sciences at the graduate level and in smaller classes.

Although academic lectures are not generally "funny" occasions, laughter has been identified as one of the interactive features employed. Interrogating the BASE corpus, Nesi (2012) shows how laughter is strategically used for the purpose of teasing, self-deprecation, error corrections and word play. Laughter and humour emerged as important aspects of the manner of talk in verbal interactions during a lab work in research by Tapper (1999).

Expert attribution is an important tool of knowledge sharing in academic discourse. An extensive body of research on attribution and lack of thereof in writing exists (e.g. Hyland 1999; Hyland and Hyland 2001; Flowerdew and Li 2007), while

spoken academic genres have been somewhat neglected. Ädel's (2008) study sheds some light on the use of attribution in university lectures that form the MICASE corpus showing that the use of attribution in lectures is as extensive as in writing. Disciplinary variations have been shown in that attribution is most frequent in academic lectures in social sciences and least used in engineering and physical sciences. Arts and humanities are positioned in the middle.

Alongside attribution and involvement, evaluation constitutes a vital element of knowledge development. Exploring the MICASE corpus, Mauranen (2001) found that negative evaluation is rarely used in academic speech and when it occurs, it tends to be softened with hedges. She argues that spoken academic discourse appears to be more consensus-orientated than academic writing possibly due to the stronger needs of face management (Goffman 1959).

Turning to another important and yet under-researched academic spoken genre, that of office hours, Limberg (2007) investigates features of office hour interactions. Drawing on the tools of conversation analysis, this study shows that office hours are highly structured events in which participants not only exchange knowledge but negotiate their goals. The study highlights the relevance of office hour interactions in explaining complex academic matters but stresses, at the same time, the demands and risks of institutional conversations. They can fail if there is a lack of mutual orientation and not enough attention to "facework" (Goffman 1959).

Given the increased mobility of academics and internationalisation of higher education contexts specifically in English-speaking countries, there is a strand of research focusing on cross-cultural dimensions of academic speech events. For example, Schleef (2009) examines the functions of conversational support and the degree of formality in Canadian English and German lectures and reveals considerable differences between the two cultural contexts. The German spoken academic style seems to exhibit a higher degree of formality, as evidenced by the frequent use of group vocatives and read-out speech. In contrast, lectures delivered in Canadian English seem to prefer a more interactive style as evidenced through greater use of questions and progress checks.

The way in which academics interact in institutional contexts largely depends on the cultural and linguistic conventions of the academic community or the *linguacultures* (House 2012) into which they were socialised. If they are required to operate in a different academic and linguistic environment, many of the elements of their original academic *linguaculture* including communicative preferences will be transferred to the new context causing potentially, but not necessarily (House 2011), some misunderstandings and cross-communication. House (2012) explores the use of English as a Lingua Franca (ELF) in the context of academic advising sessions with German-speaking academic staff and international students. The analysis shows that certain moves, which from the point of view of English *linguaculture* are often interpreted as impolite, for example, direct requests, shotgun opening moves and interruptions are not necessarily seen as such by academics who are native speakers of German, who seem to

focus more on the content of interactions than interpersonal relationships. In her concluding remarks, House (2012) calls for more cross-cultural pragmatic research into communicative preferences in ELF interactions, which due to the internationalisation of higher education are increasingly becoming the norm.

In medicine and medicine-related fields, knowledge development takes place mostly in practical speech events including patient rounds and morning reports and these speech events have received considerable attention in research (Erickson 1999; Apker and Eggly 2004). Emphasising the role of interactions within the community of practice, Apker and Eggly (2004) explore interactions between medical students and senior physicians during morning reports. Verbal morning reports are important clinical events during which professional knowledge, values and traditions are imparted. They are also public displays of professional identity. Apker and Eggly (2004) show that morning reports are, in fact, a highly routinised discourse practice, which follows a predictable structure. The senior physician is always in control of the interactions through asking questions. He or she reinforces a hierarchical model of communication, which is based on the medical ideology of objectivity and neutrality. This, in turn, acts as a role model for students and junior doctors who adopt and later transfer this model to their own interactions with patients.

## **4 Spoken language in interactions between experts and lay audiences**

Communication of scientific matters to a lay audience has been high on the agenda since the end of World War II (Stilgoe, Lock, and Wilsdon 2014). Since then we witnessed seven decades of exponential growth in science and technology fundamentally changing our lives at a very fast pace. Never before have science and technology played such a significant role in everyday life and there has never been a greater interest in scientific matters by lay audiences. Yet, communicating scientific matters to lay people is not as straightforward as many scientific and educational establishments seem to believe. Often, the relationship between science communicators and society is far from cordial and the ways in which scientists communicate tend to cause, at times, public outcries and mistrust. The case of communication around BSE (also known as the mad cow disease) in the UK is a classic example of what can go wrong when science and society (mis)communicate (e. g. Reeves 2011).

The view of the public in science communication has long been based on the belief that the public operates within a cognitive deficit and does not know enough about science to comprehend complex scientific matters (Irwin and Wynne 1996). Accordingly, the role of the scientist is to enlighten lay audiences and persuade them to believe that science and technology have all the answers and help make rational choices. Some of the communication fiascos of the 1990s surrounding the BSE crisis,

discussions around GM food and vaccinations have shown the inefficiency and sometimes disastrous consequences of this one-way and top-down model of communication, which disregards the lay understanding and experience of the world. Since then, an engagement model has been proposed based on a dialogue and two-way relationship with the public. It is now recognised that scientists should be careful in making general statements outside their academic and laboratory conditions and need to learn from alternative forms of knowledge. With the change in the communication paradigm, a more engaging stance on the part of scientists was required and this led to the burgeoning of new interactive science programmes in public and private broadcasting (Bennett 2009) including digital media. *People of Science* or *Wonders of the Universe* produced by the BBC and presented by Brian Cox, physics professor and media celebrity, or TED talks with cutting-edge scientists are good examples of this new interactive approach to science communication (Davies and Horst 2016).

With the rise of public engagement, spoken language has assumed an important role as a medium of communication, but it has so far received less attention in research, which continues to focus on written texts. Exception is work by Davies (2008), Armon (2017) and Armon and Baram-Tsabari (2017). Davies' (2008) work attempts to tap into scientists' ideas and assumptions about public communication. It shows that scientists whose research is more closely related to public concerns are more likely to see communicating with lay audiences as a two-way process, whereas those who conduct a more "detached" research find it difficult to communicate with lay audiences. Emphasising the vital role of metaphors in framing abstract scientific concepts, Armon (2017) investigates metaphors used by scientists in live broadcast. Scientists employ a range of metaphors to explain complex matters and to build shared understanding similar to the ways in which metaphors are used in scientific writing. However, in contrast to writing, the kind of metaphors used in live broadcast depend on the interactions, specifically the tone and frame of the interview which is set by the interviewer.

The area in which scientific knowledge has the most direct impact on people's life is in encounters with medical professionals. It is therefore not surprising that this realm of communication has received a great deal of scholarly attention. It is beyond the scope of this chapter to offer a comprehensive overview of research on interactions between doctors and patients; readers are referred to Hamilton and Chou (2014) and Jones (2013) for more detailed summaries. Here, I indicate studies that focus specifically on aspects of spoken discourse. Two aspects have been foregrounded: the structure of practitioner–patient consultations and the asymmetry prevalent in such encounters.

One of the most widely cited models of doctor–patient consultation is the framework proposed by ten Have (1989), which includes the following stages: opening, complaint, examination, diagnosis, treatment or advice and closing. Each stage is dedicated to a specific task and these tasks are performed jointly by medics and patients through the use of specific lexico-grammatical and discursive resources. Research has

shown that each phase accommodates only a certain type of discourse and roles; deviations from this order may lead to interruptions and misunderstandings. For example, Chatwin (2006) demonstrates that patient narratives are attended to when they come in the complaint phase. Outside this phase they are less likely to be listened to. Generally, doctors due to the time pressure do not like the consultations to diverge from the established “order” and use devices such as interruptions to bring the conversation back on track (Jones 2013). But patients too use specific discursive resources such as pauses or upward questioning intonation to align with doctors’ expectations (Chatwin 2006). Although most doctor–patient consultations will follow the discursive order proposed by ten Have (1989), this is not a universal model and in certain circumstances, both doctors and patients can diverge from this order to fulfil specific goals.

The primary aim of medical consultations is to arrive at a diagnosis and treatment and hence the interactions can be seen as transactional type of discourse based on exchanges of information. Yet, they are never purely transactional and may involve interactive and social frames to varying degrees (Jones 2013). Sarangi and Clarke (2002) and Sarangi (2010) show that in consultations which involve communication about uncertainties and risks, which are inherently face-threatening (Jones 2013), doctors depart from the established discursive order and engage in different discourse types to encourage patients to come to their own conclusions or to modulate their own medical assessments without explicitly admitting to their lack of knowledge.

Research on the structure and discursive resources employed in doctor–patient consultations has brought to attention the asymmetry of such encounters. Much of the research in this area has been stimulated by insights from medical sociology, which tends to see physicians as powerful, authoritarian and promoting a biomedical model of illness at all cost, while patient experiences are undermined (cf. Maynard 1991). Researchers in (applied) linguistics have been interested in the ways in which spoken language is used to interactionally enact these power relations in doctor–patient consultations. Small and large pragmatic and discourse devices have been investigated showing that doctors make an extensive use of speech acts associated with power such as asking questions, giving orders and interruptions and in doing so, control the order of interactions (see Jones 2013 for a detailed overview). Yet, as Jones (2013) observes, we need to be careful in making direct links between the interactional devices used in consultations and power relations. Power is not inherent in a linguistic structure of spoken language, but a structure or device can become powerful when used by those who are in a position of power, which in turn is determined by wider institutional, social and cultural factors. Overlooking those could lead to simplifications such as the claim that interruptions always signal a more powerful status. Also, the responsibility of the physician is to gather information about the wellbeing of the patient and questions are efficient pragmatic devices to do so. Finally, the assumption that asymmetry is always a bad thing discounts the fact that some patients may feel comfortable with it and would see a more equal and informal interactional style as a sign of not being taken seriously (Gwyn 2002).

## 5 Conclusions

Far from the common assumption that spoken language is an ordinary and fragmented deviation of the written standard, this overview shows that it is an incredibly rich and dynamic resource used to perform a variety of communicative goals across academic contexts and settings. Whereas written texts are examples of final polished products and can be seen in Goffman's (1959) sense as an aspect of the front stage of academic know-how, spoken language can offer insights from the back stage into the everyday interactions in which scientists and academics across fields engage. Research studies reviewed above demonstrate that spoken language is not just a tool of information exchange but a resource used interactively to co-construct knowledge and arrive at shared understanding. Larger discursive features of spoken language such as direct questions, reformulations, hedges, metaphors and emotive vocabulary play an important role in this process. From this it should become clear that notions such as knowledge, expertise and evidence are not stable objective entities but dynamic constructs achieved interactively through talk, in which the "voice" of the discipline interacts with other "voices", for example, the "voice" of the institution or the person. Moreover, this overview has shown the critical role of spoken language in establishing engagement and involvement with audiences. Several studies reviewed above demonstrate that academics employ a variety of linguistic resources to engage with listeners including shorter sentences, personal references, hedges, stance markers as well as humour and laughter. In contrast to a common assumption that academic speech is dry and monologue-like, the studies discussed above highlight a great deal of interactivity even in events such as academic lectures that traditionally have been delivered through monologues. Yet, the status of an academic within the institution as well as her or his cultural background cannot be overlooked as they seem to play an important role when it comes to the use of certain devices such as humour.

The forms of talk discussed in this chapter are embedded within an institutional context and the institution together with its agendas, goals and roles poses certain constraints on who communicates with whom and how. Hence, it is not surprising to see that most speech events in academia or clinics are highly structured events with clearly demarcated phases. Diversions from these structures may result in misunderstanding, miscommunication and jeopardise relationships. Using spoken language in institutional contexts requires therefore skilful deployment of interactional resources to avoid miscommunication and manage face threats. Hence, spoken language is not just an agglomerate of phatic and fixed phrases but a complex resource that enables the management of interactions and relationships within institutions and beyond.

Compared to the body of research on written communication, research concerned with spoken language use in science and the humanities is relatively small in scope. Nonetheless, the studies reviewed above point to a wide range of aspects and contexts investigated and multitude of methodological approaches used including qualitative methods such as conversational analysis, interactional sociolinguistics, narrative

analysis and discourse analysis, and quantitative approaches such as corpus-based methods. Despite the breadth of this research, there are still several areas that future research would need to explore. First, spoken language is inherently multimodal and works together with para-linguistic features such as intonation, gestures and visual elements. Yet, most of the studies look at spoken language as a monomodal phenomenon and focus on aspects of grammar, lexis and discourse. A multimodal approach combining the analysis of spoken language with paralinguistic and visual elements could contribute to a more comprehensive understanding of the role of spoken language in science and the humanities. Arguably, this is not an easy task but frameworks for multimodal analysis developed within discourse analysis can offer some valuable methodological pointers (cf. Machin and Mayr 2012; Adolphs and Carter 2013; Fandrych, Meißner, and Wallner 2017).

In the last decade, digital and social media such as Twitter and Facebook have emerged as important tools of communication for scientists and academics fostering engagement with the public and contributing to the development of citizen science (Davies and Horst 2016). Communication in these new digital channels draws on the interactive resources of spoken language but we know very little about the extent and specific ways in which spoken language is utilised to share knowledge and engage with the public in these digital settings. Research on digital communication in applied linguistics can offer here some useful directions (e. g. Tagg 2015; Jones and Hafner 2012).

The studies above demonstrate that spoken language is a complex interactional phenomenon embedded in structured speech events with various spoken devices being employed to accomplish different goals depending on the topic, participants and setting. There is a need to recognise spoken language as the key component of interactional competence necessary for the management of knowledge exchanges and interactions across academic contexts. Yet, teaching spoken language is rarely practised and most pedagogical efforts are spent on academic writing. Moreover, the relevance of the subject matter on the ways in which spoken language is used has been repeatedly highlighted. Yet, academic literacy training remains largely general and discipline-specific features are seldom considered.

Finally, given the increased mobility and internationalisation of academia and scientific communication, there is a need for research and training in communicative spoken styles across academic communities and specifically their use of English as a Lingua Franca (ELF). Cross-cultural research on everyday and business interactions have shown that participants from different cultural and linguistic backgrounds adopt different turn-taking patterns and strategies of topic management (e. g. Du-Babcock 2006). A greater focus on cross-cultural facets in the use of spoken language would shed light on differences and possibly similarities in interactional strategies used to communicate scientific subject matters across different *linguacultures*.



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Gerd Fritz

## 14 Scholarly reviewing

**Abstract:** The present article gives a survey of the practice of scholarly reviewing, dealing with basic parameters of reviews and their variation in various disciplines and providing a sketch of the history of reviewing and of the state of the art in research on reviewing. Basic parameters include the functional elements of reviews (e. g. summarizing a piece of scientific work, critically discussing such a work and evaluating it), topic management in reviews, and communication principles for reviews. Special emphasis is given to the role of evaluation in reviewing, which has been an important topic in recent research. Finally, present developments in the practice of reviewing are discussed, including open peer review, especially the introduction of online review sites with different publication systems, which, among other advantages, afford the opportunity to develop the basically monological practice of reviewing into an interactive enterprise.

**Keywords:** reviews, basic structures – reviews, types – evaluation – communication principles – reviewing, history of – interactive reviewing – peer review

### 1 On the role of reviewing in scholarly communication

In the wide array of text types that make up the communicative cosmos of academic publishing, reviews seem to play a modest role compared with the research article in the sciences and the research monograph in the humanities, which are often considered the only genuine vehicles for the presentation of original research. Reviews have been looked upon as an academic Cinderella (see East 2011) and, consequently, have long been “a somewhat unsung genre of the academy” (Hyland 2004: 43). On the other hand, it has often been noted that reviews play a fundamental role in the dissemination and critical evaluation of research, thereby contributing not only to information management and the establishment and assessment of standards but also to the constitution of scientific communities. As for the productive aspect of the critical activity performed in reviewing, the essential role of criticism for the formation, evolution and evaluation of scientific theories has frequently been emphasized (see Dascal 1998: 147). And a more detailed analysis shows that reviews serve other scientific purposes as well, e. g. the creation of intertextual relations among scholarly works. Also, on a somewhat more mundane level, “[t]he task [of reviewing] is of the utmost importance: Careers, reputations, positions, salaries – all these and more are likely to be at stake” (Mazlish 2001: 1). So, we see that “[l]ike the research article, the book review is a crucial site of disciplinary engagement, but it is a site where the

interpersonal stakes are much higher” (Hyland 2004: 41). Book reviews are, therefore, “more interactively complex than research articles since they do not simply respond to a general body of more or less impersonal literature as is the case in research articles. Instead, they represent a direct, personal, public and often critical encounter with a particular text, hence, with its author who is the primary audience of the book review” (Salager-Meyer, Alcaraz Ariza, and Berberí 2007: 1771).

There is also another aspect of reviews that I shall only mention here, going into it in more detail in a later section of this article: Reviews are often contributions to a dialogue by either relating to earlier discussions or by sparking off controversies which develop by responses to reviews and replies to responses (see section 6). So, in many cases reviews not just mirror research but contribute to research.

In view of these remarkable features and functions of reviews it is not surprising that a growing body of research on reviews and the process of reviewing has been accumulating in the last 15 years or so. (Early contributions to the study of reviews and the history of reviewing include Roper 1978, Wiegand 1983, Forster 1990, Rowland and Fink 1995.) However, in spite of these gratifying developments there is still much uncharted territory, especially in the functional analysis of different types and variants of review and the history of reviewing.

In addition to the fact that there are various contexts and types of review (pre-publication reviews, post-publication reviews, brief reviews, standard length reviews, review essays), we can also distinguish reviews and review-like texts in various media formats (e. g. books, print journals, online journals, mailing lists and blogs). Furthermore, the practice of reviewing can be considered as a field of activity which includes various sub-activities like organizing the production and distribution of reviews, writing reviews and using reviews. With the advent of new digital media formats in the last 20 years and the development of a lively field of digital science communication providing affordances for all kinds of communicative needs, the practice of reviewing has been in a process of massive change, with new formats competing with traditional print formats in making available to the various scientific communities opportunities for social interaction and information exchange (see Chapter 30, this volume). (On recent developments of digital science communication, see Gloning and Fritz 2011. On the use of digital media formats in reviews and the practice of critique and controversy, see Fritz and Gloning 2012.) Comprehensive studies of these developments in the practice of reviewing are an urgent desideratum of science communication research.

The present article aims to give a survey of the basic functions of reviewing and the various dimensions of variation that we find in the practice of reviewing, including its organization and some of its historical developments. In a final passage I shall look at the future prospects of reviewing in the context of recent developments in online reviewing.

## 2 The organization of reviewing

From its early days in the late 17th century onwards, professional academic reviewing needed an infrastructure for the publication of reviews, which was mostly provided by scholarly journals, some of them featuring a book review section, others specializing in publishing only reviews. So the history of reviewing is intimately connected to the history of scholarly journals. Providing the necessary infrastructure had and still has both organizational and financial aspects. From the very beginnings of journals publishing reviews to the present day, problems of editorial, production and management costs have frequently been mentioned by editors of reviews. Recently, this aspect of scholarly journals has been discussed in terms of a “business model” in the context of demands for publishers to provide open access to online journals. This discussion is too complex a topic to be dealt with in this article. In order to show, however, that financial matters have a long history in scholarly reviewing I shall make a few remarks on the problem of financing (review) journals in the early days of scholarly reviewing (see Habel 2007: 103ff.). In many cases, in addition to the printing cost, sometimes including costly illustrations, journals had to pay the editor(s), the reviewers and sometimes also the books to be reviewed, if the publishers were unwilling to provide a review copy, which was normally the case up to 1780. So, publishing a review journal could be a risky commercial enterprise if the journal was not sponsored by high-ranking personages, like in the case of the *Acta Eruditorum*, or by some institution, e.g. a university or an academy, which was the case with some of the more well-known journals of the 17th and 18th centuries. In any case, editors felt they had to provide value in order to sell their product, i.e. to present the readers with interesting and helpful reviews.

In addition to these issues, modern review journals have to deal with the problem of information overload, which is more pressing now than it was 300 years ago, as a quote from the book reviewing section of the *American Historical Review* shows: “The sheer volume of books received is one determinant in the reviewing process. At present, the *AHR* receives over 3,000 books a year; we have the staff resources to publish at most 1,000 reviews a year (up to 200 per issue)” ([https://academic.oup.com/ahr/pages/reviews\\_guide](https://academic.oup.com/ahr/pages/reviews_guide); accessed 22 June 2018). This also points to another interesting aspect of the organization of reviewing, i.e. the role of journal editors or review editors in the process of selecting books for review. As the editors have influence on the selection of books to be reviewed, they have an important gatekeeper function in this process, a function that is often not transparent. A frequently used criterion for the selection of books for review is obviously the reputation of the publisher, not necessarily a reliable criterion in all cases. A bibliometrical study showed that the more prestigious the publisher was, the higher was the mean number of reviews generated by the monographs (see Lindholm-Romantschuk 1998: 132).

A different kind of gatekeeper function lies in the fact that review editors not only select the books to be reviewed but also the scholars being invited to write a review,



as reviews are mostly commissioned by the journals, while unsolicited reviews are discouraged. There is a tendency to change this practice, especially in recent online review journals, allowing would-be reviewers to volunteer for a review or for comments on the book or to apply to be added to the database of reviewers. I shall return to this point in section 8.

The problem of finding qualified reviewers, a major factor of quality management, has always been one of the major challenges of the organization of academic reviewing. Whereas in the early days of scholarly reviewing reviewers generally received a certain amount of remuneration, sometimes depending on the renown of the reviewer, this is normally not the case today, where the remuneration usually consists in getting a free copy of the book under review and maybe a (small) discount on publications of the respective publisher. In view of the fact that writing reviews is time-consuming and that institutions do generally not give academic credit for writing reviews, this is not a very strong incentive, unless the book is quite expensive. In addition, a negative review may create problems for the reviewer in his community and with important colleagues. So, the readiness of scholars to undertake the task of writing a review cannot always be taken for granted. Reasons for a scholar to act as a reviewer could be, among other reasons, the honor of being invited by the editor of a prestigious journal, the opportunity to show one's expertise in a given field, especially in the case of young scholars, the opportunity to emphasize the quality of a book that one considers important or a feeling of responsibility towards the scientific community, which relies on this kind of service.

### 3 Reviews and related forms: a family of text types

Looking at the functions performed by various review-like text types and the constellations of functional elements to be found in individual reviews and review-like texts, we find that typical functions like summarizing a piece of scientific work, critically discussing such a work and evaluating it are spread over a variety of text types and media formats. Functional elements like the ones mentioned just now can be found in reviews of literature that form part of PhD theses, they can be found in prepublication peer-reviews, in comments in open peer reviews, in reviews published in print or online journals, on mailing lists, or as blog posts, in "notes" on a book that are printed together with the book and in open peer commentary on a target article of the kind published in *Behavioral and Brain Sciences*. This list could be continued. So, reviews in a narrow sense of the word form part of a complex network of related text types and contexts of publication.

Book reviews in the narrower sense of the word themselves show (and showed historically) a wide array of functional elements in addition to the ones mentioned before, e. g.:

- (i) descriptions of the relevant state of the art,
- (ii) summaries of relevant discussions in the respective community,
- (iii) presentations of competing theories,
- (iv) comparisons with work on a related topic,
- (v) attempts at a refutation of the author's theses,
- (vi) polemical attacks on the author (or the school he represents),
- (vii) remarks on the status and qualification of the author,
- (viii) presentations of extra data collected by the reviewer,
- (ix) attempts to adjudicate in a controversy of which the work under review is a part,
- (x) statements of remaining research desiderata.

It is true that there has been a process of standardization in various scientific disciplines restricting the accepted range of functional elements, a standardization which evolved both “naturally” by the selection of useful textual strategies in the course of the professionalization of these disciplines and “normatively” by the influence of explicit review guidelines issued by the editors of journals or even by the introduction of “structured book reviews” that are prevalent in some medical journals (see Hartley 2006: 1204). Another factor is the advice given to novices by universities on how to write a book review (e. g. [https://guides.library.ualberta.ca/ld.php?content\\_id=16869607](https://guides.library.ualberta.ca/ld.php?content_id=16869607); accessed 22 June 2018). However, in a sufficiently large corpus of reviews we find all these moves and others. And this latitude also makes sense functionally, as all these types of elements are potentially useful contributions to scientific information and exchange. So, from an empirical and especially an historical point of view, it makes sense to keep an open mind as to what was or is considered a well-behaved review and an open eye as to which kinds of variation the practitioners of reviewing actually use.

## 4 Basic structures of present-day scholarly book reviews

Due to the standardization mentioned above many reviews show a standardized length of 800–1200 words and a number of functional elements that have been described as “canonical moves”. As an example of a collection of such basic elements I give here a short list of moves and subfunctions – to use the author's terminology – presented in a study of present-day English reviews in the fields of chemistry, linguistics and economics (Motta-Roth 1998: 35):

|               |                                        |        |
|---------------|----------------------------------------|--------|
| Move 1        | Introducing the book                   |        |
| Subfunction 1 | Defining the general topic of the book | and/or |
| Subfunction 2 | Informing about potential readership   | and/or |
| Subfunction 3 | Informing about the author             | and/or |
| Subfunction 4 | Making topic generalizations           | and/or |

|                |                                                          |        |
|----------------|----------------------------------------------------------|--------|
| Subfunction 5  | Placing the book in the field                            | and/or |
| Move 2         | Outlining the book                                       |        |
| Subfunction 6  | Providing a general view of the organization of the book | and/or |
| Subfunction 7  | Stating the topic of each chapter                        | and/or |
| Subfunction 8  | Citing graphs/illustrations etc.                         | and/or |
| Move 3         | Highlighting parts of the book                           |        |
| Subfunction 9  | Providing focused evaluation                             |        |
| Move 4         | Providing closing evaluation                             |        |
| Subfunction 10 | Definitely recommending/disqualifying the book           | or     |
| Subfunction 11 | Recommending the book despite indicated shortcomings     |        |

A slightly modified structure is given in Nicolaisen (2002).

In a more fine-grained description of the communicative acts performed in writing a book review one could, for instance, further differentiate between the description of the book's topic structure and the description of its structure of argumentation or between the evaluation of aspects of the book and the arguments given in justification of the evaluation. And, as mentioned before, in more elaborated reviews we find many other types of act like, for instance, comparing the book with earlier publications of the author, analyzing an argument, presenting the reviewer's own view of a problem discussed in the book, giving examples of the author's errors, and making suggestions for improving the book in a second edition. In assessing the quality of a review, it is often the presence of such acts which make it a *good review*.

As for the sequencing of the basic moves, it has been noted that a general evaluation of the book under review is standardly used as a closing move, but often also as an opening move. (On variants of the final move in reviews see Dalmás 2001). The evaluation of specific aspects of the book, however, is often closely linked to the description of these aspects, so evaluative elements tend to be dispersed all over the text. Concerning the topic structure of reviews, one often finds a movement from more general to more specific aspects of the book, a sequencing strategy that contributes to a systematic structuring of information. This is, for instance, true of the description of the general topic, followed by the subtopics of individual chapters. Then again, a reviewer might prefer highlighting a particularly interesting detail before mentioning the general topic of the book.

The functional element – or complex of functional elements – that has attracted most attention in the literature is evaluation (e.g. Hyland 2004, ch. 3; Suárez and Moreno 2008; contributions in Hyland and Diani 2009). Aspects of an academic book that may be evaluated include the coherence of its argumentation, the clarity of its exposition, the relevance for a particular readership, the qualification of the author, and the production standards of the book (see Hyland 2004: 47).

Forms of evaluation can be categorized as explicit or implicit. In giving an explicit evaluation in English the reviewer may use linguistic expressions of different gram-

matical categories, e.g. *excellent, disappointing, well-organized, a weakness, this mistake, unfortunately, he misunderstands* (see Shaw 2009). In implicit evaluations the reviewer states a (presumptive) fact about the book under review, assuming that it is common knowledge in the target audience that this fact is to be seen as a positive or negative feature of this kind of book. If, for instance, a linguist reviewing a book for an audience of corpus linguists states that the book does not make use of corpus methods, this statement is very likely to be taken as a critical remark. Both forms of evaluation are frequent in reviews. In a way, implicit evaluations are more subtle, but they risk not being understood adequately. Therefore, reviewers tend to give their closing evaluation in explicit form. Interesting observations concerning the distribution of praise and criticism have been made by Hyland, e.g. concerning the “tendency of writers to criticize specific issues and praise more global features” (Hyland 2004: 47). He assumes that “the overwhelming preference for a global focus of positive comment appears to obey another imperative, perhaps the injunction of review editors, for writers to convey overall impressions within a restricted space” (Hyland 2004: 48).

As criticism may be easily taken as a face-threatening act, there is the further tendency to mitigate negative evaluations by using hedges like *one might consider this misguided* or by using praise–criticism pairs (Hyland 2004: 55). To mitigate the possible shock of being subject to sharp criticism in a review, the editors of the review section of *Language* recommend that reviewers send copies of their review to the book’s author in advance, particularly if the review is more negative than positive. “No one likes to open the latest issue of *Language* to a negative review of his or her work, and advance notice of a review can both avoid hard feelings later on and cut down on the number of potential corrections that we are asked to adjudicate by providing authors with an opportunity to give feedback directly to reviewers” (<http://www.linguisticsociety.org/publications/language/bookreviews/faq#q6>; accessed 30 April 2018).

It is interesting to note that there also seem to be disciplinary differences in the balance of praise and criticism. In Hyland’s corpus of reviews from different disciplines the percentages of criticism (vs. praise) were substantially higher in the fields of philosophy and sociology than, for instance, in physics or electrical engineering (Hyland 2004: 49).

## 5 Communication principles and guidelines for reviewers

As with other text types, there are a number of communication principles that have been considered and discussed as being particularly relevant for the proper functioning of the practice of reviewing. These principles are both historically variable

and dependent on the intended audience, especially the respective scientific community for which a review is being produced. (On the role and status of communication principles, see Fritz 2017, ch. 5. For the history of communication principles, see Fritz 2008.)

From the early days of review journals, editors often prided themselves on providing non-partisan (German “unpartheyisch”) reviews and urged their reviewers to follow the principle of neutrality, a principle that seemed to harmonize well with other enlightenment principles. At the same time, however, many 18th-century reviews are in fact full of harsh criticism and biased polemics, so that we seem to have a typical case of a communication principle that forms part of a communicative ideology without necessarily being conformed to all the time.

The application of this principle is sometimes related to the primary function that a review is expected to perform. Reviews in 18th-century newspapers and journals for a general audience were mainly expected to summarize the content of a book and not to get immersed in scholarly controversies, whereas reviews in specialized journals often belonged to a different subtype of review, discussing controversial points and sometimes expounding the reviewer’s own theories. In present-day practice, this divide does no longer seem valid, as reviews of scholarly books, e. g. in the field of history, that appear in papers for the general public very often seem to be explicitly intended to spark controversy. Generally, the editors of present-day specialist review journals tend to advocate a middle path concerning the admission of forms of criticism. The following quotation from the “Guidelines for Reviewers” of the online review journal *Aestimatio*, a journal for “critical reviews in the History of Science”, probably voices the common-sense view in this matter:

Please remember as well that reviews may have consequences in the long term, and while disagreements may be serious and important, reviewers should avoid inflammatory language and aim for criticism that is fair and balanced, respectful, and focused on the work written, not on the author. (<http://www.ircps.org/aestimatio/guidelines-reviewers>; accessed 30 April 2018)

In addition to banning verbal polemics in general, the editor here also specifically endorses the ban on *ad personam* moves which has a long tradition in rhetoric and dialectics. The principles mentioned in this quote are particularly relevant for reviews, as reviews may present negative evaluations that may hurt the reviewee, maybe even negatively influencing his or her career, and may also cause a disruptive effect in the relevant community.

Another principle that is frequently mentioned is the principle that the author of a review should take into account his target audience and make an effort to write comprehensibly. This principle mainly applies to journals with a heterogeneous readership or papers for the educated non-specialist.

A completely different communicative principle is the principle of brevity. Limited space in print products often forces the editors to insist on brief reviews, as

for example in the guidelines for reviewers for *GERMANISTIK*, a review journal in the field of German studies, which prescribe an upper limit of 150 words for its brief reviews. Following this seemingly superficial principle often goes hand in hand with a certain reluctance to voice pronounced criticism, as criticism – here we have another important principle – should be explicitly and thoroughly justified, which, of course, is often difficult to achieve within the space of a few lines. On the other hand, longish reviews are not uncommon in specialist journals. So, the application of the principle of brevity obviously depends on the type of publication in which a review is printed. This is certainly true of recent digital online review formats, where length of text is not necessarily an issue. For example, in the “Guidelines for Reviewers” of the journal *Aestimatio* mentioned before, the editor explicitly waives any restrictions on length:

It is important to bear in mind that reviews in *Aestimatio* are not bound by extrinsic questions of length. Indeed, you are free to engage the book critically in a manner and at a length that you think will be useful to our readers. (<http://www.ircps.org/aestimatio/guidelines-reviewers>; accessed 30 April 2018)

Apart from the communicative principles mentioned so far, there are a number of principles that refer to the relationship between reviewer and reviewee. It is generally considered unacceptable that the reviewer and reviewee should be closely related, e. g. as members of a team cooperating on a project, as supervisor and PhD student, or as long-standing enemies or known opponents in a virulent controversy. These restrictions, which assume conflicts of interest and problems of impartiality in the case of such closely related persons, are, however, sometimes difficult to implement, as expert reviewers in a particular field may be rare and hard to find.

## 6 Reviews and responses

As we have seen, writing reviews is in itself an implicitly dialogic activity in which the writer addresses a certain audience, taking into account shared knowledge and attitudes as well as characteristic needs and interests of his readers. In many cases, however, reviewing becomes part of an *explicitly* interactive process. This is the case whenever the reviewee responds to a review, an action that is, however, considered bad form in some scientific communities today. Such a rejoinder may either take the form of a personal discussion or a personal email or it may be made public. A public response again may take various forms and may use various media. The writer of a book that has been unfavorably or in some other way unsatisfactorily reviewed from the point of view of the writer may use a footnote in his next book to criticize the reviewer or to clarify a point which the reviewer – again in the writer’s view – misunderstood or intentionally misrepresented. He or she may write a whole book or pamphlet defending his/her original book against the objections raised by the

reviewer. The latter was not uncommon in the 18th century. In those cases where journals provide the opportunity to respond to reviews, the writer may avail himself of this opportunity and reply to the reviewer in the same journal. Many 20th-century and present-day journals did and do not provide this opportunity, whereas, as I shall illustrate in the section on the history of reviewing, both early journals of the 17th and 18th centuries and present-day online-journals or mailing lists allow(ed) or even encourage(d) such responses. In some cases, the sequence of review and response may lead to extensive controversies (for an example see Fritz and Gloning 2012; see Chapter 15, this volume).

From the point of view of discourse analysis, responses to reviews and ensuing controversies are particularly interesting as they make explicit the implicitly dialogic nature of reviewing and sometimes lay open essential aspects of reviews, e. g. the author's understanding of the type of review he is confronted with, the common ground of reviewer and author and the (presumed) goals and strategies of the reviewer.

## 7 Dimensions of variation in book reviewing

Apart from the aspects of variation of text types in reviews we have so far dealt with, there are at least three dimensions of variation which are worth mentioning and which have also attracted some attention in research on reviews, i. e. cross-disciplinary variation, cross-linguistic and cross-cultural variation, and historical variation. As I shall deal with historical aspects of reviewing in the following section, I shall restrict myself here to a few observations on cross-disciplinary and cross-linguistic/cross-cultural comparisons.

Although some of the standard features of reviews are to be found uniformly across the disciplines, a number of studies indicate that various disciplines have their own practice of reviewing, based on traditions and conventions of the respective field. A first difference consists in the general relevance of book reviewing to the respective disciplinary communication. It has been noticed, for example, that in physics and other sciences book reviews lost their importance at the beginning of the 20th century as a consequence of “the shift from book to article science” (Bazerman 1988: 81). In the *Physical Review*, for instance, “by 1910, new books were only listed, not reviewed; after a short revival of reviews in the 1920s, all mention of new books in physics vanished in the early 1930s” (Bazerman 1988: 158).

A much-cited study comparing reviews in different disciplines is Motta-Roth (1998), a paper that analyzes reviews in the fields of chemistry, linguistics, and economy. As I mentioned earlier on, Motta-Roth found a number of basic moves across disciplines in her corpus. As for differences between disciplines, she found reviews in chemistry in her corpus to be generally shorter (an average of 592 words) than those in economics (1089 words) and linguistics (1115 words). This difference in

length she related to a preference in chemistry for giving a general overview of the book as opposed to economics, where in many cases “a more evaluative, detailed, and lengthy argumentation could be found” (Motta-Roth 1998: 46). “Economics can also be regarded as the most evaluative of the three areas, because reviewers dedicate larger portions of text to evaluation than they do in the other disciplines” (Motta-Roth 1998: 50). Of course, this generalization does not mean that there are no highly critical and evaluative reviews in linguistics, as anyone knows who follows the literature.

A second example of a comparison of reviewing in different disciplines is Hyland’s chapter on “praise and criticism: interactions in book reviews” (Hyland 2004: ch. 3) which I already mentioned in connection with the role of evaluation in reviews. In this chapter, Hyland compared reviews across a range of eight disciplines, including philosophy, sociology, electrical engineering, physics and biology. One of the major results of his analysis accords well with an observation made by Motta-Roth: Whereas in reviews in the soft knowledge fields writers “sought to exploit the discursive space available to them to explore issues in depth, anchoring the text in the concerns of the wider discipline and often expanding their own views at length” [...], “reviews in science and engineering [...] were much shorter and assessments more compressed and more dense [...]” (Hyland 2004: 49 f). “In the soft fields, where controversy and debate are more important than demonstration and proof, greater attention was devoted to the quality of exposition and detailed critique of particulars” (Hyland 2004: 52). These and other observations draw attention to the different expectations and practices of different disciplines concerning the appropriate expression of criticism and the adherence to communicative principles. In a later study, Tse and Hyland found that the use of boosters (i. e. expressions like *definitely*, *clearly*, *it is evident*) to reinforce arguments and to express conviction were used more frequently by male reviewers than by females. This result represented the widest gender difference in the corpus, especially in the field of philosophy (see Tse and Hyland 2009: 110).

Using a different methodology, namely a questionnaire study, Hartley (2006) explored how academics in the arts, the social sciences and the sciences read and write book reviews. His study corroborated Motta-Roth’s finding that there is a canon of key elements used in reviews across the various disciplines. Furthermore, many respondents in all three disciplines thought that more academic references than currently contained in reviews would enhance the quality of reviews (Hartley 2006: 1203) and that a chapter-by-chapter structure of a review was not particularly useful (Hartley 2006: 1204). Some of the key moves were, however, more highly valued in one field than in the other, e.g. social scientists attached more importance to an attempt to position the book in its historical context than scientists did, whereas scientists, for obvious reasons, placed more value on the assessment of the use of tables and diagrams than readers of reviews in the arts did (Hartley 2006: 1202). In general, however, his findings suggest that with regard to the ideas of what makes a good review, there seem to be few differences between the opinions of his respondents in the different disciplines.



A completely different approach was taken by Lindholm-Romantschuk (1998). Using bibliometric methods, she analyzed differences between the practice of book reviewing in the social sciences and the humanities, two fields in which researchers rely heavily on monographs, for the period from 1971 to 1990. In her study she “explore[d] the flow of information within and among academic disciplines in the social sciences and humanities through analyses of the patterns of scholarly book reviewing” (Lindholm-Romantschuk 1998: vii). Of the many interesting findings of this study I shall only mention a few. Judging by the number of reviews written in journals outside the respective discipline of the monograph, she found a fairly lively exchange between disciplines, “the main direction of the flow of information across disciplinary groups being from the social sciences to the humanities” (Lindholm-Romantschuk 1998: 131). “Sociology, for instance, appears to be a discipline with a great deal of appeal outside its boundaries – more than two-thirds of the book reviews are found externally” (Lindholm-Romantschuk 1998: 135). Other disciplines, however, seemed to be fairly isolated, e.g. music, where she found “very little inflow and outflow of information” (Lindholm-Romantschuk 1998: 131).

As to the more detailed findings about academic book reviewing, she found that the typical scholarly monograph did not generate a very large number of reviews. The mean number of reviews per monograph for her sample was just under 8, and the highest number found was 33. She also found that “the reviewing process in the humanities tends to be somewhat more delayed than in the social sciences, a finding that should not come as a surprise, as it reflects more far-reaching differences between these disciplinary groups as a whole” (Lindholm-Romantschuk 1998: 132). Another central finding, which I already mentioned earlier on, was that the reputation of the publisher had an effect on the flow of information. The more prestigious the publisher was, the higher was the mean number of reviews generated by the monographs.

A second dimension of variation in the practice of reviewing is cross-linguistic and cross-cultural variation, which I will briefly consider here. Suárez and Moreno studied the characteristic moves made in a corpus of 40 academic book reviews in the field of literature published in journals in English and Spanish around the year 2000 (Suárez and Moreno 2008). Their study produced two main results. First, they found evidence of the fact that Spanish book reviewers are more likely to use the descriptive moves of the book review, and secondly, that Spanish book review writers seem to be more sympathetic in their evaluations than English writers (Suárez and Moreno 2008: 163). Their result that literary book reviews in Spanish were considerably less critical and offered more praise than the ones in English was confirmed by a later study, in which they formulated the contrast even more bluntly:

[W]hile the academic book review in Anglo-American literary contexts can be considered as a truly evaluative genre, the academic book review in Castilian Spanish contexts can best be taken as a laudatory or/and promotional genre (Moreno and Suárez 2009: 176).

A somewhat larger corpus, consisting of 180 academic book reviews across two languages, Brazilian Portuguese (BP) and English, in three disciplines (applied linguistics, history and psychology), was used in a recent comparative study by Junqueira and Cortes (2014). Their analysis focused on the use of so-called metalinguistic expressions, including attitude markers (e.g. *interesting*), emphatics (e.g. *clearly, in fact*) and hedges (e.g. *may, perhaps*) and their BP counterparts. One of their principal findings was that the BP corpus employed fewer metadiscourse devices. “This might suggest that these reviews may have a more descriptive rather than argumentative or persuasive nature, which are marked characteristics of genres with a high density of interpersonal metadiscourse” (Junqueira and Cortes 2014: 101). Referring to other studies comparing Romance language and English language reviews, they arrive at the following conclusion:

[...] at this point it seems safe to conclude that writers from the studied romance language backgrounds do not engage with and perhaps evaluate their reviews in the same way writers publishing in the English international community do (Junqueira and Cortes 2014: 102).

In spite of these remarkable results, the researchers working in this area feel that further studies still need to be conducted to reach a fuller understanding of the factors determining the practice of reviewing in different languages and cultures.

## 8 The history and future of reviewing

### 8.1 The history of reviewing

The basic functions of reporting on (new) works of other authors and discussing such works have been performed in letters or in writers’ own works since the times of classical antiquity. However, a systematic and professional practice of reviewing goes back to the establishment of learned journals in the late 17th century. In this period, scientific activities multiplied all over Europe and scholars and scientists of the period felt the need to be informed about what fellow-scientists discovered and invented all over the continent. Journals like the *Journal des Sçavans* (1665), the *Philosophical Transactions of the Royal Society in London* (1665) and the *Acta Eruditorum* (1682) in Germany catered for these needs and played a central role in the development of what was called the Republic of Letters. The editor of the *Journal des Sçavans*, in his introduction to the first volume, prided himself on not only listing the titles of new books but also giving information about the content of the respective books and their usefulness. In these journals short reports of theoretical findings and practical inventions (e.g. newly developed telescopes) were interspersed with – mostly short – reports on new books and extracts from such books. In this context, variants of reviews emerged as a new text type.

In the early period up to the middle of the 18th century many review journals mainly provided extracts and summaries of new books, sometimes with brief evaluative remarks. In the first volume of the *Acta Eruditorum*, for instance, a reviewer praised the editor of a work on the ancient Greek church for illustrating the text with scholarly notes (“notis eruditis illustravit”), doing this with “diligent effort” (“diligenti studio”; *Acta Eruditorum* 1682: 6). According to Habel (2007: 228), the middle of the 18th century saw a change in the practice of reviewing, at least in German review journals, from a preference for merely reporting the contents of books to the combination of a summary with more detailed analysis and evaluation. For similar developments in England around the middle of the 18th century, see Forster (1990: 3f.).

Generally speaking, the balance of these two functions, report/summary and evaluation, remained a topic of dispute throughout the early history of review journals. This balance was not only precarious in individual reviews but was also maintained differently in different types of journals. Whereas periodicals for the general public tended to emphasize the summarizing function, reviewers in specialist journals often added a critical discussion, including their own views on the topic under discussion. From the second half of the 18th century onwards many variants of reviews can be found, which contain various types of functional elements, including polemical and constructive moves. (For an analysis of different types of review of a theological book in the late 1770s, see Fritz and Glüer 2018.) As far as the 18th century is concerned it is worth noting, furthermore, that the difference between scholarly reviews and literary reviews was less clearly demarcated than we mostly see it today (see Urban 2004 and the contributions in Rowland and Fink 1995). However, the variety of forms of what we should today consider literary criticism with their dialogical, satirical or epistolary patterns did not shape the mainstream of scholarly reviewing.

As mentioned before, an important function of scholarly journals and the reviews published in them consisted in facilitating the international exchange of research results and introducing new theories abroad. For example, several reviews of Lavoisier’s *Traité élémentaire de chimie* (1789) in German journals in the year of its publication played an important role in making his new chemical theories and empirical results known to German chemists. (On controversies played out in the course of the introduction of the “new chemistry” in Germany, see Fritz 2018.)

As could be expected in the age of enlightenment, scholars not only wrote and edited reviews but also reflected on the goals, the principles and the actual practice of reviewing. Such reflections can be found in the prefaces to review journals, in reviews of review journals, in responses to reviews, and, as far as the German scene is concerned, at least in one case, in an explicit attempt at a “theory of reviewing” (Greiling 1799). Among the general goals of reviews (and review journals) the following are mentioned in relevant passages: Reviews should try to provide a historical panorama of the development of the sciences by focusing on innovations and placing them in the context of accepted knowledge. They should promote the diffusion of a mentality of rational critique and further the cohesion of the republic of letters. Reflections on

reviews also often mention principles of reviewing, sometimes called “maxims” in the Kantian tradition. Such maxims included: Reviewers should actually read the books under review and should be thorough in their treatment of the book, they should be competent in the relevant discipline – which was sometimes considered a problem, especially in the case of young reviewers –, they should practice impartiality of judgment and refrain from *ad personam* criticism, they should present the author’s ideas in their respective context, and they should utter their ideas frankly, but should avoid an arrogant “tone” and instead aspire to urbanity of tone.

Problems of reviewing mentioned in these texts concerned, for instance, the question of the reviewers’ anonymity, which was general practice until the late 18th century, and the disadvantages of disclosing the names of reviewers. (On the debate about reviewers’ anonymity see Pabst 2004.) Another problem was the question what to do with books of poor quality. Some editors decided not to mention such books at all, whereas others decided to either present only the bare bibliographical data or to confine themselves to short notices. This, of course, left open the question of how this preliminary evaluation should be done. A further problem concerned the desirability and usefulness of responses to reviews. On the one hand, we find the view that reviewer and author should stand on a par and that, therefore, the author of the book under review should be allowed to respond to the review and that this could lead to a fruitful debate ending only when all the arguments available had been exchanged (see Greiling 1799: 375). In fact, some journals were specially designated for “anticriticism” (“Antikritik”; see Habel 2007: 250 ff.; for the role of anticriticism in late 18th-century review journals see also Denissenko 2004). On the other hand, painful experience taught the practitioners of reviewing that such controversies easily degenerated into exchanges of accusations, causing emotional upheaval.

One of the most important developments in the practice of reviewing in the second half of the 18th century is the founding of specialist journals for different disciplines, e. g. chemistry or medicine, which contributed to the formation of disciplinary communities as we know them today (see Chapter 25, this volume). This process continues throughout the 19th and 20th centuries up to the present day with its many foundations of journals representing the continuing diversification of the sciences.

In closing this section I will mention two recent analyses of some developments in the history of reviewing and pinpoint some desiderata for future research in the field. Salager-Meyer et al. (2007) analyzed a corpus of 100 French-written book reviews, 50 published between 1890 and 1900 and 50 between 1990 and 2000. According to their results critical book reviews are more frequent in the earlier corpus than in the later one, although the difference is not very substantial. They also show that hedged critical reviews outnumber unhedged ones in the whole corpus and that unhedged critical reviews are more frequent in the earlier reviews than in the later ones. They assume that these results reflect a growing awareness of review authors “of the importance of the negotiation of social interactions that take place in the book review space”, a negotiation “that calls for a polite realization of critical remarks in order to find the

proper balance between collegiality and critique and to minimize personal threats, while simultaneously demonstrating an expert understanding of the issues dealt with in the book reviewed” (Salager-Meyer, Alcaraz Ariza, and Berbesí 2007: 1771). (For a similar analysis of forms of criticism in English review journals published in the periods 1890–1900, 1950 and 2000–2005 see Salager-Meyer 2010.)

Shaw (2009) studied the lexis and grammar of explicit evaluation in a rather small corpus of English academic book reviews published in the *Economic Journal* 1913 (11 reviews) and 1993 (12 reviews). He found that the 1993 *Economic Review* texts showed significantly more negative evaluations than the 1913 ones. As a possible explanation for this change he proposes the hypothesis that positive evaluation was more necessary in the small closed group of 1913, often reviewing each others’ books, than in the more open and competitive environment of 1993 (Shaw 2009: 227). These studies present useful pioneer work in the evolutionary history of reviewing. What is necessary for future research in the historical pragmatics of reviewing is the analysis of larger corpora and a widening of the analytical perspective to other elements of text structure and function and, of course, to earlier periods and other languages. As part of this future project it could be useful to have longitudinal studies on individual review journals similar to Atkinson’s fruitful investigation of the *Philosophical Transactions of the Royal Society of London 1675–1975* (Atkinson 1999), which, however, focuses exclusively on research articles, or studies on individual reviewers like Samuel Thomas Soemmerring who around 1800 contributed about 1300 reviews to important journals like the *Göttingische Anzeigen von gelehrten Sachen* (see Enke 1995).

## 8.2 Peer review and open peer review

A type of reviewing that is considered particularly important and at the same time highly problematic is peer review, the prepublication evaluation of scientific works, mainly scientific articles and books, by specialists working in the same field. Peer review of some kind is generally considered a necessary mechanism for quality control in science. Relevant aspects of quality include originality, correctness, importance, and clarity of exposition. (For the history of peer review, see Spier 2002, Biagioli 2003, and Csiszar 2016.) In the case of articles for scientific journals, the editor traditionally asks two or more qualified referees to evaluate anonymously an article submitted for publication and to give their opinion on whether the article should be published, rejected, or resubmitted after revisions. The editor then communicates to the author of the article his/her final decision and possibly suggestions for revision. This process has come in for harsh criticism at least since the 1980s. Useful sources for a survey of critical points are the two symposia organized by the journal *Behavior and Brain Sciences* in 1982 and 1991, which consist of a target article each (Peters and Ceci 1982; Cicchetti 1991) and a large number of comments by specialists from different fields (see also Shatz 2004). Basic criticisms concern the lack of transparency of the process, the danger of review-

ers' bias against innovation, the high rejection rates in some fields, and the amount of information lost due to the non-publication of the reviewers' comments.

These and other critical reflections have led to the suggestion and implementation of new forms of peer review subsumed under the name of *open peer review*. An interesting and successful form of open peer review is the “multi-stage open peer review” practiced by the journal *Atmospheric Chemistry and Physics* (since 2001) and other journals operated by the European Geosciences Union. For details of this concept of peer review, see Pöschl (2012). The basic idea of this review system consists in the differentiation of a first stage of the process, called the *discussion forum*, and a second stage, the publication stage proper:

In the first stage, manuscripts that pass a rapid pre-screening (access review) are immediately published as ‘discussion papers’ in the journal’s discussion forum (Atmospheric Chemistry and Physics Discussions, ACPD). They are then subject to interactive public discussion for a period of 8 weeks, during which the comments of designated referees, additional comments by other interested members of the scientific community, and the authors’ replies are published alongside the papers. While referees can choose to sign their comments or remain anonymous, comments by other scientists (registered readers) are automatically signed. In the second stage, manuscript revision and peer review are completed in the same way as in traditional journals (with further rounds of review and revision where required) and, if accepted, final papers are published in the main journal. To provide a lasting record of review and to secure the authors’ publication precedence, every discussion paper and interactive comment remains permanently archived and individually citable (Pöschl 2012: 2f.).

The main advantages of this system are an increase in transparency, the participation of the scientific community, and the preservation of the information produced in the course of the interactive reviewing process. (For a case study in this interactive process, see Fritz 2011.) In spite of these advantages and the successful career of *Atmospheric Chemistry and Physics* and its sister journals, doubts about the viability of open peer review still seem to remain, especially in the humanities. One of the basic problems of open peer review seems to be the question of how to motivate prospective reviewers to participate when having to sign their comments. Further research into the affordances and problems of open peer review is certainly required.

### 8.3 The future of reviewing

Innovations in the practice of reviewing that are comparable to the revolution in scientific communication that was brought about by the invention of scholarly journals have been made possible with the introduction of online reviewing on discussion forums and in online review journals and the development of forms of review that make use of the affordances presented by online formats. Book notices, reviews and brief review-like texts are sometimes also published on scholarly blogs (e. g. on *Language Log*). Although forms of online reviewing have been active for more than twenty

years and are past a first experimental stage, online reviewing is still a developing enterprise, which, in the future, will probably fundamentally change this sector of science communication (see Chapter 30, this volume). (An excellent survey of the use of the Internet as a scholarly review resource is given in Mey 2006. Later developments in the context of the introduction of *recensio.net* are discussed in Landes 2011.)

As examples of this new trend, I shall only mention a number of online review sites with different publication systems and affordances (all accessed 24 June 2018):

*Linguist List* (Linguistics, since 1990: <https://linguistlist.org/pubs/reviews/>)

*H-Net Reviews* (Humanities and Social Sciences, since 1994: <https://networks.h-net.org/reviews>)

*HSozKult* (Social Sciences, since 1996: <https://www.hsozkult.de/publication-review/page>)

*Living Reviews* (review articles covering Physics, Environmental and Political Science, since 1998: <https://www.springer.com/de/livingreviews>)

*Sehepunkte* (History, since 2001: <http://www.sehepunkte.de/>)

*Aestimatio: Critical Reviews in the History of Science* (since 2010: <http://www.ircps.org/aestimatio>)

*recensio.net* (a review platform for reviews in History, since 2011: <https://www.recensio.net/front-page>)

On these online review sites, we find various kinds of innovation of which I shall mention a few that show the potential of online reviewing. A first kind of innovation is the increase in publication speed. Whereas traditional paper journals usually take more than a year to publish the review of a new book, online reviews could, in principle, appear directly after the publication of the book under review, the moment the reviewer puts it online. In fact, however, there is often a peer-reviewing process for reviews, so that a review might take a month or several months to be published. But it does not have to wait for the printed volume to appear. In practice, online reviews are faster and, as most online review journals are published with open access, more easily accessible.

Early online reviews tended to be tradition-bound in the sense that they were simply “normal” reviews published in a digital format, so they did not use the wide potential of the new formats. One of the first changes, however, consisted in abandoning the strict limitations of length customary with print reviews. In principle, this move could improve the quality of reviews by making possible more detailed analysis of the books under review and a more detailed justification of evaluations. It did, however, sometimes also lead to a certain loquaciousness, which readers complained about. Using the genuine potential of digital formats has only recently been discussed and implemented. Such uses consist, among others, in reviewers giving links to related publications, to background information, and to extra data. Using links in this way is not only user-friendly by improving information management, but may also be a genuine contribution to the development of knowledge by expanding the horizon of

the relevant research. Whereas reviews printed on paper are generally restricted to the form they have when printed, online reviews could potentially be updated any time when the reviewer considers this necessary. This could be particularly useful in the case of review articles documenting the state of the art at a certain given moment. *Living Reviews* has implemented this idea, giving updates of review articles, e. g. in the field of relativity theory. A recent innovation of a different kind consisted in linking reviews to the bibliographical data given in library catalogues for the user to find extra information on the books he considers reading. A further innovation is the welcoming of responses to reviews, which reinforces the interactive function of reviews and gives the authors the opportunity to make clarifications and present additional ideas and data. In a way, this takes up a practice well-established in the 18th century, but implemented now with all the advantages of online publication. A final innovation to be mentioned here also strengthens the role of the author in the reviewing process. In *recensio.net* authors can present a brief summary of their own work, which can then be reviewed or commented upon (see <http://www.recensio.net/faq/autoren>; accessed 30 April 2018).

Ideally, these innovations will further enhance scholarly exchange and turn the practice of reviewing into an even more productive part of the total practice of research than we know it today. Taking part in this type of scholarly exchange might thereby also become more attractive and even better appreciated by the scientific community than reviewing is today.

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Gerd Fritz

## 15 Scientific controversies

**Abstract:** The present article presents a survey of the basic forms and functions of scientific controversies and of the state of the art in research on controversies. Starting from the assumption that controversies are indispensable for the formation, evolution and evaluation of scientific theories and their empirical examination, the article gives a brief overview of strands of research on controversies in different disciplines. It then goes on to provide a description of the basic pragmatic organization of scientific controversies, using an action-theoretic framework of pragmatics which is partly inspired by Wittgenstein's concept of language games. In this framework, controversies are viewed not as a confrontation of standpoints or propositions but as a dynamic linguistic exchange. The main parameters of the organization of such an exchange include dialogue types and text types, moves and strategies of individual contributions to controversies, topic organization and knowledge management, communication principles, media of controversy, and the language of controversy. In a concluding passage, the article mentions desiderata for future research on controversies.

**Keywords:** scientific controversies – controversies, pragmatic organization – controversies, pragmatic parameters – communication principles for controversies – media of controversy

### 1 Introduction

Attitudes towards scientific controversies are quite varied. The man (or woman) in the street often finds it disconcerting that “scientists are always disagreeing with each other” and feels that this undermines their authority and credibility. On the other hand, many philosophers of science are convinced that “controversies are indispensable for the formation, evolution and evaluation of (scientific) theories, because it is through them that the essential role of criticism in engendering, improving, and controlling the ‘well-formedness’ and the ‘empirical content’ of scientific theories is performed” (Dascal 1998a: 147). And scientists themselves sometimes enjoy debating their research and sometimes shun controversies, because they consider them a waste of time, fearing they might deflect energies from more important empirical work, and because they see the danger of bitter disputes hurting the reputation of the persons involved. From the point of view of the sociology of science this contrast, including the “phenomenon of the systematic avoidance of overt controversy”, was noted by Becher and Trowler (2001: 126–127). In the history of controversies, we find both scientists who, like Boyle, were notoriously unwilling to engage in controversy (see Shapin and Shaffer 1985: 165) and others, like Leibniz, who frequently participated in controver-

sies (see Leibniz 2006). These different attitudes all play a role in the practice and reception of scientific controversies. And we shall have occasion to come back to them in the course of this article.

As a general background to my following exposition of the form and functions of scientific controversies, I shall, however, assume that controversies can serve a fundamental purpose in science, a view which the history of science bears out, as many of the major scientific breakthroughs in history are connected to sometimes protracted controversies. (In this article, I shall use the word *science* and its derivations not in the narrower sense of *natural science* but in the wider sense, including the humanities and social sciences.) Well-known examples are Galileo's debate with contemporary Aristotelians (see Biagioli 1993, Finocchiaro 1989), controversies on astronomy in the early days of the Royal Society (see Shapin 1994), and the phlogiston controversy in the development of modern chemistry, which involved Lavoisier, Kirwan, Priestley and many other famous chemists of the late 18th century and which was used as an illustration of the structure of scientific revolutions in Kuhn's influential book. (Different strands of this controversy are analysed in Partington and McKie 1937–1939, Kuhn 2012 [1962], Barrotta 2000, Fritz 2018a.) On the other hand, there are certainly cases where the usefulness of a debate might remain doubtful, as in the case of the “failed encounter” of Derrida and Searle (see Navarro 2017). One aspect of controversies that is particularly worth noting is the fact that we frequently find *chains* of controversies, as in the case of 20th-century philosophical debates on the status of consciousness, where “it is impossible to grasp the significance of contentions made by philosophers from a later stage without considering how these contentions are related to puzzles and antinomies that preoccupied the champions of the earlier stages” (Senderowicz 2010: 221).

In addition to internal debates within scientific communities there are many controversies that concern the public interest and (therefore) spread to a wider public, mainly through public media like newspapers and, more recently, through social media in particular. Controversies of this type are frequently related to the context of policy-making, e. g. debates on nuclear power, stem cell research or environmental policies. An example of an analysis of controversies of this kind in the biomedical field is provided by Weingart et al. (2006). (For an introduction to politically relevant controversies in the biological sciences, see also Greif and Merz 2007.) Controversies also play a role as means for creating “public understanding of science” (see Weitze 2006, see art. 21). Furthermore, there are controversies that start from a scholarly context, move into the public sphere and move back again, motivating further research and controversy. A case in point is the German “Historians’ Debate” (“Historikerstreit”) in the years 1986 and 1987 (see Große Kracht 2005: 91–114).

Finally, I want to mention a type of controversy that has been detected, for instance, in the context of climate-change debates, namely so-called “created controversies”, in which interest groups, e. g. the lobby of the coal and oil industries, manufacture controversy where in fact there is overwhelming scientific consensus, in

order to create public confusion and to avoid policy decisions unfavourable to their business model. In his book on the topic, David Harker presents several examples of manufactured controversies, e. g. the controversy staged by the tobacco industry in the USA in the 1950s and 1960s with the aim of avoiding legislation restricting smoking and advertising for smoking (Harker 2015, see also Oreskes and Conway 2010).

## 2 The study of controversies in various disciplines

Scientific controversies have been studied mainly in three contexts, (i) the theory of science, the history of ideas, and the sociology of science, (ii) the self-reflection and history of individual scientific disciplines, and (iii) linguistic pragmatics. I shall begin by making a few remarks on these fields of study of controversies.

The view that criticism and controversy contribute to the progress of science is a view that goes back at least to the scientific revolution of the 17th and 18th centuries, as the following two quotes, from Kepler in the year 1601 and the German chemist Gren in 1790, clearly show. At the end of a treatise on astronomy and astrology, Kepler made a call for objections to his position in order to test his theories and to further scientific communication:

If professors of physics should consider these things worthy of consideration and should communicate to me their objections in order to find out the truth, I would, God willing, answer them in my prognostic for the following year. I admonish all serious philosophers to join in this competition, for it concerns the honour of the Creator God and the benefit of mankind (Kepler *Gesammelte Werke* 4: 35.24–25; transl. Moira Kerr).

This is not the only place in his writings where Kepler emphasizes the usefulness of criticism and his readiness to take part in controversy, as Gloning (2018) has shown in more detail.

Similarly, the German chemist Gren, in the course of a controversy on phlogiston, pronounced his scientific *credo* that criticism and controversy contribute to the discovery of truth:

It is only by means of doubt and objections that we discover truth; and only these will illuminate the way to it. It should, therefore, be everybody's duty who wants to rightly bear the name of scientist to use all the doubts and objections brought to bear against his claims to the advantage of truth and to gratefully accept them, if they provide an indication that he has not yet realized the truth or has moved away from it. Bearing in mind this duty, I shall not hesitate to concede *aliud putavi, deceptus sum* ['I believed otherwise, but I was wrong', GF], if I can see convincing reasons for the opposing stance (Gren 1790: 371–372; my transl.).

Certainly, this statement has an ideological ring to it, but its author at least followed his precept on a memorable occasion, when he publicly converted to the “new” chemistry he had fought for years. In addition to this evidence of a positive attitude towards

scientific controversies it is worth noting that Leibniz was an important representative of the idea that controversies play a foundational role in science, see Leibniz (2006).

In the first half of the 20th century the view that critical testing of hypotheses was essential for the progress of science was incorporated into Popper's falsificationist conception of the growth of knowledge: "Thus we may say that *the growth of knowledge proceeds from old problems to new problems, by means of conjectures and refutations*" (Popper 1972: 258; author's italics). This conception of "critical rationalism" was widely accepted, but also severely criticized, for instance by Thomas Kuhn (e. g. in Kuhn 1970) and Paul Feyerabend (Feyerabend 1978). What was lacking in this view of the logic of discovery, a shortcoming also to be found in Kuhn's and Feyerabend's analyses, was, however, a realistic appreciation of the natural *locus* of criticism, namely scientific controversy. This shortcoming was forcefully exposed by Marcelo Dascal, who claimed that "the rigorous study of controversies is an indispensable means for providing an adequate description of the history and praxis of science. For controversies are the natural 'dialogical context' where theories are elaborated and where their meaning progressively crystalizes" (Dascal 1998a: 148). Dascal not only made this programmatic statement but also gave examples of such an analysis, e. g. in a study on the controversy between the 19th-century economists Malthus and Ricardo (Dascal and Cremaschi 1999). Dascal's theory of controversy and his analyses inspired much of the work on controversies within linguistic pragmatics.

As for the study of controversies in the course of the self-reflection and history of individual scientific disciplines, this kind of research can be found in many disciplines, of which I shall give a small number of examples. Classics in the literature are the controversies in the fields of astronomy and chemistry I mentioned before. An early controversy in evolutionary biology, that between Darwin and George Mivart, was analysed by Anna Carolina Regner (Regner 2008). For examples of the study of controversies in the sociology of science, see Kemp (1977) and Gilbert and Mulkey (1984), who analysed controversies in biochemistry. "Case studies in the resolution and closure of disputes in science and technology" were edited by Engelhardt and Caplan (1987). In the field of history, recent volumes of collected papers (e. g. Lamont 1998, Große Kracht 2005) bear witness to the trend to reflect on problems and the history of one's own discipline by analysing controversies in the field. The same is true of literary history and theory (see Klausnitzer and Spoerhase 2007) and the historical study of scholarly controversies in various fields of the republic of letters (see Bremer and Spoerhase 2011; 2015). In the field of sociology, a recent volume of case studies aims to reconstruct the history of German sociology in the 20th century in terms of major controversies, among them the well-known "debate on positivism" ("Positivismusstreit"), in which Adorno and Popper famously engaged in 1961 (see Ritsert 2010).

Within linguistic pragmatics, the study of controversies is a fairly new area of research. Starting with early work in the 1980s (e. g. Dascal 1989, Schwitalla 1983), pragmatics of controversies has emerged as a field of study in its own right since the late 1990s (e. g. Bach 1997, Gloning 1999, Schwitalla 1999, Glüer 2000, Fritz 2003,

Dieckmann 2005, Fritz 2005, Gloning 2005, Fritz 2008, 2010). So far there has been particular emphasis on controversies in the 16th to 18th centuries (see Fritz, Gloning, and Glüer 2018). But there are also related historical studies on 19th-century controversies, e. g. the one on Darwin's polemics mentioned before (Regner 2008), and on medical controversies (Salager-Meyer and Zambrano 2001, Ratia 2011, Ratia and Suhr 2011). Recently, scientific controversies in new digital formats like weblogs, mailing lists and open peer review have been analysed with methods of linguistic pragmatics (see Herring 1996, Fritz 2011, Fritz and Gloning 2012, Bader 2018).

### 3 The pragmatic organization of scientific controversies

In describing basic structures of scientific controversies, I shall use an action-theoretic framework of pragmatics which is partly inspired by Wittgenstein's concept of language games (see Wittgenstein 1953) and a dynamic text-theory (see Fritz 2017). This theoretical framework provides a particular perspective on controversies. Whereas in much of the earlier research on controversies, especially in the history of philosophy and science, there is a tendency to view a controversy not so much as a dynamic linguistic exchange and a case of social interaction but as an opposition of standpoints on a certain issue, including arguments for these standpoints. So, what is involved is essentially a confrontation of propositions: "In studying the histories of many debates, we find that their authors have reduced them to their abstract intellectual contents with at most some reference to human actors involved but more often focused wholly on the cognitive structures" (Mendelsohn 1987: 99). From the vantage point of pragmatics we get a different picture, which diverges in several respects from the propositional view of controversies: Pragmatics focuses not primarily on a particular disagreement as such, but on the pragmatic organization of the exchange in the course of which proponents of the different views deal with this disagreement. This perspective includes not only the propositional structure of a disagreement, but takes account of the dynamics of linguistic interaction, its contexts, text types, types of moves, etc.

#### 3.1 Pragmatic parameters of scientific controversies

Scientific controversies form a highly complex family of forms of communication, which depend heavily on a background of disciplines, social organization of scientific communities, mutual knowledge, routines, traditions and norms in given disciplines, the use of media, and on other socio-historical factors. As language games in Wittgenstein's sense they are part of forms of life – e. g. of the life of scientists and schol-



ars – and, again like Wittgenstein's language games, they are also subject to historical change (see Wittgenstein 1953: § 23).

In studying scientific controversies as a form of communication it is useful to organize one's analysis by distinguishing different parameters of pragmatic organization, which interact and thereby create the complexity which is characteristic of the structure of controversies. In the approach to pragmatic analysis taken here, this system of parameters defines the basic structures of forms of communication. The following is a list of the most important parameters that have to be considered:

- (i) dialogue types and text types of controversy,
- (ii) stages of a public controversy,
- (iii) individual contributions to controversies and their internal organization (moves and strategies),
- (iv) topics, topic organization, and knowledge management,
- (v) communication principles,
- (vi) media of controversy,
- (vii) the language of controversy,
- (viii) the persons involved, their social background, background assumptions, preferences, aims etc.

In each of these parameters we find a wide range of variation, and in each parameter we find historical changes.

### 3.2 Types of scientific controversy

As a starting point to my description of the organization of controversies I shall take a typology created by Marcelo Dascal. He distinguishes three ideal types of polemical dialogue, namely discussion, dispute, and controversy (in a narrower sense). As I cannot improve on his description, I shall quote his introduction of these types verbatim (Dascal 1998a: 150; italics by the author):

*A discussion* is a polemic whose object is a well-circumscribed topic or problem. As the discussion develops, the contenders tend to acknowledge that the root of the problem is a *mistake* relating to some concept, result or procedure within a well-defined field. Discussions allow for *solutions*, which consist in *correcting* the mistake thanks to the application of procedures accepted in the field (e. g. proof, computation, repetition of experiments, etc.)

*A dispute* is a polemic that also seems to have as its object a well-defined divergence. But at no point do the contenders accept its definition as grounded in some mistake. Rather, it is rooted in differences of attitude, feelings, or preferences. A dispute can be terminated by some arbitrary procedure (calling the police, throwing dice), but it is not thereby "solved", but only (temporarily) *dissolved*. As a result, the underlying divergences tend to recur in disputes over other topics.

*A controversy* can begin with a specific problem, but it spreads quickly to other problems and reveals profound divergences. These involve both opposed attitudes and preferences and disagreements about the extant methods for problem solving. For this reason, the oppositions are

not perceived simply as a matter of mistakes nor are there accepted procedures for *deciding* them – which causes the continuation of controversies and sometimes their recurrence. However, controversies are not mere unsolvable conflicts of preferences. The contenders in a controversy pile up arguments they believe to increase the weight of their positions as against the adversaries' objections, thereby leading, if not deciding the matter in question, at least to tilting the "balance of reason" in their favour. Controversies are neither "solved" nor "dissolved"; they may be *resolved*. Such a resolution may consist in the acknowledgement (by the contenders or by their community of reference) that enough weight has been provisionally accumulated in favour of one of the positions, or in the emergence (thanks to the controversy) of modified positions acceptable by the contenders, or simply in the mutual clarification of the divergences at stake.

For each of these types a characteristic central type of move can be specified: For discussions it is a *proof*, for disputes a *stratagem*, and for controversies an *argument* (see Dascal 1998b: 25).

What is innovative in this top-down schema is the tripartite system as opposed to the traditional division into two basic types, the "good" discussion aiming at the joint attainment of truth and knowledge ("dialectic") and the "sophistical" or quarrelsome dispute ("eristic") aiming at winning the game by any means available. Thus, it is the introduction of the third type, namely "controversy" in Dascal's sense, that creates a more sophisticated approach to the typology of polemical dialogue. Generally speaking, Dascal's typology is an extremely useful object of comparison that helps the student of controversy to focus attention on important features of polemical dialogue. (For the purposes of this article, I shall, however, not use Dascal's terminology and use the word *controversy* to refer to all types of polemical exchange.)

There is one aspect of controversies that is underrepresented in Dascal's typology, namely the *dynamics of controversies*. (Of course, Dascal is aware of this aspect, as his description of the Searle–Derrida exchange shows; see Dascal 1998b: 23.) In some cases controversies move from a calm discussion to a heated dispute and end in a controversy in Dascal's sense, with the participants trying to clarify their positions and presuppositions. In such a case it would, of course, not be possible to assign the controversy under analysis to one of the ideal types. Sometimes we even find these different types present in *one* debate, e. g. in cases where different participants make different types of contributions at the same time, using proofs, stratagems, and arguments. Frequently, we also find a dynamic development of topics of controversy, which, again, may be connected to different types of moves, e. g. to types of proof. So, generally speaking, the dynamics of controversies is an important aspect of the structure of controversies not to be missed. An additional point worth noting is the fact that in some cases different participants may have different views of what is going on. Whereas participant A sees himself as participating in a discussion, participant B perceives the exchange as a dispute. This kind of diverging perspective may lead to a strange dynamic of the exchange.

As for the *empirical analysis* of given controversies, there is much to recommend a *bottom-up* methodology, starting from individual utterances, moves, sequences of

moves and strategies of the participants, analysing topics and topic-shifts, leading to the description of stages of controversy, and thereby, finally, to the determination of the type of dialogue. As a result of this kind of approach one tends to find that the controversies under analysis belong to a family of types with individually differing traits and family resemblances and, maybe, certain prototypes. It is not unlikely that as a result of an extensive study of different controversies Dascal's ideal types will turn out to be close relatives of empirical prototypes.

### 3.3 Stages of a public controversy

In many cases public controversies have a previous history of private discussion. Going public may then occur for various reasons and may be considered a notable and not particularly agreeable step. Knowing that entering a controversy may be risky, participants frequently explicitly mention such reasons, thereby trying to legitimize their actions. Well-known reasons for entering a public controversy include the felt necessity to defend one's scientific reputation or that of one's colleagues against unfair criticism or unjust accusations, the need to clarify misunderstandings, and the desire "to make the truth known".

As for the moves in *opening stages* of controversies in general, we find two basic types: In the first type the starting point is a text which is not necessarily intended as a polemical contribution, but which in some way affects the interests or the reputation of some other person or school of thought. In this case the actual controversy is initiated by the opponent who refers to this publication and tries to refute whatever seems to affect him. On the other hand, we have polemical writings which are expressly written to open up a controversy or to make public a controversy that is already in the making. In some cases the author of a text will avoid explicit criticism of a fellow scientist or scholar, knowing, however, that the position presented in his text runs counter to established views of a certain scientific group or community. This is true, in particular, of dissenters and heretics challenging the orthodoxy by presenting unconventional views.

Communicative tasks involved in the opening stage of a controversy include presenting the respective standpoints of the antagonists and their points of conflict (the "status controversiae" in disputation theory), establishing the central topics, and creating common ground by making explicit shared and divergent assumptions.

In *mid-play* of a controversy we find the full array of dialectic moves, of which I shall mention a few later on. Some interesting variants of the course of a controversy are the following: Initially, two persons start the debate, and later on others join in to make it a multi-party affair, thereby developing forms of team-work. After some rounds of controversy somebody tries to adjudicate in the conflict or to suggest a compromise. In the course of a longer controversy, somebody writes a history of the controversy so far, thereby siding with one or the other party.

A particularly interesting stage of a controversy is its *closing*, a stage that has attracted much attention in research on controversies (see Engelhardt and Caplan 1987). Frequently, closings of controversies are discussed in terms of their *outcome*. Typical outcomes include the correction of a mistake, the clarification of a misunderstanding, the solution of a problem, the persuasion and conversion of one of the parties, the reaching of consensus or a compromise, the clarification of the conflict involved, and the demarcation of the opposing positions. A possibly unintended consequence of a controversy may consist in its strengthening the ties within a group of controversialists and thereby contributing to the emergence of a new scientific community. Such an effect was claimed regarding the emergence of the community of scientific chemists in Germany in the course of the phlogiston controversy (see Hufbauer 1982: 1).

One of the remarkable results of the study of the concluding stages of controversies is that in many cases there is no resolution and closure of disputes at all. This is true of many controversies in the fields of philosophy, religion, and politics in particular. In some cases the opponents grow weary and lose interest, so that the controversy peters out and other topics of conflict take precedence. Illness and death of one of the opponents are other causes of a termination of controversy. And sometimes an end of the controversy is externally enforced as in the case of Galileo, who in 1633 was forced by the Inquisition to abjure his “errors and heresies” (see Finocchiaro 1989: 291).

### 3.4 Moves and strategies

Typical opening *moves* of the *proponent* in a polemical exchange are assertions, criticisms, and accusations. In making an assertion we “commit ourselves to the claim which any assertion necessarily involves. If this claim is challenged, we must be able to establish it [...] and show that it is justifiable” (Toulmin 1958: 97). Similarly, specific commitments are incurred with the other moves mentioned, for instance accusations. In cases where the proponent can assume that his assertion is controversial he will go ahead and face the challenge straight away by giving arguments for his claim. The point of such arguments is to produce support for the original assertion. In a written controversy, the exposition of a standpoint may involve complex constellations of moves, including descriptions of relevant situations, the history of the standpoint etc. Similarly, the presenting of arguments may involve a quite elaborate structure of backing moves, including statements of fact, giving information on the background of the original assertion, and making explicit relevant presuppositions.

Particularly interesting types of move are arguments and proofs. What counts as a (successful) argument or as proof may depend, among other things, on the discipline in which the controversy is conducted. In mathematics and closely related sciences deductive proof is the gold standard. In the empirical sciences various types of inductive procedures are accepted as supporting empirical claims. Theologians might

accept arguments taken from the Bible which philosophers would disdain. Generally speaking, arguments from authority are problematic and frequently disputed, as they may be either fallacious or valid, depending on the context of use. In controversies within the empirical sciences, a claim may be supported, for instance, by narrating an experiment, describing an instrument, or showing an illustration of the instrument, by referring to general experience in the field, to earlier research, and to the principles of research accepted in this community. In recent years visual argumentation and multimodal argumentation in general have been a topic of lively discussion (see for instance Groarke 2015). An interesting example of an analysis of the use of illustrations in the course of a controversy is Dove's study of a "visual archaeological debate about the proper place of *Australopithecus africanus*" in 1925 (Dove 2017).

After the move(s) made by the proponent the *opponent* will challenge the claims of his adversary by contradicting his assertions, making objections, casting doubt on the truth of the initial statement(s), attacking the commitments incurred by the proponent, showing the inconsistency of his commitments, and trying to dismantle his arguments. In scientific controversies, objections are probably the most frequent moves of the opponent. A useful move for the refutation of generalizing statements consists in mentioning and enumerating counter-examples. In the case of initial accusations, the opponent may answer by making counter-accusations, by attempting a justification, by questioning the validity of the norms presupposed in making the accusation, and by trying to prove that he was in fact not responsible for the incriminated act at all. (For the strategies of answering accusations in controversies, see Fritz 2005.) As for the forms of argumentation used in backing his claims, the opponent may use the same types of moves as those of the proponent mentioned before. All these moves, e. g. assertions, forms of criticism, and accusations, have a complex internal structure of commitments that can be made explicit and can be attacked in argumentation. Part of this structure consists in the fact that further acts can be performed *by* making an assertion or *by* criticizing a person. One can, for instance, disqualify an opponent *by* stating that he represents a scientific discipline that is apparently not relevant to the controversy at hand or *by* criticizing his earlier research.

In analysing controversies, we not only have to identify individual moves and sequences of moves like argumentations, but we also have to concentrate on *strategies*, i. e. constellations of moves that serve particular purposes in a controversy. To illustrate typical kinds of strategies we might encounter in controversies, I here insert a short list:

- (1) accumulating large numbers of objections or accusations,
- (2) frequently repeating the same (kind of) argument,
- (3) combining different types of argument, e. g. empirical arguments and arguments from authority,
- (4) making minor concessions as a preparation to introducing strong objections,
- (5) exposing presuppositions harmful to the opponent's argumentation at a critical point,

- (6) starting with relatively weak arguments and continuing with increasingly strong ones,
- (7) shifting the burden of proof,
- (8) anticipating objections an opponent might make and answering them preemptively,
- (9) interrupting the course of argumentation with (frequent) points of order,
- (10) shifting from discussion to dispute and back,
- (11) shifting the topic from central to (supposedly) marginal issues,
- (12) introducing digressions.

When analysing controversies, we find that different persons and different scientific communities show different preferences concerning the use of moves and strategies. This aspect of controversies is definitely a desideratum for further research.

### 3.5 Topics, topic organization, and knowledge management

As for the topics of scientific controversies, these can be quite diverse and, in many cases, interlinked in various ways, forming a network of topics and often leading to shifts between subtopics within a controversy. A non-exhaustive list of characteristic types of topics of controversies could be given as follows:

- (1) the theory/theories on which the research is based,
- (2) the results of the research at hand and their interpretation,
- (3) the methods/data/instruments used for research,
- (4) questions concerning the morals/principles of research,
- (5) questions concerning the application of the research and its consequences,
- (6) questions concerning the presentation of the research,
- (7) problems of priority,
- (8) the scientist/scholar as a person, his competence or reliability,
- (9) the form and usefulness of scientific controversies in the respective field.

In the following I shall give a number of examples of these types of topics.

In many cases, a controversy about a particular piece of research is connected to general differences in *theoretical outlook* and therefore focuses on theoretical divergences. Examples of this kind of controversy abound in the history of science, especially in those cases where the controversy is part or indicator of a paradigm change or a “turn” in a given discipline, e. g. in the case of Lavoisier’s “new” chemistry, or in cases of criticism of “traditional” philosophy in the course of the “linguistic turn” (see Rorty 1967). A more recent example, well-known to linguists, is the debate between representatives of generative semantics and interpretive semantics that took place in the USA during the late 1960s and 1970s (see Harris 1993).

*Data* and *results* of experiments or analyses frequently allow different interpre-

tations, depending on the preferred theory of scientists discussing these results. It might even be debatable what the results are. In such a situation the results and their interpretation may become the topic of (part of) the controversy.

Theoretical outlook is frequently closely related to *methods of research*, which can also be the topic of controversy. An early modern example are debates on the use of the telescope in astronomical observations in the 17th century (see Gal and Chen-Morris 2011). As a present-day example one could adduce controversies between corpus linguists and generative grammarians. An instance of this kind of controversy is analysed in Fritz and Gloning (2012). Questions of research methods can, again, be closely related to *moral questions*, as in the case of stem cell research. In such cases, there is a tendency for the topic of debate to shift from methods to morals. *Research ethics* in a narrower sense may become the topic of controversy in cases where a participant voices doubt as to the truthfulness of his opponent's reports on his experiments. As a means to forestall this doubt, early modern experimenters developed the practice of relying on the testimony of competent eye-witnesses. This practice itself could then become the topic of debate. (See Shapin and Shaffer 1985: 55–60 on Boyle's practice of performing experiments in the presence of witnesses in the 1660s; for the reference to expert and socially high-ranking witnesses in a chemical controversy of the 1790s, see Fritz 2018a.)

In controversies concerning scientific research with practical, in particular technological *applications*, topic shifts from the results of such research to the advantages or disadvantages of its application and to moral aspects of its application are frequent.

Another well-known topic of controversy are matters of *priority of discovery*. Due to the fact that frequently different scientists worked on the same or similar problems, important discoveries were sometimes made at (more or less) the same time by different persons, the discovery of oxygen by Priestley and Lavoisier being a well-known example, which was discussed by Kuhn (2012 [1962]: 52–55). In some cases this leads to actual *priority disputes*, e. g. the priority debate over the discovery of calculus between Leibniz and Newton, which included “charges of intellectual theft and personal dishonesty” (Hall 1980: 4).

As to the *presentation* of theoretical views, lack of comprehensibility and perspicuity can become a topic of controversy, as in the case of Kant's *Critique of Pure Reason*, which was frequently criticized for being incomprehensible by his opponents. Lack of comprehensibility is, of course, a standard topic in debates between experts and laypersons.

Focusing a controversy or parts of a controversy on the *persons* involved has generally been deprecated, at least in theory, as an *ad hominem* fallacy (see Hamblin 1970: 41–42). In practice, however, moves insulting one's opponent by casting doubt on his intellectual qualification or his truthfulness in reporting experiments are quite frequent in controversies. Whether such a move, e. g. doubting the opponent's qualification, is in fact a fallacy, will depend on the context of the move. If an expert in a given field, e. g. a climate scientist, is attacked for his views in this field by a non-expert, it

is possible that criticizing the attacker's lack of qualification is a perfectly relevant move.

Finally, the form and usefulness of scientific controversies in the respective field may itself become the topic of (part of) a controversy. On the one hand, we find authors who doubt the usefulness of controversies in general or even consider them harmful, e. g. Bacon, who was critical of disputations in the scholastic mode. In fact, Bacon held “that disputations and controversy only can occur when there is no proper method” (Machamer 2000: 95). Throughout the history of controversies there has been a continuous stream of criticism of (some forms and aspects of) the practice of controversy, especially in disciplines where controversies were frequent, for instance in the field of theology and religion. Recently, for instance, Deborah Tannen discussed pervading “agonism in academic discourse” in the USA and argued “for a broadening of our modes of inquiry, so that agonism is, one might say, demoted from its place of ascendancy and for a re-keying or ‘toning down’ of the more extreme incarnations of agonism in academic discourse” (Tannen 2002: 1652). On the other hand, some of the quotations I gave earlier in this chapter show reflections on controversies that assume their usefulness. One context in which we find the critique of certain forms of controversy is the discussion of communicative principles or maxims, which I shall deal with in the following paragraph.

Apart from choosing an agenda of topics for a controversy, participants have to *organize* the relevant topics, which can present considerable problems for the protagonists. In many cases, the participant opening up the controversy will introduce a topic structure that imposes certain restrictions on his opponent. If the opponent does not want to be seen to evade points of this structure, he will have to follow the lead, at least to a certain extent. In controversies of the 16th to 18th centuries we find a fairly strict principle of point-by-point response being followed by the disputants. Not following this procedure was considered a weakness and a sign of defeat. In order to avoid some of the restrictions of this procedure, participants sometimes introduced digressions and additions to the parts of the text which followed the point-by-point procedure.

*Topic management* not only concerns the organization of topics in the flow of text, but also includes helping readers to keep track of the proceedings, which is a particularly important task for writers of longer polemical texts. For this purpose they often introduce detailed tables of contents and include summaries of the subject matter, indices of topics, systems of numbered paragraphs, and marginalia.

### 3.6 Communication principles

The history of controversies is full of complaints about dialectical malpractice. Controversialists tend to annoy their opponents by evading their arguments, by writing incomprehensibly, by intentionally misunderstanding them, by insulting them, and by committing all kinds of fallacies. These complaints or accusations indicate a back-



ground of principles or maxims which seem to be accepted in a given scientific community, even if they are frequently violated. Such principles form an important part of what one could call the normative element of an implicit theory of controversy that people apply in their practice. The classic statement of communication principles is Grice (1989: 26–31). For a detailed analysis of the status and types of communication principles and their forms of application, see Fritz (2017: ch. 5). A normative approach to argumentation is presented in the “rules for critical discussion” formulated by van Eemeren and his associates (Eemeren, Grootendorst, and Snoek Henkemans 2002: 182–186).

Most of the time speakers and writers follow communication principles as a matter of routine without having to formulate them explicitly. Sometimes, however, occasion arises to make such principles explicit, e. g. in the context of complaints or “points of order” (see Hamblin 1970: 303). Principles can be formulated as follows:

- (1) One should not say what one believes to be false.
- (2) Contributions should be relevant.
- (3) Do not skip from one issue to the other.

To give an idea of the kinds of principles involved, I draw up the following short list of principles that seem to be particularly relevant to controversies:

- (1) Claims should be given adequate backing.
- (2) The critic carries the burden of proof (*onus probandi*).
- (3) One should address all the opponent’s objections.
- (4) One should avoid irrelevant remarks/topics (*principle of relevance*).
- (5) One should avoid unnecessary repetition of arguments.
- (6) One should be brief (*the principle of brevity*).
- (7) One should write clearly and comprehensibly (*the principle of perspicuity*).
- (8) Contributions should be textually well-organized.
- (9) One should avoid formal fallacies (e. g. a *non sequitur*).
- (10) One should avoid ambiguity.
- (11) One should be reasonable in argumentation.
- (12) One should avoid personal attacks (*ad hominem*).
- (13) One should give a reasonable interpretation to the utterances of one’s opponent (*principle of charity*).
- (14) One should not set up a straw man.
- (15) One should not make fun of the opponent and take his arguments seriously (*principle of seriousness*).
- (16) One should not use rhetorical devices like irony or sarcasm.
- (17) One should be polite towards the opponent (*politeness principles*).

These principles could be grouped into different categories, including logical principles (e. g. principles banning formal fallacies), dialectical principles (e. g. backing of claims, burden of proof, *ad hominem*), rhetorical principles (e. g. non-repetition,

brevity, perspicuity), and politeness principles (e.g. seriousness, no sarcasm, polite address, etc.). One problem with such principles is that their meaning may be subject to interpretation: What counts as reasonable or polite, for instance, may not be beyond doubt. The importance of individual principles and their forms of application may be a matter of dispute, and scientific communities differ as to which principles they consider particularly relevant. Finally, communication principles and their forms of application are historically variable. (For a historical study of communication principles in early modern controversies, see Fritz 2008. For communication principles in 18th- to 20th-century controversies in Germany, see Dieckmann 2005.) The historical variability of communication principles is particularly obvious in the case of politeness principles. The following quotation emphasizes principles of clarity as part of a communicative ethics for philosophical discourse (Popper 1972: 44):

But the search for truth is only possible if we speak clearly and simply and avoid unnecessary technicalities and complications. In my view, aiming at simplicity and lucidity is a moral duty of all intellectuals: lack of clarity is a sin, and pretentiousness is a crime. (Brevity is also important, but it is of lesser urgency, and is sometimes incompatible with clarity.)

A deterring example of the violation of these principles, according to Popper, is “Hegel’s bombastic and mystifying cant” (Popper 1945: 26). Similarly, Searle claims of Derrida’s prose style that “the text is written so obscurely that you can’t figure out exactly what the thesis is” (Searle 1983). In other contexts, showing brilliance and cleverness may be valued higher than comprehensibility, and, of course, comprehensibility is a matter of degree.

### 3.7 Media of controversy

Contributions to public controversies can take different forms. We find polemical utterances in oral debates (e.g. at conferences), written polemical dialogues, personal letters, open letters, polemical tracts, pamphlets, whole books, articles in journals, reviews, polemical prefaces and footnotes in books, polemical sermons, polemical poems, combinations of text and pictures, and, in recent times, in blogposts, contributions in Twitter and Facebook, postings in mailing lists and comments in open peer review. The total array of such text types, genres, and media available at a given time changes in the course of history.

Personal letters are probably the medium with the strongest tradition in the history of controversy. In many cases personal letters were made public, with consent of the writers or without, and sometimes personal letters were explicitly meant for (later) publication, as in “letters to the publisher” of the *Philosophical Transactions* or in the case of the letters of the Leibniz–Clarke controversy (1715–1716) on matters of science, philosophy, and theology (see Vailati 1997). In some cases, a public controversy went

parallel to a private correspondence, and sometimes the public controversy was continued in private correspondence, as in the case of the Leibniz–Papin controversy on gravity and motive forces in the 1690s (see Rey 2010). Examples of scientific controversies conducted by means of correspondence include a number of 17th- and 18th-century debates (with the participation of Boyle, Leibniz, and others) as well as the “great Devonian controversy” on geology in the 1830s (see Rudwick 1985).

The availability of the printing press fundamentally changed the practice of controversy. Whereas private discussions and even semi-public disputations generally reached only a limited public, the printed form of such disputations and pamphlets had the potential to reach a wide audience. In fact, controversies of this period, especially the Reformation period, contributed to the formation of a reading public and to the emergence of forms of public opinion (in particular a public with a special interest in controversies emerged in the late 17th and the 18th centuries, see Goldenbaum 2004).

From the 16th century onward, up to the late 18th century, pamphlets were the most conspicuous medium of controversy. In this period, controversies frequently consisted of longish exchanges of pamphlets. Pamphlets of this period show a characteristic text structure. They normally comprise a title page, a dedication, a preface, the body of the text organized into “points”, and a final section containing a summary, a conclusion, or a pious wish (see Gloning 1999: 88). The titles of pamphlets are often quite complex and indicate the function, the topic, the opponent, and the status in the sequence of pamphlets (e.g. *answer* or *reply*). The organization of the body of the text into points follows the tradition of disputations and legal texts of this period and is intended to provide a well-organized treatment of topics and arguments. As I mentioned before, once a certain number of points are introduced by one participant, the author of the following pamphlet is obliged to thoroughly refute each point individually in the given order, starting with the quotation of the opponent’s point and going on to refute this point. This point-by-point structure is characteristic of early modern pamphlets and explains why these texts get longer and longer as the controversy progresses.

Generally speaking, the point-by-point procedure in its strict form was practised much less from the middle of the 18th century onwards. There are, however, exceptions, even in the 20th century. An interesting instance is Derrida’s answer to Searle’s *Reply* to his (i.e. Derrida’s) criticism of Austin, written in 1977, concerning which Derrida stated some years later: “[...] I try to submit myself to the most demanding norms of classical philosophical discussion. I try in fact to respond point by point, in the most honest and rational way possible, to Searle’s arguments, the text of which is cited almost in its entirety” (Derrida 1988: 114).

The next major step in the development of media of controversy is the invention of the scientific journal in the late 17th century, the *Philosophical Transactions of the Royal Society of London* and the *Journal des Sçavans* appearing from 1665 onwards, the *Acta Eruditorum* from 1682 (see Habel 2007: 46–53). In these journals we find basically

two types of controversy. In the first type, an author produces an article or a letter containing certain scientific claims, and an opponent makes objections to these claims or tries to refute them, whereupon the proponent tries to defend his claims and to parry the opponent's objections, and so on. In the second type, a reviewer criticizes a scientific publication, and the author tries to defend his book, whereupon the reviewer in turn defends his review, and so on. One interesting aspect of controversies of these types is that texts produced in journals are generally much shorter than traditional pamphlets, one of the reasons for this being that obviously the point-by-point principle with its demand of *complete* refutation was relaxed in the new medium. An interesting complication of this media environment is that sometimes reviews in journals were answered by longish pamphlets, as, for instance, in the case of the theologian Johann Salomo Semler, who responded to two of the reviews of his treatise on the biblical canon (1771) in this way (see Fritz and Glüer 2018). With the shift of the natural sciences "from book to article science" (Bazerman 1988: 81) at the beginning of the 20th century the importance of science journals as a medium of controversy further increased.

Recent developments in digital media have presented new opportunities for controversy. Relevant media include mailing lists, weblogs, digital review journals, and open peer review journals. Recently, Twitter has also become a medium of serious scientific controversy. Major properties of such media are speed of publication, breadth of diffusion, and open access. These media facilitate speedy communication and the participation of groups of scientists and scholars that might otherwise be excluded from this communication by gatekeeping agencies, and they create the opportunity for explicit dialogue where traditional media do so much less, for instance in the case of reviewing and peer review (see Chapters 14 and 30, this volume). But these positive properties also have their downsides. For instance, speed of reaction in a controversy can easily prevent calm deliberation and impede the production of well-balanced responses. And fast diffusion of face-threatening acts may be harmful to reputations on both sides of a controversy. So far, there has been a remarkable difference in the use of these digital (social) media in different scientific communities. Open peer review, for example, has so far been mainly accepted in the natural sciences, whereas the humanities tend to be more reluctant to avail themselves of these opportunities. But developments in these fields are quite dynamic and difficult to prognose. So far, there have been several studies of controversies in these media, but much more research is definitely needed to provide a balanced view of the forms of controversy being practised in the new digital media. (For studies of scientific controversies in digital media, see Fritz 2011; Fritz and Glöning 2012; Bader 2018.)

### 3.8 The language of controversy

A person taking part in a controversy in a given language has to know not only useful moves and strategies, but also the linguistic means to perform these moves. The language of controversy includes on the one hand the special vocabulary of the respective domains, e. g. the vocabulary of astronomy, chemistry, or medicine, but on the other hand also the general everyday language of scientific controversy used in the respective domain.

This general language of controversy includes expressions like *to claim*, *to object*, *to presuppose*, *to justify*, *irrelevant*, *inconsistent*, *a standpoint*, *a hypothesis*, *a fallacy*, *ad hominem*, phrases like *to put forward an argument* or *to point out that*, expressions for particular moves like introducing a possible state of affairs for discussion (*let us assume*) or introducing an example (*a case in point is*), intensifying a statement (*and what is more*) or mitigating a face-threatening move by hedging (*this seems doubtful to me* instead of *this is simply wrong*) etc. In order to see that this is no trivial point, we must only imagine what it would be like for us to conduct an argument in Latin, as scientists regularly did in the 16th to 18th centuries, or to debate with English scientists of the 17th century, who used expressions like *impertinent* ‘irrelevant’, *exception* ‘objection’, *inconvenience* ‘unwelcome consequence’, *the state of the question* ‘the main topic’, *reducing an argument into form* ‘putting an argument in the form of a syllogism’, etc. (For a study of the German language of controversy around 1600, see Fritz (2016). Gloning (2018) presents observations on the “lexical profile” of the astrology/cosmology debate in which Kepler was involved.)

In many cases, certain expressions played a central role in a controversy, e. g. *environment* in the still ongoing environment debate, *phlogistonist* “an advocate of the phlogiston theory” or *pietist* “a follower of the movement opposed to Protestant orthodoxy in the controversy on Pietism around 1700” (see Gierl 1997). An interesting example of such a word is the term *Devonian* in the geological controversy of the same name (Rudwick 1985: 401):

The controversy is epitomized in the change of meaning and usage of its central term. When it began, the word “Devonian” was applied by geologists, in simple extension of its everyday usage, to any rocks or fossils found in Devonshire. By the time the controversy subsided, the same word was used internationally in a new and strictly technical sense: to denote any rocks or fossils that had originated during a specific period in the history of the earth.

### 3.9 The persons involved in controversies

Finally, I shall add a few remarks on the persons involved in controversies. As players in this type of language game they have their aims, their tasks, their resources, their weaknesses, and, frequently, their personal styles. Typical personal aims and tasks

consist in creating and protecting one's personal reputation and defending one's honour. The resources a controversialist brings to the game include his scientific competence, his knowledge of the field of debate and his experience of debating, his verbal dexterity, his natural aggressivity or reticence, his personal style, and his entrenchment within an "academic tribe". (For the study of scientific communities as "academic tribes", see Becher and Trowler 2001.) These personal factors play an important role for the way in which a participant will act in a controversy.

As I mentioned at the beginning of this chapter, some persons are reluctant to join in controversies in general or to participate in one particular controversy, whereas others seem to be attracted to debating their ideas and those of their opponents. There are also stereotypes for certain groups of persons in this respect, e.g. the stereotype of the "quarrelsome scholar". An example of a person who did not want to be drawn into one particular controversy is John Locke, who refused to discuss his *Essay concerning human understanding* with Leibniz, who was quite keen on doing so and staged a "virtual controversy" with Locke in his *New essays on human understanding* (see Fritz 2018b). The influence of the respective disciplinary background of the opponents on the course of a controversy is obvious, for instance, in the case of the philosopher Hobbes and the theologian John Bramhall in their controversy on free will in the 1650s. This clash of disciplines not only determined the topics of the debate and their dynamics but also the language used by the contenders, i. e. (mostly) ordinary English vs. scholastic terminology, the kinds of accusations they made to one another, e.g. Bramhall's accusation of heresy, and the kinds of arguments they preferred. On the other hand, they were both accomplished dialecticians and rhetoricians, which we can see by many sophisticated moves they make (see Fritz 2018c). Similarly, in the controversy between Searle, a representative of analytic philosophy, and Derrida, a postmodernist with a background of "continental philosophy", the antagonists brought to the confrontation different methods of doing philosophy and different styles of controversy. Concerning the personal style of individual players, we find many relevant remarks in controversies and in the literature on controversies, for instance the following complaint of the German author Gotthold Ephraim Lessing: "Lessing, for example, in his controversy with Goeze [a protestant theologian, GF] complains about Goeze's *immoral style of discussion* ('unmoralische Art zu disputieren')" (Glöning 2005: 272). Goeze, for his part, complained about Lessing's habit of using metaphors, parables, and satirical language in the debate. To give another example of personal style, Leibniz attempted "conciliatory approaches in scientific controversies", by means of which he tried to reconcile conflicts of different philosophical traditions (see Dascal and Firt 2010). Thus, by analysing in detail the moves preferred by individual polemicists, one can frequently discern typical "player personalities".

## 4 Conclusion

In presenting a survey of the main pragmatic parameters of scientific controversy I have tried to give an overview of the aspects involved in the study of an important form of communicative knowledge-making, giving at the same time an idea of the state of the art in controversy studies, especially in linguistic pragmatics. As for future developments of research in controversies, it will be necessary to further widen the horizon of types of controversies in various fields and to concentrate on systematic and comparative studies of preferences for certain moves and strategies in different cultures and in different disciplines, including the use of media, the communication principles, and the styles and criteria of quality for controversies accepted in different academic tribes. At the same time it will be useful to analyse different forms of topic management and knowledge management involved in controversies in different disciplines. By a process of charting the field it will, in the long run, be possible to provide a survey of families of forms of controversy and their embedding and use in socio-historical environments.

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Thomas Gloning

# 16 Symbolic notation in scientific communication: a panorama

**Abstract:** In different branches of scientific communication forms of symbolic notation play an important role, e. g. in mathematics, symbolic logic, chemistry, physics, linguistics, astronomy, etc. as well as in some of their historical predecessors like alchemy. This chapter provides an overview of some of the major forms, communicative practices and epistemic functions of systems of symbolic notation, their elements and their uses. The chapter also provides an outlook on aspects of the intertwining of elements of symbolic notation with natural language texts, forms of visualization and diagrammatic devices. In addition, it is shown how the idea of symbolic notation relates to other notions like scientific rigor, formalization, computability and the idea of an ideal language. Further perspectives include desiderata like the use of scientific symbolism in popular science contributions.

**Keywords:** symbolic notation – scientific communication – communication in scientific disciplines – history of science – epistemology and communication – symbolic notation and science communication

## 1 Introduction

In a wide range of scientific disciplines different forms of symbolic notation play and have played a key role for the way intellectual work is done and how results are achieved. I use “scientific” here in a very broad sense, including the natural sciences like physics and chemistry, the humanities, life sciences, technology, formal disciplines like mathematics and logic, the sciences of music and of dance, etc. In addition, I include several historical predecessors of these disciplines and even historical disciplines which do not have a modern scientific equivalent like alchemy.

Systems of symbolic notation include the structure formulae for chemical compounds and reactions, the formal notation systems of different logical calculi, the notation systems in a wide range of branches of mathematics, tree representations and structure formulae in modern syntax theory, linguistic morphology or in formal semantics, but also the notational systems of music, dance, choreography and the sciences that deal with these subjects to name but a few. Apart from their theoretical and epistemic role, symbolic notation and formalization are also important prerequisites for many applications, e. g. in statistics and most notably in many branches of computation and applied fields of technology.

Systems of symbolic notation do not come out of the blue. They were developed for specific purposes in the light of different problems and tasks in the history of dif-

ferent disciplines. Hence, each system of symbolic notation has both a history of its own but also in respect of the history of the disciplinary “field” and of concurrent symbolic notations which are or were alternative solutions for similar scientific problems and tasks.

Even though different present and past systems seem to be specific and heterogeneous, it is worthwhile to look for family resemblances in respect of their communicative and epistemic functions, their construction principles and the pathways of their historical evolution.

The structure of this chapter is as follows: In the next section, I will first introduce the concept of symbolic notation and some of its key topics (section 2). I will then give examples of systems of symbolic notation in different branches of scientific communication and their history (section 3). With these examples I shall introduce and illustrate a certain variety of basic aspects of function, construction and evolution of discipline-specific systems of notation. The subsequent section will deal with the intertwining of symbolic notation with natural language and other modes of communication, e.g. visual display (section 4). In the next section I will discuss how symbolic notation is related to concepts like “rigor”, “formalization” and “computation” (section 5). I conclude with a number of “Further perspectives” (section 6).

## 2 The concept of symbolic notation and its near relatives

Looking from a bird eye’s view on scholarly communication it becomes apparent that forms of symbolic notation other than natural language are used for different purposes in many branches of science and the humanities. Mathematics, chemistry, physics, logic, linguistics, astronomy, cosmology, many fields of technology, medicine and biology rely heavily on a broad range of forms of symbolic notation. To give an example, in a specific field of the humanities, editorial philology, one finds a broad range of symbols used in a systematic and coherent way in order to present a historical text, to document its history and to justify the editorial decisions. It is obvious that such a system is in many respects different to, say, a specific logical calculus, but it may be fruitful to look for differences and common properties.

Starting from the diagnosis of an incredibly wide and historically deep spectrum of forms of symbolic notation, we can nevertheless try to gain overarching principles or certain family resemblances both in respect of structure and in function of systems of symbolic notation.

## 2.1 What is symbolic notation?

In a famous chapter entitled “The theory of notation” of his *Languages of Art*, Nelson Goodman (1969: ch. IV) distinguished “between languages and nonlinguistic symbol systems” (1969: 130) and asked for the differences. Among the basic concepts for a theory of notation are “character”, more specifically “character in a notation” (a type, a class, e. g. “+” in mathematics), “mark” and “inscription” (instances of a class, e. g. the various hand-written “+”-signs in manuscripts of mathematicians, which all are instances of the one “+”-character). Furthermore, he introduces the idea of atomic and compound characters, rules of combination of characters (e. g. concatenation), the correlation of a symbol scheme with a “field of reference” and the notion of “compliant” (something that fulfills the criteria related to a character). He also discusses core requirements of symbolic schemes like unambiguousness, redundancy and others.

Inspired by Goodman’s exposition we can propose a number of core aspects of systems of symbolic notation in scholarly communication:

(1) The basic units of systems of symbolic notation are “characters”, symbolic devices that are either introduced and motivated newly in scientific texts in specific ways or that are already established. Examples of such established symbolic devices are “ $\sqrt{\phantom{x}}$ ” for the square root or “ $\pi$ ” for the number pi in mathematics, “O” for oxygen in chemistry, “p” as a variable for propositions in logic, “r” in the International Phonetic Alphabet for a specific range of sounds within the spectrum of r-sounds, the use of “>” for historical developments in the history of words and so forth.

(2) Symbolic notation in different fields of scholarly communication is organized in more or less complex and coherent systems of symbolic notation. “O” in chemistry is part of a system that includes “H” and “NA” etc. as well. The basic symbolic devices of the periodic table together with combinatory rules allow for the structural description of an immense number of organic and inorganic substances. In a similar way, the symbolic devices of mathematical operations in different branches of mathematics (see Mazur 2014), the symbols that represent sounds and sound classes in phonetics and phonology, etc. make up more or less complex systems that are organized in a coherent way.

(3) The combinatorial rules that govern the use of basic symbolic devices in order to build more complex symbolic expressions are also part of the systems of symbolic notation. Combinatorial rules are equally subject to introduction and communicative specification and the distinction between established and newly suggested ones.

(4) Systems of symbolic notation are designed with specific aims in view. Apart from coherence there are several other design principles like economy, precision, freedom from ambiguity or elegance. Design principles can be used as the basis of discussion, dispute and suggestions for improvement of systems of symbolic notation. For example, Kneale and Kneale (1964: ch. IX.1) show in a section on “Varieties of Symbolism” of their *Development of Logic* that Frege’s apparatus was on the one

hand “extremely ingenious” but that his script was “admittedly cumbersome” (Kneale and Kneale 1964: 513). Authors like Peano, Russell, Hilbert and Łukasiewicz suggested alternative systems that superseded Frege’s formalism.

(5) The use of symbolic devices in systems of symbolic notation fulfills specific communicative and epistemic functions. One of these functions is classification. To classify “objects”, to constitute classes and to justify a certain way of classification is both a familiar communicative practice and an important epistemic element of scholarly communication. For example, establishing and justifying a sound system for a language and to craft and discuss a suitable system of symbolic notation go hand in hand (Raffelsiefen 2018). The use of symbolic devices for specific functions is subject to historical development. To give an example from the history of logic: “Although the use of letters to express universality without the help of quantifiers appears in Frege’s account of his script as a device of abbreviation, it is historically the earliest use of variables in logics and mathematics [...]” (Kneale and Kneale 1964: 519).

(6) Systems of symbolic notation are intimately related to discipline-specific goals and functions. Contributing to the calculus of temporal logic is one thing, contributing to the phonology of one of the many varieties of English in the world is another. Hence, describing a symbolic system, its structure and use also means to characterize how it relates to specific communicative and epistemic tasks in a specific discipline.

In the next section I will turn to several near relatives of symbolic notation: Formalization and algorithmic representation, the idea of symbolic machines and computation.

## 2.2 Formalization and algorithmic representation, symbolic machines, computation

Many symbolic devices are “meaningful”. Their use is bound to something that users must conventionally mean if they use the device in question in a certain environment. For example, to use the device “NP” in a linguistic environment, to use “H” in chemistry texts or to use “ $\pi$ ” in a mathematical paper commits the writer to a specific “meaning” which is due to the traditions in the respective fields.

The use of symbolic devices without reference to aspects of “meaning” is the core aspect of formalization. According to Krämer (1988), the idea of formalization has a long history in mathematics that goes back to antiquity in different cultures. It was during the 17th century, especially in the work of Leibniz, that formal methods were used to construct logical systems of scientific expression (Krämer 1988: 135–137; see also Krämer 1991). The basic operation is transformation of expressions into other expressions according to specified rules. For example, from the expressions “ $a=b$ ” and “ $b=c$ ” one gets “ $a=c$ ” on a purely formal basis.

If the application of the transformation rules and their sequencing is specified equally in a formal way, one has an algorithmic representation which is the basis of a

“symbolic machine” (Krämer 1988: 2–3) and can be used for the construction of a real machine or a computer program (Krämer 1988: 159–175; see Turing 1950).

Older and newer systems of computational programming like Algol, Snobol, dBase, Java, Python, Perl, JSON, C++, etc. are all based on algorithmic representation. Symbolic code written in one of these languages serves, among other things, to analyze scientific data, to present data to the public (e.g. the data of the German woerterbuchnetz.de), to produce data visualizations, to provide interactive access to scientific databases, to perform statistical analyses. Symbolic notation is also at the heart of computation in technology research, physics and many other disciplines. But computation has not only practical and “ancillary” functions. For example, in many branches of logic, computation and computability are important instruments and concepts of theoretical progress (Schwichtenberg 2012; Siekmann 2014). In addition, computational simulation is not only an instrument to solve practical problems but also an important epistemic means to model relevant aspects of a subject field in a theoretical and rigorous way.

### 2.3 Why use forms of symbolic notation?

In order to motivate the use of symbolic notation, far-reaching goals and principles of quality control have been mentioned like precision, explicitness, freedom from ambiguity, accuracy, perspicuity, simplicity, generality, defensibility, formal testability or “Übersichtlichkeit” and enhanced expressive power. Some elements of symbolic notation combined with diagrammatic devices may also contribute to the vividness of forms of representation, e.g. chemical structure diagrams.

The first two of these principles are precision and explicitness. For example, what is and what is not a case of category X often is and was a case of dispute in many branches of science. To specify clear criteria for category X in an explicit and a formal way contributes to the fulfillment of principles of explicitness and precision and to cope with problems of vagueness and with phenomena of prototypicality that are pervasive in ordinary language. However, specifying criteria even in a formal system ultimately has to rely on natural language resources. In the end, there is no alternative to using natural language as the tool for specifying systems of symbolic notation, even if this process may have taken place way back in the history of a discipline.

Decidability is another important goal. Starting from more or less academic examples what is or is not a case of a forest (8 trees, 12, 24, ...), there are clearly more relevant examples in practical contexts with aspects of the design of technical devices in the background (e.g. what are the criteria for a storm or an inundation and the criteria for an automatic storm warning?). In addition, there are many interesting approaches in the field of formalization and visualization of argumentative contexts, and some of them include elements of the formalization of argument structure or content, argument dynamics or the specification of core concepts. In such contexts formalization



not only contributes to decidability (storm warning or not) but also to progress in the theoretical underpinnings of the discipline (e. g. what exactly are the criteria and indicators for a storm to be expected).

Among the epistemic and theoretical goals have been attempts to construct symbolic systems that “mimic” the components, the structure or the working of the subject field, e. g. formal grammars that are said to represent the working of the brain. In a weaker sense, symbolic systems can be said to be models of a subject field: they organize specific aspects of the knowledge about a subject field in question.

Historically speaking, some of the “drawbacks” of natural languages have been a starting point for the design of (“better”) systems of symbolic notation. Vagueness, ambiguity, metaphoricity and other sources of indeterminacy have, among other things, been mentioned as such drawbacks of natural languages. Some of the suggestions for ideal languages are closely connected to this line of thought. In other cases, forms of symbolic notation followed different principles and pathways, e. g. in the history of chemistry, physics or mathematics.

## 2.4 The costs and some of the drawbacks of using forms of symbolic notation

The use of symbolic notation has its costs. These costs and drawbacks are different in respect of internal scholarly communication and in respect of science communication for public readers.

Even in the specialist literature there is often mention that forms of symbolic notation are not easy to understand, that they are “cumbersome” or that they present difficulties in reading (Kneale and Kneale 1964: 520 and 522), that readers may have even been deterred by the symbolism of a book and that this had an influence on the reception of a book like Frege’s *Begriffsschrift*. In addition, there are pedagogical discussions about the question whether or not it is worth the while to learn a specific symbolism like the one of the *Principia Mathematica*. The use and learnability of forms of symbolism have also been a matter of tension between scientific groups and generations (e. g. Heringer 1971).

In forms of communicating scientific results to a wider public, forms of symbolic notation do not seem to play a crucial role. This certainly has to do with the lack of prerequisites for the understanding of forms of symbolic notations. In addition, the concentration on key results does not require the technicalities of details and their formal representation. It is an open question, however, if and in which way elements of symbolic notation can be used to contribute to a specific image of science and of scientists in the public understanding of science.

## 2.5 Communicative and epistemic functions of symbolic notation and its elements

Seen from a perspective on scientific communication, different practices of symbolic notation serve to perform specific communicative and epistemic tasks of the field in question in a more explicit and a more rigorous way. For example, analyzing and describing the structure of a sentence in a formal way can be said to be more explicit and more rigorous because the categories are defined in an explicit way and because the rules of analysis and their application are equally defined explicitly. There are, however, many cases where the primary status of a symbolic object (e.g. a specific operator) depends on its role in a formal system.

Within systems of symbolic notation, one can identify a set of basic communicative functions and a wide range of further, more far-reaching or even ultimate goals. The basic communicative functions are intimately connected to epistemic goals. They often have counterparts in natural language use. Among the core functions of elements of systems of symbolic notation, three stand out:

- (i) representing a specific entity, category, or variable;
- (ii) indicating a specific structure;
- (iii) representing a specific operation.

Of course, these core functions can be combined in a notational system and very often are.

(i) The prototype of the first core function is a symbolic expression representing a specific entity, category or variable. Examples of this function are “NP” for the category *Noun phrase* in the early symbolism of Generative Grammar (Chomsky 1957; 1965), the symbol for the representation of sulphuric acid in Early Modern Alchemy or “pi” (“ $\pi$ ”) for the respective mathematical concept. The very long history of pi (Berggren, Borwein, and Borwein 1997) shows that the status and the problems connected to pi have considerably shifted in the more than 2000 years of research on pi. They include the increasingly finer grained calculation of  $\pi$  with computational techniques and equipment to 100,000 decimals in the last century and I would not be surprised if the length of pi would be further increased in the 21st century.

In addition, there are symbols that have a representative function in a more general sense, e.g. “p” for any proposition in logical notation systems, or expressions for defined variables that depend on certain operations, e.g. in mathematics, logic and in computational systems. A complex mathematical formula “denotes” a certain value, but it does so by specifying the way to find out the respective value. Identifying an individual and representing a class or a *kind* of object are certainly quite different functions, they share, however, a certain representational aspect.

(ii) The second type of symbolic expression is used to indicate the structure of a specific entity or category. A basic example of this type is the expression “H<sub>2</sub>O” specifying the chemical structure of water. This example shows that even this simple kind of expression is complex and that its representational power is grounded in principles

of compositionality: The elements of the complex expression and the way they are structurally organized determine the meaning of the expression as a whole. Symbolic expressions like “ $\text{H}_2\text{SO}_4$ ” are in certain aspects related to visual representations of the structure of this kind of chemical compound.

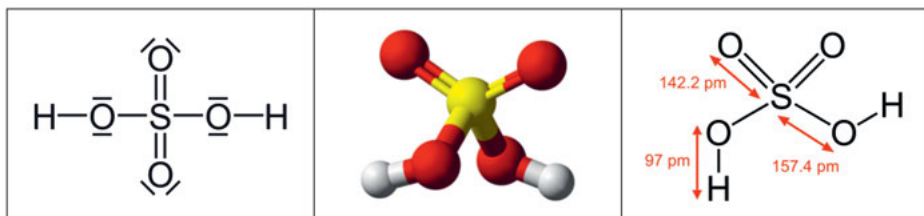


**Fig. 1:** Visual representations of sulphuric acid/Schwefelsäure from the German and the English Wikipedia pages (accessed 19 August 2018).

A second example of this kind of structural information is bracketing in syntax or morphology: In order to account for the ambiguity of the German Noun “Holzhaustür”, one can give two different structural representations:

[ Holz [Haustür] ] = the door of a house which (door) is made of wood

[ [Holzhaus] Tür ] = the door (made of whatever material) of a “Holzhaus” (a house built mainly with wood)

This kind of bracketed formula can be transformed into tree representations that preserve the structural information about components and possible interpretations of their configuration in a different format.

(iii) The third type of an element of symbolic notation consists of representations for basic or complex operations. Examples for these elements are the symbols for mathematical operations, for chemical operations or for the concatenation of linguistic expressions like “ $A \setminus P A$ ” for the construction of a derived adjective like “*unschön*” (which belongs to the category “*A*”) by adding a prefix (*P*) to another adjective (*A*) (Heringer 2009: 93).

The representation of entities, the forms of indicating structural properties and specifying ways or modes of operation/manipulation appear to be among the basic functions of forms of symbolic notation. One can certainly ask further questions: Are there other basic communicative functions of symbolic elements and of their use? What are the ways these basic elements can be combined in systems of symbolic notation? How do different forms of symbolic notation relate to possible natural language counterparts (e. g. Strawson 1952)? How are basic communicative and epistemic tasks related to different disciplines, their historical stages, their text types and their theoretical specificities (see section 3)?

### 3 Systems of symbolic notation in different branches of scientific communication

In this section I will characterize a small range of systems of symbolic notation from different scientific domains and their history in order to introduce basic perspectives related to function, epistemic role and aspects of historical evolution in respect of discipline-specific requirements and disciplinary variation.

#### 3.1 Chemistry and its predecessors

Starting from a modern beginners' textbook of chemistry, we find that two basic types of symbolic notation stand out: first, the use of structure formulas like " $\text{H}_2\text{SO}_4$ " (sulphuric acid) for chemical compounds, second, the use of chemical equations or reaction schemes like " $\text{AgNO}_3 + \text{NaCl} = \text{NaNO}_3 + \text{AgCl} \downarrow$ ". These types of symbolic representation are intimately connected to the basic epistemic functions of knowing the structure of complex chemical substances and of knowing and understanding chemical reactions and reaction patterns. In a similar way, one can trace back further and more advanced elements and aspects of symbolic notation in chemistry to discipline-specific epistemic functions, e. g. questions of stoichiometry, aspects of molecular structure or the electric dynamics of chemical processes. Techniques and elements of symbolic notation (not only in chemistry) are highly dependent on theoretical frameworks, e. g. in respect of what may be the basic building blocks of chemical compounds or what kind of chemical reactions are possible. For example, our knowledge of oxygen and oxidation are products of the 18th-century Lavoisier theory that superseded the earlier phlogiston-theory. Notational elements like " $\text{NaNO}_3$ " presuppose a theoretical framework that includes oxygen and oxygenic reactions.

The connections and interdependencies between notational practices, epistemic functions and theoretical frameworks is also evident in the history of chemistry. In a case study about the formative period of chemistry in the second half of the 18th century, Maurice Crosland (1959) has shown how William Cullen and Joseph Black, who taught chemistry in Glasgow and Edinburgh in the 1770s, designed and experimented with different systems of symbolic notation and diagrammatic visualization. These tools were in part still rooted in the 18th century doctrine of the "elective attractions" ("Wahlverwandtschaften"), but they clearly show the interest in representing the structure of compounds and the nature of chemical reactions, depending on the structure of the compounds that are part of the reaction.

In two of the historical predecessors of modern chemistry, Early Modern alchemy and metallurgy, what we can find in terms of symbolic notation are signs that represent chemical/alchemical substances like iron, water, mercury or gold, signs for certain processes like "union" or for instruments. Yet, apart from their representative function,

the signs for substances do not convey structural information about the substance in a modern sense. Rather, these symbols are intimately connected to the history of (al-)chemical terminology, to its iconic traditions and to world views different from modern materialistic and molecular systems. According to an unpublished lecture by W. B. Jensen (2009/15), aspects of the historical development of forms of symbolic notation in chemistry and its predecessors are described by Kopp (1844), Caven and Cranston (1928), Cajori (1928–29), Crosland (1962) and Ihde (1964). Geßmann (1922) provides an inventory of the “secret” historical symbols in medieval and Early Modern chemistry and medicine. In one of the formative texts of Early Modern alchemy (Libavius 1597), however, symbolic notation plays no significant role at all.

From the history of chemical notation, we gain, among others, the following perspectives: (i) Different types and elements of symbolic notation have epistemic functions that are dependent on disciplinary requirements (e.g. formulae indicating the molecular structure, stoichiometric or electro-chemical aspects of compounds). (ii) The development of (concurrent) forms of notation are interrelated with the evolution of the discipline. (iii) Methods of symbolic notation go hand in hand with terminology construction; they mirror the systematics of terminological organization.

### 3.2 Branches of logic and their historical development

Among the most basic forms of symbolic notation in logic are expressions like “ $F(x)$ ” where “ $F$ ” is a variable for a predicate (e.g. “is a mammal”) an “ $x$ ” is a variable for an argument of the predicate (e.g. “A cow” or “This cow”). Variables are an important device to move from individual statements like “This cow is a mammal” to general forms of assertion. Variables like “ $p$ ” and “ $q$ ” serve to formulate inference schemata within the propositional calculus which includes operators for the natural language connectors like “if”, “and”, “or” and others. The rules specified by the calculus, however, govern the use of these connectors in a much more restrictive way compared to the use of their natural language counterparts. The differences of the logical operators and the natural language connectors was a starting point for H. Paul Grice in his lecture series *Logic and Conversation* (1975; reprinted in Grice 1989), which was one of the founding documents of linguistic pragmatics. At this point, we gain a further perspective on symbolic notation: While linguistic means are the result of historical evolution within linguistic communities, the elements of logical calculi are the result of purposeful design by theorists, which includes purposeful variation, discussion of variants, the construction of alternatives to concurrent or prior systems, all of this depending on theoretical premises and goals.

During the late 19th century, the 20th and the 21st centuries research in different logical calculi loomed and still looms large. Highly specialized journals are devoted to this field of inquiry, e.g. the *Journal of Philosophical Logic*, the *Notre Dame Journal of Formal Logic* or the *Journal of Symbolic Logic*, to name but a few. The online Stanford

*Encyclopedia of Philosophy* provides highly informative surveys on different branches of logic and the evolution of their systems of symbolic notation, e. g. on the Lambda-Calculus (Alana and Korbmacher 2018) or the origins and developments of Modal Logic (Ballarin 2017).

Looking from a “scientific communication” point of view to the developments of logic and its forms of symbolic notation, one can gain the following perspectives:

(i) The idea that the search for truth is not independent of forms of symbolic representation and that thinking about forms of symbolic representation might be an instrument of improving the work on scientific truth has sharpened the awareness of the role of language and its functions for scientific purposes.

(ii) Different logical calculi (e. g. temporal logic, modal logic, quantificational logic, lambda-calculus) have highlighted important functions of language and have sharpened our understanding of natural language functions and natural language properties like ambiguity, vagueness and prototypicality of concepts.

(iii) The crafting of logical systems of symbolic notation was at times closely connected to conceptions of an ideal (scientific) language; authors like Leibniz, Frege, or Carnap might be mentioned here (see for varieties of the idea of an ideal language Eco 1993; Sinnreich 1972; Maat and Cram 2000).

(iv) There are famous examples how specific problems of logic and their discussion yielded far-reaching results way beyond the realm of logic. The Russell/Strawson controversy over the proper treatment of noun phrases like “The king of France” was an important starting point for a high-class and multi-player debate over reference, categorization, the communicative constitution of objects, the role of knowledge in language use, the role of commitments and other key topics of pragmatics and research on scientific communication. While the original papers by Russell and Strawson did not contain significant portions of symbolic notation, they eventually led to new formal developments in the treatment of existence and presupposition.

(v) The work of Gottlob Frege is a further example how questions of logic and mathematics have been fruitful for the conceptualization of natural language and for the question of the differences between ordinary language and scientific language use. According to Michael Dummett, the work of Frege was both seminal for the (usage-based) Analytical Philosophy of Language of the 20th century (Dummett 1992, ch. 2) and of (truth-based) Formal Semantics conceptions. In a famous passage from his *Begriffsschrift* (1879), Frege distinguishes ordinary language and its reach from scientific language use and its further reaching affordances, comparing natural eyesight to tools like microscopes. From this perspective, symbolic notation is a microscope-like tool that enhances the power of natural language for the specific purposes of science.

To sum up: On the one hand, the tradition of logic provides highly specialized systems of symbolic notation that constitute their own research fields. Apart from that, these developments offer a number of more general insights on language, language use and scientific language use that stem, among other things, from reflections on symbolic notation, its functions and its relation to natural language.

### 3.3 Symbolic notation in linguistics

In a number of linguistic disciplines, e.g. syntax, phonology, morphology, formal semantics, discourse representation theory and others, different types of formalization have substantially reshaped the way research is done mostly during the 20th century. The history of Generative Syntax from Chomsky's *Syntactic Structures* (1957) onward to the present day is also a history of a highly specialized technical apparatus of symbolic notation that underwent several changes and even restarts over the years. Fritz Hermanns (1977), in an early work on the intellectual and disciplinary changes that came with these developments, chose the title *Kalkülisierung der Grammatik* ('calculation of grammar').

The use of symbolic notation in Generative Grammar came with a new intellectual standard: rigorous and "serious" work is formally specified, and formal systems have to be spelled out in some detail (Gazdar et al. 1985, ix). From syntax proper the "new" style was also adopted in work on the syntax/semantics interface (e.g. Montague 1974), in studies on discourse and conversation structure (e.g. Kamp and Reyle 1993; Asher and Lascarides 2003) and others. In some disciplines, certain formal means of structural description belong to the "basics" of disciplines, e.g. trees, brackets with indices or categorial formats in word formation. A contribution of Dirk Geeraerts (1997) to the field of historical semantics is a good example how a *new* format of symbolic and diagrammatic representation was developed in order to visualize the theoretical underpinnings of prototype semantics and the question of historical development of word meanings in a coordinated way (Geeraerts 1997: 32–47).

The roles of forms of symbolic notation in these scientific fields are varied. While some forms of structural representation are mere tools of analysis, others come with more far-reaching goals, e.g. the isomorphy thesis in formal semantics and the corresponding claim that each formal rule in syntax has a counterpart on the semantic side. In addition, formal representation is also closely related to scientific principles like explicitness, economy and testability. While there were phases of heavy controversy over formalization and the role of symbolic notation in linguistics, it seems that nowadays we have a plurality and coexistence of formal and non-formal approaches. However, developments in corpus linguistics, knowledge representation, and certain branches of Digital Humanities have given the study of the question which aspects of language and language use can be formalized new momentum.

### 3.4 Further perspectives on the discipline-specific nature of symbolic notation

One could continue to ask for many other disciplines if and what kind of symbolic notation was used in the respective field of inquiry and its history, which functions were fulfilled and which role these forms of notation did play. It is evident that sym-

bolic notation played very different roles in different disciplines like ancient and present-day astronomy, astrology, cosmology, in highly technicized branches of applied sciences like robotics or in other scientific branches like the mechanics of motion in sports research. As opposed to these fields, there are others, e.g. traditional literary criticism or the history of religions, where forms of symbolic notation play virtually no role at all.

In respect of different disciplines and their historical versions one could develop “Symbolic notation profiles” with information about the types of symbolic notation which were used, the specific functions they had, the overall goal that governed their application and their embedding within the overall scientific communication of the field in question.

Apart from the disciplinary perspective outlined so far, one can also look at important authors and books that have contributed to the development of systems of symbolic notation in general (e.g. Leibniz) or in a specific field, e.g. Frege’s *Begriffsschrift* (1879; see Kneale and Kneale 1964: ch. VIII.1 and VIII.4) or Wittgenstein’s truth tables in his *Tractatus* (1921). For a case study on mathematics see Chapter 17 in this handbook. Scholars of logic have emphasized the intimate connection between a logical system with its intellectual problems and solutions and the type of symbolic notation. Given this close connection, it is, for example, still worth the while to learn the notational symbolism of Whitehead’s and Russell’s *Principia mathematica* even if it is superseded by more modern systems today (see the article “The Notation in *Principia Mathematica*” in the Stanford Encyclopedia of Philosophy).

Another perspective is to ask for the use and the role of forms of symbolic notation in specific text types of scientific communication, e.g. textbooks or handbooks of microbiology. Such a question combines a disciplinary perspective (*of microbiology*) with the look at specific text types (*textbook, handbook*). Since textbooks and handbooks are crucial for the organization of an epistemic field, they are the ideal candidates to specify the role of established forms of symbolic notation in the respective field. In addition, it is interesting to see how new forms of symbolic notation are developed in text types of cutting-edge research (e.g. preprints of journal articles) and then gradually become adopted in textbooks and handbooks.

The idea of symbolic notation is also an important component in the intellectual history of the search for an ideal and universal language (Eco 1993; Sinnreich 1972; Maat and Cram 2000). For example, Leibniz’s suggestions for an ideal and universal symbolic language (*characteristica universalis*) from the 1660s onwards until his death was closely connected to far-reaching goals like religious unification, abolishment of logomachic controversies and epistemic progress in reasoning and science, among others (Eco 1993; Cohen 1954; Heinekamp 1972; Patzig 1969; Lewis 2007). But there are also much more mundane suggestions for interlanguages based on principles of symbolic combinatory that were designed to support international communication in the economic context of 19th century industrialization (e.g. Paic 1859).



Aspects of symbolic notation and formalization were not seldom subject to considerable amounts of controversy and debate in the history of many scientific disciplines. They include debates about the question whether to formalize or not to formalize at all. In linguistics, for example, there were fulminant wars among the tribes of pro and contra formalization. Second, there were and there are controversies about specific technicalities and strategies of symbolic notation in a specific realm of research. The controversy following a review of Peter Geach (1949) on work by Carnap is an example from the field of symbolic logic; the journals of this field are full of critical discussions on specific technical aspects of symbolic notation. Third, the critical comparison of systems of symbolic notations in textbooks and handbooks of specific disciplines also shows an element of controversy and discussion.

## 4 The intertwining of symbolic notation with natural language, forms of visualization, and diagrammatic devices

In most scientific works that use symbolic notation, it is embedded in a text written in natural language. Even in mathematics or logic, articles, textbooks, etc. are not made up of symbolism alone. Therefore, the question arises how natural language text and the use of symbolic devices are intertwined in different disciplines and subject fields.

From a communicative perspective one can distinguish three groups of natural language practices that are related to systems of symbolic notation and their use.

First, there are the practices that serve to introduce new symbolic devices, to specify their meaning and to explain the way the device in question is put to use. For example, in his *Begriffsschrift* (1879), Frege uses natural language in order to introduce a new system of symbolic devices. Among the activities in this group are: introducing a device, explaining the meaning of a device, specifying the kind of use and the function it serves, giving examples for the proper use, discussing alternatives, giving reasons for the chosen device, etc.

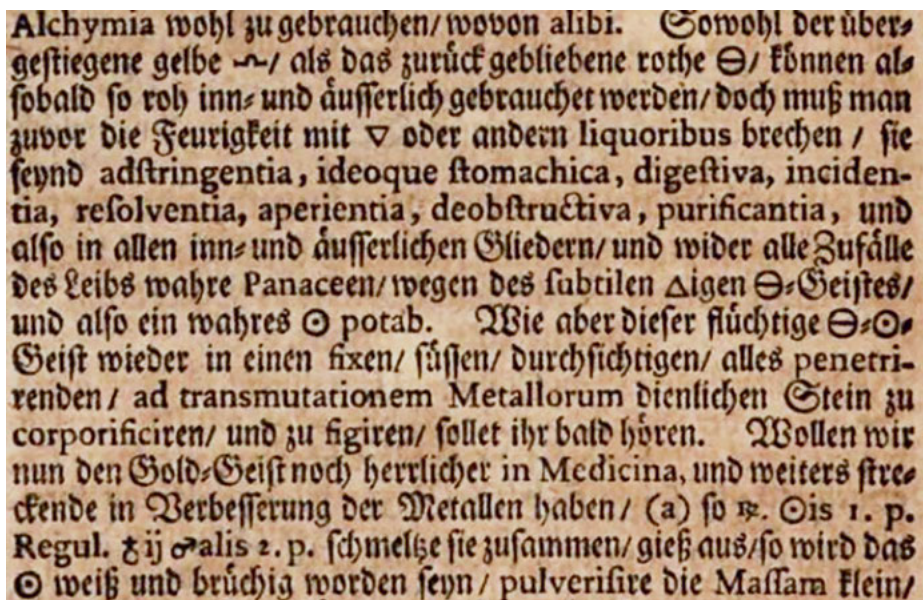
Second, there is the group of practices that serves to teach novices, e.g. students, a system that is already available. Many articles on the different logical calculi in the *Stanford Encyclopedia of Philosophy* are of this type, but also the sections in textbooks where the principles of symbolic notation are described and explained (e.g. Lang 1986). Many of the activities of the first group can also be applied in a teaching scenario, the difference being that the kind of symbolic notation is already existent.

Third, there is the use of natural language that accompanies the use of symbolic devices “at work” in scientific problem solving. In these cases, natural language activities can, among many other things, serve to introduce the question, to organize the thematic progression of the work, to comment on the use and the result of a sym-

bolic component, e. g. a formula, a structural description, a proof, an argumentation schema, etc. A mathematical proof often consists of the systematic combination and alternation of natural language and symbolic components.

There are other aspects of the relation between natural language and symbolic notation: Hamblin, for example, in a chapter on “Formal fallacies” (1970: ch. 6), first introduces his topic by giving instances of syllogisms and propositions which are presented in natural language. At one point, however, he switches to the formal notation in order to discuss the topic further in a generalized way.

In the history of alchemy and spagyric medicine there are examples of the combination of symbolic devices and natural language components even down to the level of syntactic organization, phraseology and the morphology of words composed of symbolic devices and natural language affixes. In the following passage from *Glauberus concentratus* (1715: 50) we find in only a few lines symbols that are syntactically integrated in natural text, fixed phrases with symbols plus natural language expressions, word-formations consisting of symbols and natural language components and even symbols with inflexion morphemes:



Alchymia wohl zu gebrauchen/ wovon alibi. Sowohl der übergestiegene gelbe ~/ als das zurück gebliebene rothe ⊙/ können alsobald so roh inn- und äußerlich gebraucht werden/ doch muß man zuvor die Feurigkeit mit ∇ oder andern liquoribus brechen / sie seynd adstringentia, ideoque stomachica, digestiva, incidentia, resolventia, aperientia, deobstructiva, purificantia, und also in allen inn- und äußerlichen Gliedern/ und wider alle Zufälle des Leibs wahre Panaceen/ wegen des subtilen Δigen ⊙-Geistes/ und also ein wahres ⊙ potab. Wie aber dieser flüchtige ⊙-Geist wieder in einen fixen/ süßen/ durchsichtigen/ alles penetrierenden/ ad transmutationem Metallorum dienlichen Stein zu corporificiren/ und zu figiren/ sollet ihr bald hören. Wollen wir nun den Gold-Geist noch herrlicher in Medicina, und weiters streckende in Verbesserung der Metallen haben / (a) so r. Ois 1. p. Regul. 8 ij & alis 2. p. schmelze sie zusammen/ gieß aus/ so wird das ⊙ weiß und brüchig worden seyn / pulverisire die Massam fein/

**Fig. 2:** Combinations of symbolic devices and natural language elements in *Glauberus concentratus* (1715: 50), a work of spagyric medicine that goes back to 17th century sources.

As far as I can see, the detailed investigation of all these kinds of coordinated uses and the “division of labor” of natural language and symbolic notation in the three scenarios mentioned above is still a desideratum.

There is not only the question of combining symbolic notation and natural language text alone but also the question of how symbolic notation, forms of visualization and diagrammatic practices can be related and coordinated. In the following examples, we have elements of symbolic notation, natural language text, visual elements plus aspects of spatial and diagrammatic organization:

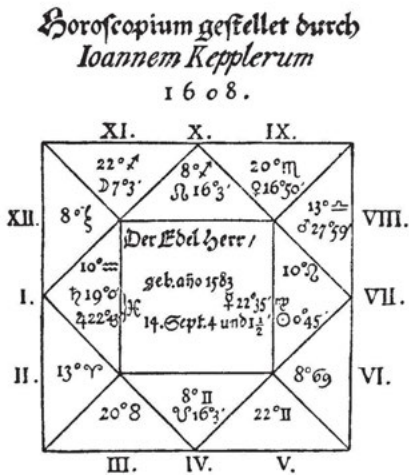


Fig. 3: Kepler's horoscope for Wallenstein (Knappich 1998: 248)

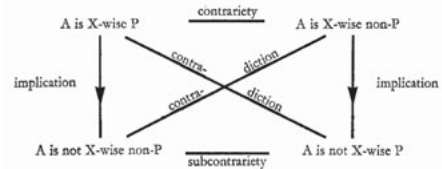


Fig. 4: Square of opposition from Hamblin (1970: 209)

As for the communicative use and multimodal organization of the combination of symbolic devices, natural language, and other visual or diagrammatical resources in an orchestrated way (Kress 2009), some crucial aspects can be formulated by three questions. First comes the question what each mode, each resource, contributes to the scientific task in a specific work at hand. Secondly, how are the different resources orchestrated, what are their functional connections? And third, how and on what basis can a reader understand how the resources are organized in an “orchestrated” way?

In the praxis of modern scientific text production there are many more relations between the use of symbolic apparatus and forms of visualization. Take, for example, a data set in an empirical discipline that is evaluated via certain evaluation formulae in a statistics software, which then yields forms of visualization of the data. According to principles of open science the data, the formulae, the processing scripts, the visualizations and the paper itself can be presented in so-called paper packages. Software packages like “R” nowadays allow not only for the analysis of data, they also come with powerful visualization libraries. Authors can integrate R-scripts into their papers in order to keep the visualizations up to date even if there are changes in the underlying data.

Working with the connection of symbolic notation and visualization can also be used for didactic purposes. To give one example: The paper by Goudar and Nanny (2012) shows how the interactive manipulation of PowerPoint diagrams can be used to teach solution chemistry. The authors write in their abstract (2012: 741):

pC–pH diagrams provide a graphical illustration of chemical speciation as a function of pH and are hence a very effective tool for understanding the chemical system being studied. This understanding can lead to assumptions that simplify problem solving. However, manual construction of pC–pH diagrams for multiprotic systems is cumbersome and is further complicated by non-standard temperature and ionic strength conditions. As a result, construction of pC–pH diagrams can become the focus of classroom teaching rather than their application to solving real-world problems. Students tend to get lost in the complexities of pC–pH diagram construction and often fail to appreciate their value in problem solving. To address this limitation, we have developed interactive pC–pH diagrams for mono, di, and triprotic systems that are all bundled into a single PowerPoint file. The governing equilibrium equations are presented adjacent to the pC–pH diagram which makes the entire process transparent. The diagrams update in real-time [...]

The basic idea here is the connection between a symbolic chemical equation and a visual representation that can be manipulated and that are updated together in a coordinated way. Comparable didactic approaches are available in the field of argument visualization, in different Critical Thinking approaches or for the teaching of symbolic query languages in corpus linguistics, to name but a few examples.

To conclude: While there is a massive body of discipline-specific research on systems of symbolic notation (especially in logic and its history; e.g. Gabbay and Woods 2004–14), forms of visualization (e.g. [www.visual-linguistics.com](http://www.visual-linguistics.com)) and diagrammatic practices (e.g. Moktefi and Shin 2012), there is still much to be done on the question of the intertwining of these different resources of scientific communication, both in a discipline-specific perspective and in respect of overarching principles and questions.

## 5 Symbolic notation, formalization, and the idea of “rigor”

The topic of symbolic notation is closely related to at least three ideas in intellectual history that are of considerable importance: the ideas of “rigor”, “formalization” and “computation” in different branches of theoretical and applied science.

Rigor and formalization are intimately related. Formalization is an instrument to achieve scientific rigor. However, as we learn from frequent criticisms of formal systems, formalization alone is no guarantee of rigor. Peter Geach’s criticism of work by Carnap (1949), already mentioned above, is but one famous episode in the long history of critical discussions of symbolic systems, their architecture and their con-

struction details. In any case, there is, in intellectual history, a clear relation between the notions of scientific rigor and the practices of formalization and symbolic notation. On the other hand, rigor is not dependent on formalization or the use of symbolic devices, as the writings of Kant or Frege show. It is equally obvious that the relation between ideals of rigor and forms of symbolic notation depends on specific developments in certain scientific disciplines. For example, in linguistics and linguistic philosophy, the 1960s and 1970s saw several important contributions on the formalization of linguistic theory (e. g. the work of Richard Montague, 1974). It is, however, important to note that not all proposals of symbolic notation come with an appeal to increase scientific rigor. Some systems of symbolic notation were meant to just make scientific communication more “economic” or to make specific tasks “computable” by digital machines.

The notion of “rigor” had a specific historical career that was closely connected to debates about the status of the humanities in opposition to the sciences that started early in the 20th century. Rigor became an ideal connected to the sciences proper, but authors working in the fields of the humanities asked whether standards of rigor were applicable in the humanities as well. Husserl, for example, asked whether or not philosophy or phenomenology could be disciplines fulfilling standards of rigor (1911; later on, around 1935, he wrote: “Der Traum ist ausgeträumt”, but the interpretation of this passage is a matter of dispute).

Even today, the old debate over formal vs. hermeneutic methods goes on and is still vital. In the speedily expanding field of Digital Humanities the question of formalizability is of crucial importance. In the best case, a research question is fully formalizable and open to computational treatment. If it is not, it is a central question to explore whether or not there are workarounds, sets of indicators, etc. that allow an answer. In other cases, there may be “second best” strategies for the investigation in question, for example by the use of intermediate annotation of data. Despite many open questions, the strategy of trying to put old research questions into a formalizable and computable format is promising even if we will learn more about limitations of the formal and computational approaches. Looking at, e. g., recent progress in computational translation systems that go far beyond the hilarious results of previous systems like *babelfish* makes the present author modestly optimistic.

## 6 Conclusion and further perspectives

In this chapter I gave an overview of key aspects of different varieties of symbolic notation and formalization in various scientific disciplines. The panorama included major forms, communicative practices and epistemic functions of systems of symbolic notation, their elements and their uses. An assortment of examples served to show the relatedness of forms of symbolic notation with epistemic tasks of specific disci-

plines. The chapter also introduced the question of the intertwining of elements of symbolic notation with natural language components and with forms of visualization and diagrammatic devices. In addition, the idea of symbolic notation is closely related to other notions like scientific rigor, formalization, computability and the idea of an ideal language.

Further perspectives include desiderata like the empirical investigation of the use of scientific symbolism in popular science contributions. Here, one can ask questions like the following: To what extent is expert symbolism used in different varieties of popularization of scientific research? What gets lost when important forms of symbolic notations are *not* used? What replaces symbolic notation in popular contributions? Are there other than epistemic functions in using symbolic notation, for example as “credentials” for persons, to give products a scientific image in advertising, to give a public audience an impression of the complexity of a scientific problem?

A second perspective consists of forms of symbolism as a learning task and as an obstacle for the reception: “With the possible exception of his *Grundlagen*, Frege’s works have never been widely read. No doubt some who have opened his books have been deterred by his symbolism” (Kneale and Kneale 1964: 511). This perspective includes questions of comprehensibility, learning strategies and problems of the acquisition of symbolic notation in different academic fields.

One of the perspectives introduced above deserves further investigation in particular, the relation of communicative aspects of symbolic notation with its epistemic functions in different varieties of scholarly communication and in the history of ideas. Wittgenstein, in his *Bemerkungen über die Grundlagen der Mathematik* wrote: “Ich will sagen: Wenn man eine nicht übersehbare Beweisfigur durch Veränderung der Notation übersehbar macht, dann schafft man einen Beweis, wo früher keiner war” (Wittgenstein 1974: 143).

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## 17 The rise of symbolic notation in scientific communication: the case of mathematics

**Abstract:** This article describes, in an epistemological analysis, the constitution of a specific language, namely mathematical symbolic writing. The framework of modern mathematics, physical sciences, and, generally speaking, of scientific communication, is today entirely organized around this language. Its initial constitution in the 17th century, with Descartes and Leibniz as main protagonists, constituted an unprecedented upheaval over previous designs – what I have called the “Symbolic Revolution”. This symbolic language has a very specific pattern: it is, in no way, the transcription in signs – a form of shorthand – of any natural language. I will show for example how, in its construction, it has undeniably relied on contradictions or ambiguities (see “The dialectic of indeterminacy”), and how much this apparently paradoxical organization has been fruitful. I will also highlight how much this language allowed, in mathematics, the invention of objects or concepts, in an unprecedented way in the construction of natural languages: see the “Invar-Ext” scheme; see also the ability of symbolic substitutability to construct new objects, in an unprecedented way, possibly without reference to the meanings. I also describe in detail how the need to dispel the ambiguity of order in the execution of the operations has led mathematicians to develop a new design that is common today, the so-called “arborescent thought”.

**Keywords:** mathematics – symbolism – epistemology – Descartes – Leibniz – exponentials – indeterminacy – arborescences – substitutability – “Invar-Ext”

### 1 Introduction. Scientific communication and mathematical symbolism

Communication between scientists today is undoubtedly made through mathematical symbolism. Symbolic writing has become a practice that is both specific and universal, regardless of the part of the world that it concerns (i. e., it is not limited to Europe).

First, we note that it has not always been so. Section 2 below describes what I have called the “symbolic revolution”; that is, the historical passage, from the writing of mathematics in natural language to symbolism, as we know it today. This was done in the 16th and 17th centuries with Viète, Descartes, and Leibniz as its protagonists.

This article is within the frame of my previous works on symbolism. In particular, I will frequently refer (by the acronym RS) to my work, *La Révolution Symbolique* (The Symbolic Revolution).

## 1.1 Descartes' *Géométrie*

The publication, in 1637, of Descartes' *Géométrie* (AT VI: 367–485) constituted the moment of rupture with writing in natural language – but this upheaval was not completely perceived as such by its author. Descartes' contemporaries, however, were not mistaken, and a part of this section is devoted to describing the function, as the “Rosetta Stone”, of this Cartesian book. The *Géométrie* of 1637 is thus the first historical text directly communicable to mathematicians and scientists today. No other text had this role in the history of science, for it dealt with the very structure of writing as a language of communication (cf. Serfati 1998: 284–285).

## 1.2 Then Leibniz came

Leibniz then fixed and theorized mathematical symbolism. If, as I have said, Descartes was not really aware of the break provided by his method, we must grant Leibniz the sole privilege of having used and thematized it. Much writing is devoted to Leibniz's work in this field (see for example, Serfati 2001, 2005, 2008, and Dascal 1978).

It is therefore Leibniz who, by his practice of symbolism, fixed the major principles of mathematical writing as we know it today. Here we must note that, due to its extraordinary singularities, this symbolic practice has, since the 17th century, gathered a community of mathematicians and scientists, while at the same time, it naturally created a form of separation with non-mathematicians.

This situation will appear normal, when I have analysed it in detail and on various points (indeterminacy – section 3, and arborescences – section 4) to what extent symbolic writing is specific – it is neither translation nor the reflection in signs of any natural language and does not obey usually observed linguistic rules.

Therefore, it is not surprising that men who are not scientists have encountered great difficulties in understanding symbolic notation. Under these conditions also, science education naturally raises very specific questions, to the point that a new discipline, namely the didactic (mathematics education), was created to try to overcome these difficulties.

## 1.3 The survival of the fittest

Using various examples, I will show that the daily use of this symbolic organization and the effective development of sign systems has been built, not upon the basis of a pre-existing theory, but on a case-by-case practice, according to the Darwinian principle of the “survival of the fittest”. This is the case for the Cartesian exponential, which has (definitely) triumphed over the notations of Cardan, but also those of Hérigone (see RS: 240). This aspect is fundamental. There is a second aspect of the

aforementioned Darwinian reference, which I can only mention briefly. The symbolic writing indeed makes it possible to invent objects and concepts, mathematical and scientific (see second part of RS, “Symbolic and Invention”: 249–406). The mathematician, especially a contemporary, can indeed receive suggestions from the symbolism and construct new concepts or objects, in a way that may seem unexpected – that of “forms without signification”. One of the main supports of symbolic language is indeed the faculty of performing unexpected substitutions – apart from the meanings (see section 5). On this point, Leibniz was again the forerunner, with his *Combinatorial Art*.

## 2 Compound concepts. The Cartesian exponential

This section is devoted to a specific practice of mathematical writing, namely the symbolic representation of a concept as a composition organized between objects or concepts. The case of Descartes’ creation of the first of the exponentials in history is here exemplary. I can only briefly describe it here – cf. my more detailed works in RS: 199–233 and Serfati 1994: 81–85.

### 2.1 The inadequacy of pre-existing systems

The origin of the question lies in the primitive representation of the powers of the unknowns (number, square, cube, square-square, etc.), which, since Diophantus, had been performed within the framework of various systems of representations, by simply displaying a list of distinct symbols.

Thus, in the cossic system (which was widely used in the 16th century: see Cajori 1928, I: 133–136, and RS: 199–201), the unknown had  $\mathfrak{u}$  as a symbol, the “Square” (or *Census*) which was usually represented, in Stifel or Rudolff, for example, by  $\mathfrak{z}$ , and the “Cube” by  $\mathfrak{c}$ . Similarly, the “square-square” had the sign  $\mathfrak{z}\mathfrak{z}$ , etc.

This representation of distinct objects by distinct symbols could seem natural and effective. As soon as the theory of equations was developed, however, an insurmountable difficulty became apparent: the mathematician of the time knew well how to write  $\mathfrak{z}$  as the square of the unknown  $\mathfrak{u}$ . On the contrary, he could not write the square of an expression as simple as  $2\mathfrak{u}+7$  in a structurally analogous way, as we do today in the Cartesian system, simply replacing  $A$  by  $A^2$ . In other words, the symbolic forms  $A$  and  $B$  could not be freely substituted for each other in the symbolic expression of a square. Naturally, this was equally impossible for any symbolic form.

This incapacity constituted one of the major disadvantages of the cossic system, heir on this point of that of Diophantus, namely the inability of changing the unknown *within the system*. In fact, as we shall see, this insufficiency was entirely based on the

failure to take into account, in the lineage of powers, two predicates; namely, the *substance* and the *relation*. If a symbolic system had decided to represent them both, the rule of univocity then required not one sign, but two. Such a concept would have been regarded as compound. Users of the cossic system had actually “chosen” to use only one sign, thus implying that the concept of power for them was simple and not compounded.

## 2.2 *Rules for the Direction of the Mind*, and the creation of the exponential

Considering that there were actually two predicates to be represented, this is what Descartes did first with his “ $2a^3$ ” in Rule XVI of the *Règles pour La Direction de l’Esprit* (*Rules for the Direction of the Mind*) – see AT X: 349–488 and Serfati 1994 – where “ $a$ ” is the sign of the substance, and “ $3$ ” is that of the relation. This analysis was fundamental. One must therefore acknowledge (RS: 240–241) the relevance and the strength of the analysis (and of the system) of Descartes.

The symbolism of Descartes immediately revealed it was the fittest. Therefore, it alone survived and spread rapidly and widely among contemporary mathematicians. Thus, the advent of the Cartesian exponential signed the complete and definitive disappearance of the diophanto-cossic symbolism, which for centuries had governed mathematical thought on the issue of powers. With it disappeared its main limitations. I am therefore in complete agreement with Cajori’s conclusion: “There is perhaps no symbolism in ordinary algebra which has been as well chosen and is as elastic as the Cartesian exponents” (Cajori 1928, I: 360).

## 2.3 On the composition of concepts or objects

I will then point out (this point is not clearly highlighted by Descartes himself) that in the new Cartesian symbolism, there were, in fact, not two but three aspects to be taken into account; first, of course, both aforementioned predicates, but also the specific way (here symbolized by the copula contained in the exponential) by which they were mutually organized to precisely create a “power” and not another concept. At the end of the century, one of the epistemological lessons drawn by the posterity of Descartes’ conclusion on the issue of powers was, thus, without any doubt (RS: 274) the analogical creation of his “New Calculus” by Leibniz. See, for instance, *Considérations sur la Différence qu’il y a entre l’Analyse Ordinaire et le “Nouveau Calcul” des Transcendantes* (in *Journal des Sçavans* (1694) = GM V: 306–308). On this subject, see also Serfati (2001).

Thus, the representation of the powers was the first, historically speaking, which led to the universally prevalent mode of representation used today in symbolic writing

of a composition of concepts. To illustrate a little more the interest of the creation of the exponential, we will find below a modern instance of the exponential  $e^A$  of a square matrix  $A$ , for example:

$$e^{\begin{bmatrix} -1 & 4 & 3/2 \\ 5 & 28 & 6 \\ 4 & -\sqrt{3} & 2 \end{bmatrix}}$$

Where the exponential is defined by  $e^A = \sum_{n=0}^{\infty} \frac{A^n}{n!}$ . This example, now well-known and used, is obviously far removed from Descartes' conceptions!

Today, the general representation of a specific connection and composition between objects or systems of any kind (they may be conceptually very distant) is a daily practice, which is carried out very simply *via* the symbolism of a law of composition (such as a  $\ast Z$ ), where the sign  $\ast$  symbolizes the specific mode of the composition concerned.

### 3 The representation of “arbitrary” numbers

#### 3.1 Explicit quantities, arbitrary quantities, before the 17th century

In the 16th century, before Viète, geometric figures were regarded (since antiquity) as “arbitrary”; that is, generic of a given geometrical situation: the figure certainly had a singularity, but this one was postulated to be not significant. Heath notes that the figure actually represented a *class* of figures: “The conclusion can, of course, be stated in as general terms as the enunciation, since it does not depend on the particular figure drawn; that figure is only an illustration, a type of the class of figure and it is legitimate therefore, in stating the conclusion, to pass from the particular to the general” (Heath 1981 [1921], 1: 370). There was not, however, symmetrically, a representation of “arbitrary” numbers. On the other hand, to represent unknown numbers in the calculation, a primitive symbol had been used; it could not be a number but, for example, a letter such as  $x$ , or a cossic sign (such as  $\mathfrak{e}$ ), precisely because the number was unknown.

#### 3.2 François Viète and the given numbers

In a famous passage of his *Introduction to the Analytical Art* of 1591 – cf. Viète 1986 [1591]: 47 – Viète then introduced *letters to also represent the given numbers*. Those that he proposed to use were, however, of a different alphabetical type, according to the nature of the quantity represented: vowels for the unknowns, consonants for

the data. This definition, however, as understood by his contemporaries, was quite surprising, for it concealed a difficulty that might seem insurmountable: in all calculations at that time the natural pattern was that the given numbers were only those that could present an explicit representation, using figures, such as 3,  $\frac{22}{7}$ , or  $\sqrt{11}$ . To say, as did Viète, that the consonant B, for example, represented a given number meant, in principle, that the sign B represented a fixed number, the value of which was known by the author of the text. Under these conditions, however, the reader, or any other protagonist, certainly had no knowledge of it! How, in this case, could Viète maintain that B was the sign of a given number?

### 3.3 The dialectic of “arbitrary but fixed” quantities

This disappearance of explicitation in the symbolization of the given numbers however, would at the time of interpretation, in turn, mechanically entail a new obligation: it was necessary to consider this given number as *arbitrary*. If, indeed, the only information provided by the letter was to indicate a convention concerning the category of the represented entity (i. e., it is a number whose value is given and not unknown) and not to make explicit its value, then the latter, although fixed, was free to be arbitrarily chosen. Under these conditions, this practice was allowed, as had always been the case previously in geometry, to represent “arbitrary” objects.

Thus, in the last analysis, Viète implicitly asked his reader for adherence to a certain convention (what I have called a dialectic), namely: on the one hand, there are “arbitrary but fixed” numbers; on the other hand, this existence is guaranteed by symbolic writing, and not by natural language. In natural language, in fact, this is a contradiction, for the univocity of representation is fully contradicted in it. In Viète’s symbolic writing, the letter B represents, in the same context, both an object and a class of objects, the one to which the arbitrary object in question belongs. The symbolic notation thus makes it possible to support two opposite concepts; the arbitrary one and the fixed one, or else the one and the multiple. This assumption within the symbolism of what constitutes incontestably a contradiction in the natural language has thus led to the creation, in the modes of mathematical knowledge, of a figure of thought absolutely unprecedented in calculation, namely “indeterminacy”.

### 3.4 On a universal spread

It must now be emphasized that, despite his seemingly inconsistent character, Viète’s convention was immediately accepted without hesitation by his successors, in particular by Descartes. After 1650, it spread very quickly and very widely to all the 17th-century authors, such as Newton and Leibniz, who used it without any reserve. Here again we may observe the practice of the survival of the fittest symbolism. The reason for

such acceptance and enthusiastic dissemination is indeed simple; they came directly from the highly successful character of the founding convention. Indeed, the latter made it possible for the first time in the history of mathematics to establish *literal formulas*. This is a fundamental practice, of which mathematics can in no way be exempted, as Leibniz accurately pointed out. One should also note that, although the acceptance of this dialectic raised no difficulties for his contemporaries, as they were quickly convinced of its absolute effectiveness, it did not fail, three centuries later, to raise retrospective questions among some logicians and philosophers at the beginning of the 20th century. Russell and Frege, in particular, vigorously opposed – without convincing themselves – the legitimacy of the acceptance of this dialectic. I analysed this controversy at length in RS (189–193).

Russell, for example, refused to accept the legitimacy of the aforementioned convention. Thus, in 1903, in *The Principles of Mathematics*, he wrote:

If a theorem is proved concerning  $n$ , it must not be supposed that  $n$  is a kind of arithmetical Proteus, which is 1 on Sundays and 2 on Mondays, and so on. Nor must it be supposed that  $n$  simultaneously assumes all its values (Russell 1986 [1903]: 90–91).

To conclude this section: this symbolic dialectic has been fundamental to the development of mathematics. Under these conditions, one should consider that, since that time, only one who after Viète agrees to accept the aforementioned dialectic can claim to be recognized as a mathematician. Such consent is, at the same time, a strong sign of membership in the scientific community, in conjunction with another of the origins of some form of separation, with respect to the members of other communities – as also a source of difficulties for apprentices in mathematics, as evidenced by numerous didactic works on the subject.

## 4 The arborescence, as a support of the symbolic communication

This section deals with another specific aspect of the conceptual revolution underlying symbolism. Indeed, mathematical symbolic thought was structured, not as one could spontaneously imagine it in the linear mode of a well-ordered succession of instructions to be performed, but around an underlying arborescence (i. e., a specific tree-like structure). It is remarkable that, even from very simple examples, the complexity of this arborescence quickly becomes considerable – making impracticable, in fact, an interpretation in natural language. Scientific communication must take account of such a tree and organize itself around it. It is indeed the arborescence, and it alone, which is primitive and fundamental to the organization of scientific thought, and not the means of describing it which are contingent (see my comments on the Polish notation in RS: 120–121).



This point is very specific to mathematical and scientific thought. It appeared, however, only very slowly among the scholars of the time. Descartes, for example, had completely ignored it and we must again recognize Leibniz as having been able to develop the truly relevant questions on this subject. For example, see below his use of *inverse commas*.

## 4.1 The ambiguity of order

I take, as an initial example, that of a very simple instruction thus expressed in natural language: “To perform a multiplication, of which one of the terms is the number of sign Y, and the other the result of this instruction: to add the number 7 to the number of sign z”. According to the scheme of representation of instructions, the mathematician could believe that, in order to symbolize the multiplication of both concerned expressions, he only had to write:

$$7 + z . Y$$

However, it is immediately apparent that the writing above is ambiguous in decoding. The same symbolism can indeed legitimately be interpreted in a different way and the two interpretations do not coincide. This phenomenon is the direct source of which, in various texts, I called the *ambiguity of order* (see for example RS: 85–125). Although the above symbolization may seem surprising to us today, historically and spontaneously, it was the first idea in Cardan, for example, in the 16th century.

## 4.2 Vincula and parentheses

To put an end to the ambiguity, the first idea of mathematicians was, quite naturally, that of a horizontal bar or *vinculum* underlining or highlighting all the signs of the interval concerned by the same operative sign, and thus obtain  $\overline{7 + z} . Y$  or  $\overline{7 + z} . Y$ . This practice had a long history, well described by Cajori (see *Signs of Aggregation* in Cajori 1928, I: 384–400).

There were then many other attempts, also described by Cajori, either by dots or pairs of dots (in Descartes for example), or commas (in Leibniz), or associated parentheses – the latter representation, which is in fact the fittest (if we except the Leibnizian inverse commas), is the norm. Thus, for our example above, we now write:

$$(7 + z) . Y$$

Whatever the system adopted, in this example we obtain a concatenation of signs intended to be an assemblage, which we shall say of *degree two* (on the degree of the assemblages, see RS: 93–94).

### 4.3 Punctuation mark of the text, or aggregation of signs?

This example invites us to consider the double register inherent in the functioning of parentheses. In accordance with the initial aim, the use of parentheses first led to the disappearance of the ambiguity of order. However, the example has at the same time exposed another function; namely, to constitute the partial result of each operation, to make it into a formed block, destined to be in its turn an object for operations of a higher degree and so, to the constitution of partial results in the calculation.

### 4.4 Non-linear assemblages

Let us now consider the slightly more complex case of this assemblage, which is also of degree two:

$$((Y \cdot N) / (7 + z))$$

Decoding must obviously be done as follows: firstly, (that is, before taking into account the “bar” (fraction), interpreted as a quotient) there are two operative signs of degree one; the “dot” (multiplicative) on the one hand and the “plus” (additive) on the other, but there is no prescribed rule of succession between these two; the order of their execution is indifferent. Such an assemblage is said to be *non-linear*. This, which is the truly everyday case, is in the very nature of mathematical writing.

### 4.5 Symbolic language, natural language. The issue of partial results

I now return to the representation of intermediate results, already mentioned above. I had chosen, as an interpretation of an assemblage of the first degree, such as  $7 + z$ , that of an elementary instruction (“add 7 to  $z$ ”), and not the result of the operation. In light of what precedes, it also appears that such an assemblage, when supplemented by external parentheses, will have to be interpreted as constituting the *result* of the instruction. The “constitution” of the result therefore consists, in fact, in disposing of it as if it were virtually executed, in a constituted block, which could itself be the object of subsequent proceedings.

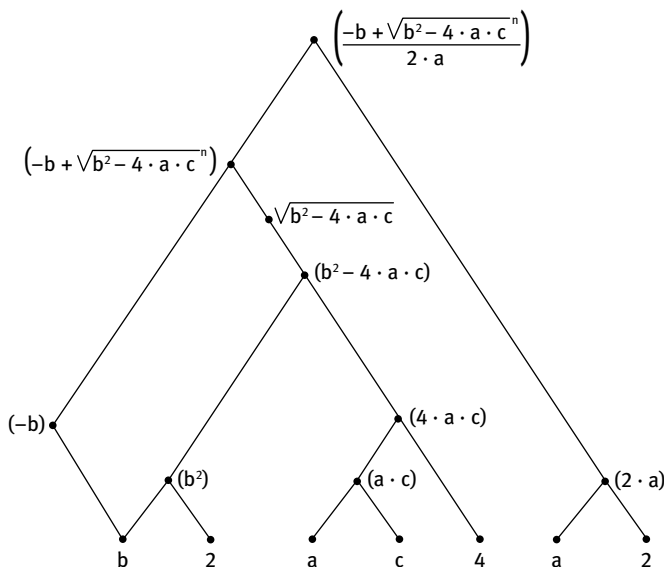
In the case of the assemblage of second degree above, where there is only one partial result, things have been so simple, however, and the rhetorical writing so clear, that the symbolic representation can rightly be regarded as a mere abbreviation.

However, once the number of entangled operations became a little more important, its interpretation within natural language became impossible in fact, if not in law. To illustrate, I gave (in RS, 99–101) an example of a translation attempt in the natural

language of some symbolism. We can see there that a very brief line of symbolic writing corresponds to an entire page of “transcription” in the natural language. Moreover, it is not precise enough, for reasons that I have also analysed in the aforementioned text.

## 4.6 Arborescences

I then showed (in RS, 118–119) how one could today grasp the entanglement inscribed in symbolism by using the theory of ordered sets. Here, I cannot give more detail on this point, only to conclude that: the entanglement is organized in an arborescence, in the mathematical sense of the term, that is to say in a lattice of a very specific type, and the arborescence can itself be described by means of a plane diagram. Arborescences, trees and forests have given rise to an abundant contemporary mathematical production, among which we can cite Ore Oystein, *Theory of Graphs* (1962) and Claude Berge, *Graphes et Hypergraphes* (1970). In RS, pages 109–111, for example, I fully explained the arborescence associated with the resolution of a certain second-degree equation taken from Descartes. To take another example, here below is the arborescence associated with the solution  $x = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$  of the general equation of the second-degree  $ax^2 + bx + c = 0$ .



Arborescence of the solution of the general equation of the second degree.

Note that, even for such a simple mathematical case, such a representation requires time and care.

## 4.7 From Leibniz's symbolic commas to parentheses in natural language

### 4.7.1 Leibniz and the symbolization of division

Those mathematicians of the 16th and early 17th century, such as Bombelli or Descartes, who had been obliged to introduce specific signs – due to the necessity to put an end to the ambiguity – did not at all feel the need to thematize this new practice. Once again, it is Leibniz, always concerned with epistemological clarification, who was the first to analyse examples of the use of what he called “signs of *comprehensio*”, as well as the equivalence between various symbols of this type that he used. In particular, he regretted that the “bar” (of fraction) made it necessary to open a new line of text. With a legitimate concern for typographical economy, as well as universal linearity of writing, he also wished to replace the “bar” with a sign that continued to be inscribed in the linearity of symbolism. The text of a letter he wrote to Jean Bernoulli, on 15 May 1696 (cf. GM III: 276; I analysed the text in RS: 107 and 125), clearly shows his symbolic concerns and, first, his deep attachment to preserving, as much as possible, the linearity of the text. He took an interest in an expression as follows:

$$\begin{array}{r} a + \frac{b}{c} \\ e - \frac{f}{g} \end{array}$$

As he writes (GM III: 276), “in order not to interrupt typography or to lose space”, Leibniz began by systematically substituting the “two-dots” of his invention, instead of the “bar”, which he likewise interpreted as a division.

### 4.7.2 Leibniz and the commas, direct and inverse

In a second step, Leibniz finely analysing the hierarchy involved in the assemblages, first attempted to distinguish the degrees by means of commas of two types: direct and inverse (cf. RS: 107). The invention of inverse commas, little noticed by critics, is in fact epistemologically remarkable. Unlike Descartes, Leibniz had in fact well understood the need for two different signs to dispel what he called *aequivocatio* (ambiguity). The inverse comma will nevertheless be an extraordinary “icon”, properly Leibnizian, which will not survive him, probably for typographical convenience reasons. Ultimately, he will rally to the use, usual nowadays, of round parentheses, according to:

$$(a + (b : c)) : (e - (f : g))$$

#### 4.8 Author or reader of a symbolic text

Placed in front of a “combinatorial arborescence” (the term “combinatorial” is borrowed here from Leibniz and his *Ars Combinatoria*) like the one shown above, which he intends to explore, a mathematician thinks he is naturally confronted with two main attitudes to make it, either starting from its root (i. e., the vertex) or from its leaves.

In RS, 109–115, I have analysed in detail these two positions, corresponding to two fundamental and opposite epistemological attitudes, which I have called the position of the reader and that of the author. I cannot here develop this crucial point further.

These two questions have found a natural resonance in the didactics of mathematics (that is, “mathematics education”). Thus, the battery of exercises (T1, T1 bis, T2, T3, T4, T5) proposed for students by Bardini in chapter V of her thesis (cf. Bardini 2003: 107–121) is mainly conceived as a “concrete” experiment of a double dialectic; author/reader on the one hand, and natural language/symbolic writing on the other.

#### 4.9 “Arborescent thought” in today’s communication

That the symbolic notation is only a transcription in signs – a form of shorthand – of the natural language, is an almost spontaneous idea, widespread among the public. It is obviously based on the implicit assumption of the existence of two reciprocal correspondences between natural language and symbolic language. In RS (chapter VII), and also earlier in this article (in section 3), I have already shown how the introduction of the “letter” in the symbolism (and its obligatory interpretation according to the contradictory formulation of a quantity “arbitrary but fixed”) definitively ruined this hypothesis.

The issue of arborescences here provides proof of another nature of the untenable character of this hypothesis. The latter is indeed destroyed here – within another epistemological register – by the impracticability of the interpretation (in natural language) of the arborescences. As we have seen, such a translation can be envisaged, but, in fact, it is impracticable. Much of our understanding and explanation patterns are, in my opinion, built on models of relations of a linear (i. e., total) order. The consequence is that natural language makes it difficult to describe non-linear statements.

Mathematical thought must therefore, each time, take account of such arborescence, and organize itself around it. This is what a professional mathematician does, spontaneously and tacitly, and this practice leads to a very specific form of scientific communication.

## 5 From substitutability to *Combinatorial Art*

### 5.1 On symbolically *inconceivable* substitutions

As we shall see, one of the major supports of symbolic language is the ability to perform unexpected substitutions, which may appear meaningless: on this point, it is again Leibniz who was the forerunner, with his *Combinatorial Art*. To illustrate, I will first take a simple example linked with the Cartesian exponential that may surprise today's mathematicians.

In writing mathematics in a natural language, for example in Cardan, we can simply point out that a substitution as simple for us to write and operate as that of substituting a square in a cube, as:

$$Z = x^2 + x + 2 \text{ in } Z^3 + 2Z$$

was an *inconceivable* operation: in the natural language and in the medieval rhetorical writing of mathematics, *there was indeed no place as to where to substitute*. Such a substitution could not therefore be thought of and, as we have seen above, it is Descartes' exponential symbolism which will have allowed it. With Leibniz, substitution became an essential everyday element. Leibniz glorified substitutability under the name of *Combinatorial Art*, a term that was often misunderstood both by contemporaries and posterity.

### 5.2 *Epistola Prior*: Newton, Leibniz, and the fractional exponents

Leibniz was initially confronted with the practice and issue of the substitution by *Epistola Prior*, a letter that Newton had sent him (via Oldenburg), in June 1676 (Bw: 179–192). At that time, the young Leibniz had just been initiated to the exponential by the text of Descartes' *Géométrie* and could therefore manipulate symbols like  $a^3$  or  $b^2$ , etc. These are cases where the exponent is quite naturally an integer. Yet here, in his letter, Newton substituted a fraction in exponent, to obtain assemblies of signs as  $5^{\frac{1}{3}}$  or  $3^{\frac{2}{5}}$ . Leibniz was greatly surprised. Any attempt at interpretation in the natural language in the Cartesian mode was unsuccessful: if the symbolic form  $5^{\frac{1}{3}}$  can indeed be described as “multiplying 5 by itself, three times”, what could mean, regarding  $5^{\frac{1}{3}}$ , this statement: “multiplying the number 5 by itself, one-third of times”?

### 5.3 *Epistola Posterior*: Newton, Leibniz, and the irrational exponents

In *Epistola Posterior* that followed (Bw: 203–225), Newton continued in the same vein, substituting irrational numbers in exponent, as in this example that he presents:

$$\frac{1}{x^{\sqrt{2}} + x^{\sqrt{7}}} \sqrt{(3)^{\frac{2}{3}}}$$

The sign (3), located in the radical of the exponent, denotes a cubic root.

Leibniz was greatly and equally surprised. These Newtonian definitions, however, are not arbitrary, nor anecdotal. There is a way to provide them with a rational constitution and origin, which are both rooted in a specific form of mathematical invention, emanating from the symbolism. I cannot here further develop this question, which I studied in various texts – cf. for example chapter XIV of RS, pages 323–337.

### 5.4 Leibniz and the indeterminate exponents

In a second step, Leibniz, learning from these two examples, proposed to exceed both Descartes and Newton on the exponential issue, *substituting on exponent an arbitrary number*, that is to say an indeterminate one; for example,  $a^x$  where, he writes, “the unknown enters the exponent” – see a letter to Wallis, dated May, 1697 (GM IV: 23–29). The question was obvious: what meaning did he give to this writing when  $x$  is the sign of an arbitrary number? Leibniz’s approach was nevertheless fruitful and this symbolism is now universal.

### 5.5 Leibniz and substitution in the Arithmetical Quadrature of the Circle

The exponential examples above, however, may seem a little too specific. Another instance will show the extraordinarily successful operative character of the substitution. I refer to the demonstration of what Leibniz called the Arithmetical Quadrature of the Circle – a very important result, which marked the beginning of his career as a mathematician, and which enabled him to communicate to other mathematicians the value of  $\pi/4$  as the sum of an infinite series; it was a major stage in the proof of the irrationality of  $\pi$  – cf. *De vera proportione circuli ad quadratum circumscriptum in numeris rationalibus expressa*, GM V, 118–122. To do this, Leibniz used, after modifying it, the demonstration that Mercator had given for the squaring of the hyperbola. Mercator had produced the power series:

$$\frac{1}{1+x} = 1 - x + x^2 - \text{etc.}$$

which he integrated term-by-term, according to:

$$\int \frac{1}{1+x} = x - \frac{x^2}{2} + \frac{x^3}{3} - \text{etc.}$$

For squaring the circle, Leibniz substituted  $x^2$  for  $x$ :

$$\frac{1}{1+x^2} = 1 - x^2 + x^4 - \text{etc.}$$

and he integrated term-by-term:

$$\int \frac{1}{1+x^2} = x - \frac{x^3}{3} + \frac{x^5}{5} - \text{etc.}$$

Such a substitution was profoundly innovative at the time. It is difficult to imagine today the sum of difficulties encountered by the scientists of the time, still indoctrinated with the irreducible geometric distinction between circle and hyperbola, to design such a substitution involving only symbolism. Because this procedure inevitably requires the use of symbolism! Thus, the emergence of this necessity was gradually discovered: the execution of an operation called substitution, of which the importance and preeminent role in the symbolic register will remain without any equivalent in the register of meanings.

## 5.6 Natural language *versus* symbolic writing. Sense and nonsense

I will return to the exponentials to emphasize this point: since an assembly such as  $a^x$  is considered legitimate, all symbolic formulas obtained by various “blind” substitutions, (that is to say, mechanically obtained), such as  $(\sqrt{3})^{\frac{\pi}{4}}$ , or  $(5 - \frac{1}{x^2})^{\frac{y}{xy+2}}$ , or else  $(\frac{x+3}{y-5})^{\frac{y}{3+2^x}}$  must also be considered legitimate, without it being necessary to ask beforehand the question of what might be their meaning.

In natural language, on the contrary, the fact that the sentence “The teacher states the result of a demonstration” is legitimate, does not allow one to make substitutions on such a “mechanical” mode. What can one say about the statements obtained if one replaces in this sentence, for example, “teacher” by “vertex”, or “states” by “brutalizes”? Or “result” by “grove” (or by “disc”), or else “demonstration” by “abnegation”?

Thus, in natural languages, substitution, this capital operation, is governed by meaning. In symbolic language, it is governed by rules; that is to say, possibly without meaning. Such a division is, obviously, epistemologically founding.



## 6 On symbolic invention in mathematics.

### The contributions of Leibniz

First of all, I will point out that, among the genuine reasons as to why symbolic writing has so completely triumphed in sciences today, there is another reason, rather than the above-mentioned Darwinian reference (i. e., the survival of the fittest). Mathematical symbolism has, moreover, another capital function; that of *to allow to invent*. The mathematician, our contemporary or that of Leibniz, can indeed receive suggestions from symbolism, and invent concepts and/or objects. So, in a way that may seem unexpected, such a process involves “forms without meaning” and the coextensive creation of mathematical objects.

#### 6.1 Return to fractional exponentials

I come back to the 17th century and the correspondence that Newton had sent to Leibniz in June 1676 (see section 5 above). In his desire to expose what is now called the “infinite binomial theorem”, Newton used a very surprising substitution in the Cartesian exponential, producing a symbolism as  $p^{\frac{m}{n}}$ . In other words, at the place where Descartes had placed an integer in exponent, as in the  $2a^3$  of the *Regulae*, Newton substituted a fraction, a quotient of rational numbers. Nothing in Leibniz’s previous experience at that time could let him anticipate what meaning Newton could bring in symbolic forms such as  $5^{\frac{1}{3}}$  or  $3^{\frac{2}{5}}$  or else  $(2x + 7)^{\frac{3}{4}}$ . As I have already said, this substitution was, however, neither a challenge nor a joke and today, it is universal in exponential representations.

This exponential example was decisive for the development of a method. Indeed, one can verify – cf. RS: 366–376 – that a same epistemological scheme (with elective formulas and extensions) was at work in the creation of extremely diverse objects, both in the 18th century in Euler (complex exponential, or “factorial” new) and the contemporary period (Moore-Penrose pseudo-inverses, derivation in the sense of distributions, etc.). Such constructions, even if they are more complex to analyse, are, in fact, an exemplary of the scheme.

#### 6.2 On the origin of success. The “Invar-Ext” scheme

On this point, here I will summarize, very briefly, what I have detailed elsewhere. Ultimately, the procedure is governed by this primordial requirement, transcending the requisites of any immediate signification; namely, *the permanence of some mathematical symbolic writings (the elective formulas)*, that nothing, in the foundations of effec-

tive mathematics, does *a priori* request – cf. RS: 376. This procedure, later established as a contingent methodological guide in the research, will be what I will call here the *epistemological scheme of Invariance-Extension* (and more briefly “Invar-Ext”). In other texts, I had denoted this pattern as the “principe de prolongement” (Extension Principle; cf. Serfati 2002). Again, the whole procedure shows one of the aspects under which the advent of symbolic writing contributed, from the 17th century, to invention within mathematics, thus trying to enlighten, in part, the intimate nature of this “power to create” among mathematicians that Dedekind evokes and that Cavaillès points out. I cannot here develop these conclusions more (cf. Serfati 2002).

### 6.3 Leibniz and the mathematical symbolism

As we have seen throughout this article, Leibniz’s contributions, in the construction of modern mathematical symbolism, as well as in the practices of invention, have been considerable. There were still other very important contributions from him, such as the invention of “fictive” numbers (such as, for example, the symbolism “21”, to designate the coefficient of a second unknown in a first equation). This last definition, unknown before Leibniz, is capital, today as yesterday, in the “intimate” seizure and in the manipulation of polynomials and power series – especially in the case of a proof by recurrence. Leibniz also introduced, for the first time in history, a symbol of operational exhaustiveness (the diacritical mark of “two-dots”), such as:

$$a^2 \cdot b$$

Such symbolism denotes the *sum of all similar terms* (in some sense) to  $a^2b$  (as, for example,  $x^2y$ ). These two inventions, which testified exceptional epistemological thought from Leibniz, are crucial in the writing of mathematics today. The exhaustive summation is today represented with a symbol  $\Sigma$ . The epistemological scheme, however, remains that of Leibniz (cf. Serfati 2001). I have studied these various innovations in detail in Serfati (2001).

### 6.4 Leibniz and symbolic invention in mathematics

Thus, the invention in mathematical symbolism was, on the part of Leibniz, a fundamental activity and by no means anecdotal. As Marcelo Dascal pertinently notes, his practice stems from his philosophical positions on the symbolism:

‘Semiotic’ considerations of this kind appear almost everywhere in the mathematical work of Leibniz. They clearly show that the invention of adequate mathematical notations, one of Leibniz’s fundamental concerns in this field, was guided by general principles and did not constitute a purely *ad hoc* activity (Dascal 1978: 215).

Also, this symbolic invention was sometimes made, as I have already noted above, apart from any question of immediate signification. Relying on the *Characteristica* of 1679 (GM V: 141–168), Dascal, describing the conceptions of Leibniz, writes:

It is possible to perform all necessary operations without having to worry about their ‘meanings’. In other words, again, one can proceed as in a formal, uninterpreted calculation. The success of this procedure, and the possibility of obtaining at the end a correct interpretation is guaranteed by the establishment, from the beginning, of a correspondence between characters and ‘things’.

We have seen above, on the example of the exponentials, to what extent this philosophy of symbolism could be fruitful and Leibniz is, to my knowledge, the only commentator and practitioner of mathematics to have stated it in clear terms as an active operating principle.

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Benedetto Lepori and Sara Greco

## 18 Grant proposal writing as a dialogic process

**Abstract:** The goal of this chapter is to provide some directions for a broader understanding of grant proposal writing as part of a socially and institutionally embedded communicative process between scientists and funding agencies. It involves a variety of (formal and informal, textual and oral) communicative exchanges and the production of a network of interconnected texts – including grant proposals, but also decision letters, external reviews and guidelines by the funding agencies. First, we provide a “primer” on the grant proposal process, highlighting its main characteristics, the nature of the interactions that take place and the type of texts that are produced in each phase. Second, we review the literature on grant proposal writing and on textual features of grant proposals, highlighting particularly those studies that open to a broader understanding of grant proposal writing as a communicative and dialogic process. Third, we illustrate three directions to further our understanding of the communicative process and function of grant proposals, i.e. a) introducing a representation of the communicative context that allows understanding how the textual characteristics of grant proposals are related to key dimensions of their context, b) analysing grant proposal writing as a dialogic process that unfolds through different social and communicative interactions and over time and c) interpreting grant proposals as part of an argumentative dialogue, which enables the reconciliation of their rhetorical goals with the pursuit of reasonable argumentation around the notion of *strategic manoeuvring*.

**Keywords:** grant proposal writing – funding agencies – argumentation in context – strategic manoeuvring – scientific dialogue – literary genres

### 1 Introduction

As witnessed by other chapters in this handbook, studies of science communication so far largely focused on two dimensions: first, communication of science to the public, covering topics like popularization and public understanding of science (see Chapters 4, 5 and 19 in this handbook) and the use of scientific expertise in political decisions (see Chapter 23); second, the study of communication processes within science, including the characteristics of scientific papers and books (see Chapter 10), scientific controversies (see Chapter 15) and the study of disciplinary differences in communication (see Chapter 16 and 17). However, particularly after the Second World War, science underwent a process of institutionalization: in most countries, science policy has become a recognized and institutionalized policy domain through

processes like the definition of national scientific priorities and the negotiation of a national research budget (Guston 2000). While practices of fund-seeking have a long tradition in science, their relevance clearly escalated after the Second World War following also the rapid increase of the science budget in the developed countries (Stephan 2013). The allocation of funds largely takes place through funding agencies evaluating grant proposals submitted by researchers (Braun 1993); universities have become strategic actors that actively manage internal decision-making processes, but also their relationships with the state and society (Bonaccorsi and Daraio 2007).

This process of institutionalization also created new communicative arenas and processes that share three features: first, they tend to be more formalized and regulated than communication within science and with the public, as they are embedded within formal decision-making structures and processes; second, they typically involve different audiences, like policy-makers, scientists and research administrators, sharing different cultures and the related language conventions; third, they are not geared towards developing and disseminating knowledge, but towards more mundane and pragmatic goals, like deciding about priorities and allocating resources.

In this context, the process of writing, submitting and evaluating grant proposals – a general term we adopt to label texts submitted by researchers to funding agencies to acquire funds – represents an interesting case study that highlights some important features of institutional communication within science. This (communicative) process has become a central component of researchers' activities in the last decades, since governments consider it as a convenient way to target resources to the best researchers and to selectively promote scientific domains of policy interest (Dasgupta and David 1994; Lepori 2011). So-called “project funds” allocated in this way currently account for between one-quarter and one-third of public subsidies for research in most Western European countries and for the largest part of public research funding in the US (Lepori et al. 2007).

Grant proposals are part of an interesting process from the perspective of science communication: they are communicative acts directed to a policy audience and, therefore, involve the interplay between different social communities and the involved discourse genres (Tardy 2003); the communication process is centred around a specific and formalized text, the *grant proposal*, that is embedded in a web of less formal communicative exchanges and dialogues (Tseng 2011); finally, grant proposals can be considered as “promotional” texts to convince the state to disburse funds and, therefore, raise questions on the function of rhetoric and argumentation in science communication (Keith and Reigh 2008).

As we highlight in section 3 of this chapter, there are a few studies that focused on the textual features of grant proposals, like the presence of rhetoric or argumentative moves (Connor and Mauranen 1999). On the contrary, studies of how grant proposals are negotiated between scientists and funding agencies (Myers 1985), respectively studies that embed the textual features of grant proposals within their broader institutional and communicative environment (Tardy 2003; Tseng 2011), are exceedingly

rare. The literature that focuses on the linguistic and rhetorical aspects of proposals also lacks a realistic representation of the institutional context of grant proposal writing (see the discussion on communication contexts in Rigotti and Rocci 2006). Such a representation would allow linking the meso-level of the communicative interaction context (and its variation across scientific domains, countries and applicants) with the micro-level rhetoric and linguistic processes adopted in the proposal's text.

The goal of this chapter is to provide some directions for a broader understanding of grant proposal writing as a part of socially and institutionally embedded communicative process between scientists and funding agencies that involves a variety of (formal and informal, textual and oral) communicative exchanges and the production of a network of interconnected texts – including grant proposals, but also decision letters, external reviews and guidelines by the funding agencies. Such a programme brings together insights from distinct traditions in the study of science communication, i.e. sociology of science and science policy studies (see Latour 1987 and Keith and Reigh 2008), ethnographic studies of textual production in science (Bazerman 1981; Myers 1985), studies of the textual features of grant proposals (Connor and Mauranen 1999; Feng and Shi 2004) and finally studies of argumentation in social contexts (Van Eemeren and Houtlosser 2009; Rigotti and Rocci 2006).

We enact this programme in three steps. In section 2, we provide a “primer” on the grant proposal process, highlighting its main characteristics, the nature of the interactions that take place and the type of texts that are produced in each phase.

In section 3, we review the small literature on grant proposal writing and on textual features of grant proposals, highlighting particularly those studies that open to a broader understanding of grant proposal writing as a communicative and dialogic process (Myers 1985; Tseng 2011; Tardy 2003).

In section 4, we illustrate three directions to further our understanding of the communicative process and function of grant proposals, i.e. a) introducing a representation of the communicative context (Rigotti and Rocci 2006) that allows understanding how the textual characteristics of grant proposals are related to key dimensions of their context (see Connor 2000), b) analysing grant proposal writing as a dialogic process that unfolds through different social and communicative interactions and over time (Tseng 2011), and c) interpreting grant proposals as part of an argumentative dialogue, which enables to reconcile their rhetorical goals with the pursuit of reasonable argumentation around the notion of *strategic manoeuvring* (Van Eemeren and Houtlosser 2006).

We conclude the chapter with a discussion of the potential benefits of such a broader communication approach to grant proposals for studies of science in general and of science communication more specifically.



## 2 Grant proposal writing: a primer

We describe the core of the communicative process as a dialogue between the funding agency and the applicant (Tseng 2011). This process starts with the issue of a call for proposals by the agency, goes on with the process of writing a proposal (including internal reviews by colleagues; Myers 1985) leading to the submission of the grant proposal. Thereafter, the agency evaluates competing proposals based on their merit, takes funding decisions and, finally, issues an agency's response, i. e. a decision letter that communicates whether the funding agency decided to fund the project or not and provides arguments supporting the decision.

We highlight three aspects of this exchange that have deep implications on how proposals are written. First, the dialogue is highly institutionalized. The agency sets the stage by defining the goals to be achieved and the evaluation criteria in the call; it also provides guidance on how the proposal should be organized (structure, table of content, requirements) and on the administrative and financial requirements. While other forms of scientific communication are also characterized by norms on how texts should be written, grant proposals display two distinguishing features: first, rules are more formalized and, accordingly, leave less room for manoeuvring to grant writers – for example, the structure of the table of contents is usually mandatory; second, unlike scientific papers where conventions are largely discipline-specific (Bazerman 1988), (formal) rules for grant proposals tend to be generic. An important question is therefore how applicants manage the overlay between the generic formal structure and the domain-specific arguments.

A second aspect is that the interaction process (and the relative communicative exchange) is *repeated over time*: most scientists submit proposals repeatedly to a funding agency and most of grants are awarded to a restricted core of applicants who receive grants regularly (Viner, Green, and Powell 2006). In economic terms, grants can be seen as a way of avoiding a major risk of funding projects, i. e. shirking by scientists (Braun 1993), by awarding resources only for a short period of time and linking the award of further grants to the outcome of the previous ones. In communication terms, grant proposals can be seen as a part of a communicative process in which applicants negotiate with a funding agency over the merit of specific line of inquiry (Myers 1985) and on the results that would justify the continuation of funding. Some traces of this dialogue can be found in proposals (for example one might find references to previously funded projects), but most of them remain implicit, albeit they are relevant for the arguments brought forward by applicants.

Third, unlike scientific reports, grant proposals are a promise of future research and, therefore, involve some level of uncertainty – the funding agency does not only assess the relevance of the proposal to its goals, but also the credibility of the promises made (Lepori and Rocci 2009). Yet, credibility claims need to be substantiated by arguments referring to the past track record of the applicant, the availability of research facilities, the presence of institutional support, etc. In other words, affor-

dances related to the specific contextual situation constrain and at the same time enable the promotional act by the grant writer (Tseng 2011) and its associated rhetorical and argumentative strategies (see further in section 4).

This highly formalized and apparently impersonal communicative exchange embeds two other types of exchanges that involve different audiences and are more domain-specific.

First, within funding agencies, proposals are usually evaluated by peers in the same scientific domains – while they are not directly identifiable, grant writers are well aware of their presence and might target a specific disciplinary audience by providing signals like keywords, a title, or references. The dialogue with the peers concerns selected aspects of the grant proposal, like the credibility of the claim, the soundness of the methods, etc. This exchange is embedded within the broader scientific dialogue in that domain and largely builds on arguments and validity claims from the scientific discourse.

Second, grant proposals are embedded within a policy arena, as funding agencies receive resources from the state responding to policy goals and, therefore, are requested to mediate between policy demands and scientific priorities (Guston 2000). Such requests are frequently conveyed to grant writers by introducing specific sections in the proposal, for example sections that require to detail the project's contribution to gender equality or its social impact. The dialogue here is even more indirect, given that policy-makers and societal stakeholders are usually not part of the evaluation process; the policy arena might however provide argumentative resources to grant writers to argue about the relevance of their proposal. How they come to play into the grant writing process will however depend on the institutional setting of the agency and of the funding programme (Connor 2000).

In grant proposals, these two dialogues are embedded within the generic formal structure of the proposal. Some sections clearly signal to the applicants which dialogue (and related discourse genre) to select – the state of the art section mostly belongs to the scientific dialogue, while social impact to the policy one; in other sections, like the research question one and, most notably, the proposal summary (Feng 2006), the different dialogues tend to overlap (see section 4).

This analysis illustrates the importance of considering grant proposals as texts directed to multiple audiences and, beyond the generic statement that grant proposals involve different literary genres (Tardy 2003), the need of defining analytically the roles and interests of stakeholders within a proposal in order to understand the argumentative strategies deployed by grant writers (Palmieri and Mazzali-Lurati 2016).

### 3 Literature review

When compared with the large literature on scientific texts (Bazerman 1988) and, even more, scientific communication, the literature on grant proposals is exceedingly small, including probably not more than a couple of dozens of international publications in the last two decades. This might be explained by two reasons: first, the lower visibility and accessibility of grant proposals, since they are not public; second, a general neglect of the institutional dimension of scientific communication (section 1).

The available literature on the research grant proposal can be roughly categorized into two traditions (Tseng 2011). The first tradition focuses on the description of the generic structure of proposals (e. g. Connor 2000; Connor and Mauranen 1999), whilst the second focuses on the social and cognitive dimension of grant proposals (Myers 1985; Tardy 2003; Tseng 2011).

The first stream considered grant proposals as forms of persuasive writing and focused on the identification of the rhetorical moves, defined as “a discoursal or rhetorical unit that performs a coherent communicative function in written or spoken discourse” (Swales 1990: 228). These studies have shown that writers of grant proposals mobilize a set of generic moves, like the identification of a “gap” in the existing knowledge, a “competence claim”, arguing for “benefits” of a proposed research project, etc. (Connor and Mauranen 1999). Beyond this stylized representation of persuasion in grant proposals, following studies observed variation in the use of moves depending for example on the nature of the funding programme and identified four recurrent moves, i. e. the “territory”, the “gap”, the “goals” and the “means” moves (Connor 2000). Other studies adopted corpus-linguistic techniques to quantitatively measure the frequency of moves in grant proposals, thereby showing systematic patterns in their recurrence and distribution among different parts of a proposal (Feng and Shi 2004). While these studies provide some general insights on the rhetorical structure of grant proposals, generic moves remain very shallow and do not allow to grasp the specific strategy deployed by grant writers to convince their multiple audiences within a specific context. Moreover, the study of these moves tends to be detached from an understanding of the different argumentative dialogues which a grant proposal is part of.

The second stream builds on the notion that texts are constructed within social interactions, but at the same time constitute norms for communication within specific communities of practices (Bazerman 1981). This is typified in discourse genres, i. e. largely standardized ways of expressing situations or recurrent patterns of action (Tardy 2003). Genre studies of grant proposals shift therefore the focus to their conventional nature and tend to go beyond the textual surface to inquire about the social interactions that generate such texts. In this perspective, grant proposals are not seen as written strategically to convince the funding agency to provide money, but rather co-constructed in an interactive process between scientists and the funding agency. In one of the most cited ethnographic studies of academic writing, Myers analyses the

process of successive revisions of two biologists' grant proposals, in which the acceptable claims are negotiated between authors, reviewers and the funding agency (Myers 1985). He demonstrates how the research agenda and the *persona* of the writer evolve in this process – showing how grant proposal writing shapes its own authors and, therefore, contributes to the enforcement of social norms in science (Latour 1987). The analysis of the interactions within grant proposal writing highlights the overlap and coexistence of different discourse communities and of the related discourse genres, showing how grant writers continuously switch between genres (Tardy 2003). In such a perspective, writers need to be acquainted in proposal writing through a socialization process (Tardy 2003), particularly for what concerns young scholars through a process of apprenticeship (Ding 2008).

Moving beyond these studies, Tseng analyses the grant proposal genre as a form of dialogue in the Bakhtinian sense – to see it less as a mere type of conventionalized text with a communicative purpose, but as a synthesis emerging from a series of interactions between participants (Bakhtin 1981; see also section 4.2). Moreover, he argues that proposals have inherently a pragmatic and performative function that takes place in three main acts, i.e. the self-promotion of the grant writer, persuasion and promise. In this perspective, writers mobilize and enact moves strategically, by taking into account their specific environmental affordances (Tseng 2011). His analysis moves therefore from the focus on the conventional and standardized characteristics of grant proposals towards the inquiry of how the genre features are mobilized by writers within a specific context of interaction.

We highlight three gaps in this literature. First, there has been limited connection between the analysis of textual features on the one hand, and of the one of social context on the other hand. Indeed, the two traditions stay largely separated and at different levels of analysis (writing process vs. the textual content). Yet, identifying recurrent rhetorical patterns and other linguistic features is only useful if we understand how these are used within a dialogic relationship between applicants and funding agencies, what their function is within an argumentative dialogue and what their limits might be.

Second, this literature is characterized by a somewhat non-realistic introduction of the social context of writing because of lack of suitable analytical categories of how institutional contexts are “realized” through communicative flows (like the categories provided in the model by Rigotti and Rocci 2006), but also because of lacking links with science policy studies and their extensive analysis of the grant application process (Braun 1993; Guston 2000). Institutional differences between national contexts as of their scientific priorities, but also between administrative contexts have also been largely overlooked (Lepori et al. 2007); the same applies for the difference in mission, organization and social structure between funding agencies that are likely to strongly influence how proposals should be written (Braun 1998).

Third, there is limited understanding of the specific argumentative nature of grant proposals – like all other texts in science (Rehg 2009) – on the relationship between

rhetorical features and argumentation and on how argumentation in grant proposal is enabled and co-constructed over time by scientists and funding agencies.

## 4 New directions

### 4.1 Conceptualizing context and its implications for grant proposal writing

As introduced in section 2, grant proposals are a standardized discourse genre that fits within complex dialogical relationships involving multiple institutional actors. This complexity and the need for accountability make this communication context a highly regulated one (section 2). In order to get a project funded, a researcher will know what opportunities he or she has (in terms of open calls and other initiatives), which are open to the whole scientific community and have pre-defined selection criteria. The type of texts to be sent will also be clearly regulated.

For this reason, grant proposal writing counts as a *communicative activity type*, intended as a conventionalized type of communication (Levinson 1979; Van Eemeren 2010). To describe the communication flows expected within this activity type, we refer to the categories elaborated by Rigotti and Rocci (2006) to describe communication contexts in such a way that the institutional dimensions are re-interpreted with a focus on the expected communication that they create. Of course, the possibilities for human interaction are never *totally* pre-determined by an activity type, even in cases – like this one – in which there is a high level of formality and very clear institutional expectations. However, a model of context allows describing some lasting characteristics of the interaction context, which frame and sometimes limit the co-construction and negotiation process that has been highlighted in previous studies (for example, Myers 1985, see section 3) and might help generalizing some findings of this tradition.

According to Rigotti and Rocci (2006), communicative activity types are composed of an *interaction field* and an *interaction scheme*. An interaction field is defined as “that piece of *social reality* where the communicative interaction takes place” (Rigotti and Rocci 2006: 172, emphasis in the original). Interaction fields – like the complex web of institutions that we have described in section 2 – are defined and distinguished by their shared goals. Interaction fields could be seen as containers of interaction, because they pre-determine a range of communicative and non-communicative interactions.

Within each interaction field, different interaction schemes will be enabled; interaction schemes are “culturally shared ‘recipes’ for interaction” (Rigotti and Rocci 2006: 173), which respond to specific goals, including, for example, deliberation, dispute mediation, teaching, problem-solving, counselling, and others. Deliberation,

for example, can be applied to a broad range of interaction fields to achieve the goal of making collective decisions; deliberation in a school board will be different from deliberation in a research funding agency, in terms of goals, roles and procedures, although there will be common traits concerning how this type of interaction scheme should work. Any specific activity type is created when an interaction scheme is mapped onto an interaction field (Rigotti and Rocci 2006: 173).

*Grant proposal writing in science*, in this sense, can be considered as an activity type: it combines the interaction scheme of grant proposal writing with the interaction field of scientific research funding. Grant proposal writing per se, in fact, is a scheme that can be applied to different interaction fields (e. g. one might write proposals in domains other than science). Grant proposal writing in science acquires the specific characteristics of the research funding interaction field, such as the presence of different segments of readers in the public (see below), or the expectation of a high standard argumentative text (section 4.3).

In this interpretation, some of the micro-linguistic and rhetorical patterns that have been analysed in grant proposals (see section 3) can be comprehended as strategic moves to be interpreted within the broader functions of this activity type. In fact, analysing specific linguistic or rhetorical patterns in isolation does not take into account the global context in which these patterns are used (Bakhtin 1981); interpreting grant proposal writing as a communicative activity type gives a perspective that, starting from the goals of grant proposals and the broad communication contexts, permits to better account for micro- and macro-strategies at the textual level.

Rigotti and Rocci (2006) draw a second distinction between an *institutional* and an *interpersonal* dimension of context. This distinction calls attention to the fact that institutional roles in any interaction field will be covered by individuals, who are connected to institutions through *agency relationships* (in the sense of economic theory): they will have their own goals, perceptions, personal histories and narratives. Albeit institutional roles (researchers, reviewers, policy makers) appear as prominent in the context of research funding, interpersonal communication has some importance even in a highly regulated genre such as grant proposal writing is. For example, as remarked in section 2, the personal research record of a single researcher and his or her international reputation will play a role, as funding agencies will be more likely to fund proposals coming from well-established and internationally well-known researchers. In communicative terms, this may be subsumed under the term *ethos*, an Aristotelian term that refers to the speaker's (or communicator's) personal authority and is one of the components that influence persuasion (see McCroskey 1966).

Also, it has been shown that if applicants know someone in the board of reviewers or decision makers personally, their chances of getting funded are higher (Van den Besselaar and Leydesdorff 2009), while the core of successful applicants is essentially composed of well-embedded and networked people that are also frequently involved in the evaluation process (Viner, Green, and Powell 2006).

The apparently highly formalized and institutionalized interaction taking place

in grant proposals covers in reality a dense web of personal relationships and interactions that are highly relevant to understand the specific textual strategies of applicants and the outcome of proposals.

## 4.2 Grant proposal writing as a dialogue

The activity type of grant proposal writing in science is realized by means of a *dialogue* that is performed through highly institutionalized means: funding agencies publish calls for proposals (regularly or ad hoc), researchers respond to those calls through documents that count as communicative acts, grant proposals being a typical case in point.

A scientist who writes a proposal for the first time is asking to enter a dialogic relation with policy makers. A funding agency or a government that establishes new opportunities for funding significantly changes the context by opening new possible communication flows. In a Bakhtinian perspective, any text is inherently and internally dialogical, because it is shaped by preceding discourses and anticipates other discourses (Bakhtin 1981). In the specific case of grant proposal writing, the dialogic relationship does not only regard researchers and funding agencies.

Notably, funding agencies are complex institutions and, therefore, a grant proposal will be read by people with different roles. It will be read by policy makers; it will also be read by research administrators who check whether it is formally adequate (in terms of number of words, eligibility criteria, etc.); it might be read by scientists of different disciplines who are permanent consultants of the funding agency and make final decisions over acceptance/rejection of proposals. Finally, it will normally be read by (international) reviewers in the same disciplinary field as the applicant, who will be asked to evaluate its scientific quality.

Researchers who apply for funding are normally aware of these different levels of readers (section 2) and write their proposal trying to carefully take into account all of them. A grant proposal is a typical *multi-audience* text with a variety of *ratified readers* that are anticipated by the writer. It is even difficult to identify one single category of addressees (Palmieri and Mazzali-Lurati 2016: 480) for this text. An applicant will probably primarily address policy makers and reviewers equally; given the difference in institutional roles, their expectations, knowledge and backgrounds will be different; therefore, an applicant will carefully weight arguments for both categories (see section 4.3). An applicant will also be aware of *meta-readers*, who “are expected to read the message without, however, entering into the merit of its content and argumentation” (Palmieri and Mazzali-Lurati 2016: 480). In the case of grant proposals, meta-readers include ethical committees and functionaries who will formally check the adequateness of the texts. An applicant will strive to write a text that will be accepted by meta-readers, lest the proposal should be excluded from the competition because it does not meet formal criteria.

As mentioned in section 2, some categories of readers might be prioritized in some sections of the proposal – for example, the literature review is primarily addressed to reviewers – but in some sections the different dialogues between an applicant and all the addressees are kept together. Therefore, an applicant is contemporarily managing different levels of dialogue when making specific rhetorical and argumentative moves. In this sense, applicants continuously shift across genres (Tardy 2003) because they manage multiple dialogues simultaneously. At the same time, managing these different tasks and levels is part and parcel of the one communicative activity type of grant proposal writing.

### 4.3 Argumentation in grant proposal writing

#### 4.3.1 A purposefully designed argumentative dialogue

The dialogue between researchers and funding agencies that is typical of the activity type of grant proposal writing may be qualified as an *argumentative* dialogue or *argumentative discussion* as shown in Lepori and Rocci (2009).

Broadly speaking, argumentation might be defined as a persuasion-oriented discourse ideally oriented to reasonableness. However, as Schwarz and Baker (2017: 67) observe, “the term ‘argumentation’ covers several related phenomena” that vary across theories. Some approaches highlight the dialogical nature of argumentation as part of a social interaction (see for example Plantin 1996). In this paper, we adopt a broad pragma-dialectical perspective, which sees argumentation as a *critical discussion* (van Eemeren and Grootendorst 2004) and is, therefore, part of the dialogical approaches (see Schwarz and Baker 2017: 68). The focus on argumentation as a discussion is crucial in our approach, as we are trying to explain a communication dialogue between scientists and funding agencies. Moreover, the concept of *strategic manoeuvring*, elaborated within pragma-dialectics (van Eemeren 2010), is particularly fitting for the context of scientific communication, as it enables to illuminate some of the dimensions of persuasion as based on rational grounds.

The main aim of researchers who write proposals is to obtain money, and they will need to persuade the funding agency that their research plan is worth funding – more than those of competitors. Persuasion needs to be based on arguments. Grant proposal writing, thus, counts as communicative activity type that is fully argumentative (according to the typology proposed by Van Eemeren 2010: 146). As analysed before, grant proposal writing is a dialogic discourse genre, embedded in a complex communication context and addressed to a multiplicity of different readers.

Its argumentative nature is thus best understood by assuming a *dialogical* perspective on argumentation, such as the one proposed by pragma-dialectics (Van Eemeren and Grootendorst 2004). In this perspective, argumentation is seen as an ideally reasonable discussion (*critical discussion*), in which arguers will try to solve



a *difference of opinion on the merits*, i.e. without renouncing reasonableness whilst trying to pursue their goals. The context of research funding, as we have outlined above, de facto creates an (implicit and anticipated) difference of opinion. When applicants prepare a proposal, they know that they will need to explicitly justify why their proposal is better than others. In a competitive context, in which research funding can only cover a minority of the submitted projects, this difference of opinion requires to be solved by good arguments. Each applicant is in opposition to the others, because of scarcity of resources.

Despite competition, however, applicants will tend to provide a reasonable argumentation, i.e. one that is well-founded and not manipulative. There might be different reasons for this commitment to reasonableness. The main reason depends on the interaction field: grant proposal writing in science is embedded in the scientific discourse, which is argumentative by nature, and inherently based on rational dialogue (Latour 1987).

Moreover, other contextual constraints in grant proposal writing play a role in the participants' commitment to reasonableness. First, the activity type of grant proposal writing normally foresees a long-term relationship between an applicant and a funding agency; being known for an ethical and responsible behaviour is crucial for future communicative interactions. Second, applicants are aware that their proposals will be read by multiple addressees; there will be competent readers for each and every area touched upon in the proposal (from disciplinary knowledge to data and timing management, to social implication of research), which makes it difficult to make claims that are not reasonably grounded. A third reason is that, if applicants need to justify why their project is eligible for funding, funding agencies are *accountable* for how they use public money, particularly since the diffusion of New Public Management rationales (Ferlie et al. 1996). Therefore, they are equally subject to an argumentative requirement to give reasons for the projects they accept and for those they reject.

Reasonableness is always to be understood as a normative ideal for argumentation. This means that it is neither automatic nor compulsory for applicants (or funding institutions) to produce reasonable argumentation, as every arguer always has a choice. However, the reasons outlined above show that the institutional context of research funding, which we have described in sections 4.1 and 4.2 from a communicative and dialogic viewpoint, is purposefully created to be as reasonable as possible with an effort of *argumentation design* (Jackson 2015). As things stand, for an individual arguer, deciding to act within the boundaries of reasonableness means both to comply with norms imposed by scientific discourse in general and by the activity type of grant proposal writing in particular; and to co-design it by creating (and, possibly, modifying) standards of successful practices of dialogical negotiation.

### 4.3.2 Strategic manoeuvring in applicants' argumentation

Before proceeding to illustrate how argumentation is structured in grant proposals, it is worth noticing that, so far, research on grant proposal writing is still scanty. The role of argumentation in science has been investigated for other types of activity (see Keith and Reigh 2008 for an overview). Most works concern scientific controversies (Dascal and Boantz 2011; Van Eemeren and Garssen 2008; Fahnestock 2013) and the problem of how scientific results are communicated to the wider public; the latter topic is intertwined with the problem of argumentation from authority and its limits (Walton 2010; Goodwin and Honeycutt 2009; Goodwin et al. 2014; Greco Morasso and Morasso 2014).

In grant proposal writing, applicants will make efforts to present reasonable arguments that make their proposal stronger than their opponents. In terms of a pragma-dialectical theory of argumentation, this “continual efforts made in all moves that are carried out in argumentative discourse to keep the balance between reasonableness and effectiveness” (Van Eemeren 2010: 40) is called *strategic manoeuvring* (Van Eemeren 2010: 40). For an applicant, manoeuvring strategically means trying to achieve their goal of getting a proposal funded through the use of reasonable argumentation. A noteworthy feature of argumentation in science is that it tends to be largely covert within textual elements that might look purely descriptive and/or objective, like presenting a state of the art (to argue the topical relevance) or a project plan (Bazerman 1981). While this feature may represent a challenge for textual analyses looking for explicit markers of argumentative patterns, we generally consider that all the content of grant proposals has an argumentative nature, very much like other scientific texts (Latour 1987). Descriptive and narrative parts, in fact, can be considered as subservient to the overarching goal of persuasion, which is achieved through argumentative means. Notably, the choices at the level of strategic manoeuvring that we are going to detail in what follows are relevant not only in those bits of the proposals that are more explicitly argumentative, but also in the descriptive and narrative sections, which contribute to the overarching argumentative aim of these texts.

There are three inseparable aspects to strategic manoeuvring, which create a strategic manoeuvring triangle: adaptation to *audience demand*, *topical potential* and *presentational devices* (Van Eemeren 2010: 95). The three aspects work together and determine the delicate balance that an applicant will have to consider when writing a proposal. In what follows, we will briefly discuss how each of these three aspects will have an impact on grant proposal writing in science as an activity type. Our discussion is meant to open research avenues for the study of grant proposal writing as scientific communication.

In the case of grant proposal writing, *adapting to audience* is crucial. In section 4.2, we have briefly outlined the different levels of addressees that are typically to be foreseen in grant proposal writing: applicants will have to adapt to these different

addressees simultaneously. On the one hand, it is likely that they will write keeping in mind the objectives and keywords of the policy makers at the funding agency (Lepori and Rocci 2009: 183). On the other hand, they will anticipate an average potential reviewer, and imagine the arguments that will be persuasive for such a reviewer. The preferences of the two categories do not always coincide; if this is the case, applicants will have to fine-tune both levels of addressees, for example by advancing different arguments that could be more persuasive for the one or the other group of readers. Finally, applicants will also bear in mind the expectations of functionaries who check the formal aspects of their proposal; this does not determine content choices but layout and structure might be heavily influenced by this segment of audience.

*Topical potential* refers to “the (not always clearly delineated) repertoire of options for making an argumentative move that are at the arguer’s disposal in a certain case and at a particular point in the discourse” (Van Eemeren 2010: 93–94). As Lepori and Rocci (2009: 179–180) suggest, manoeuvring strategically with the topical potential in grant proposal writing means selecting good arguments within the boundaries of a structure that is to some extent pre-defined by the call.

Normally, the main standpoint of an applicant will be: “The proposed research R is worth funding” (Lepori and Rocci 2009: 179). This standpoint will be jointly supported by two arguments: a “relevance claim” (“The proposed research R furthers significantly the objectives of the funding agency”) and a “credibility claim” (“The proposed research R is likely to be successfully carried out by the applicant”) (Lepori and Rocci 2009: 179). Both the relevance and the credibility claim will be backed by further arguments; in order to select them, applicants will capitalize on their personal strengths.

For example, the personal ethos of a researcher (see section 4.1 above) might make a difference: an established researcher will find it easier to prove that he or she is capable of producing scientific results; whilst a young researcher will make other aspects more salient (showing, for example, that he or she has a promising CV and an international reputation despite his or her young age).

The selection within the topical potential in grant proposal writing also touches upon a more structural aspect. Applicants, in fact, will not simply select between arguments at a micro-level within the single sections of a research proposal. They will also need to select a research topic for their proposal, which they deem suitable to be funded (Lepori and Rocci 2009). Then, they will create a coherent text within the proposal, going through the constraints imposed by the different sections, and trying to design a text that is persuasive and consistent as a whole. In other words, applicants will manoeuvre strategically to cover all aspects that are required, whilst introducing and arranging the different parts in such a way that makes the proposal a convincing narrative about a problem and how to solve it. Arranging the materials – in terms of sections and sub-sections is part of the presentational devices (see below). It is normal that the three aspects of strategic manoeuvring in argumentation work together, as they are interrelated in each move. For example, by deciding to focus on different

strengths, applicants can give different *framings* of their proposals, thus emphasizing strengths over weaknesses, or putting some aspects in the foreground, if they happen to be in line with the funding call.

*Presentational devices* concern linguistic and semiotic aspects, i.e. “how the argumentative moves are to be presented in the way that is strategically best” (van Eemeren 2010: 94). Applicants will manoeuvre with presentational devices to write a text that is as conveniently arranged and written as possible whilst remaining in the boundaries of what is permitted by the funding agency (for example, in terms of layout, number of words, use of images and tables, etc.). In some countries, it is possible to manoeuvre strategically by choosing to write a proposal in different languages. In such cases, applicants will make a choice on the basis of their command of languages; they will also probably anticipate potential reviewers that are included (or excluded) by these choices.

As Lepori and Rocci (2009: 183) observe, presentational devices are the aspect that has been most studied in linguistic studies of grant proposal writing (see section 3 of this chapter). However, the significance and impact of such linguistic features and patterns are best understood if taking into account all the three aspects of strategic manoeuvring and the general pursuit of the applicant, who needs to do the most effective moves strategically in the framework of what counts as a “good argument” in terms of reasonableness.

The concept of strategic manoeuvring, as embedded in a dialogical view of argumentation, allows therefore to connect micro-linguistic choices to the communication contexts in which these choices are made. This gives a more profound understanding of how communication unfolds in this context. It also permits to understand strategic choices not only at the micro-level but also at the level of the whole proposal text as a communicative move (What problem it touches upon? How it is structured and why?).

## 5 Conclusions

In this chapter, we have focused on a specific form of communicative interaction between scientists and their funding and policy environment, i.e. grant proposal writing. Beyond the specific literature on that topic, we have introduced a set of theoretical concepts derived from discourse analysis and argumentation theory that help highlight the embeddedness of the communicative exchanges within a specific interaction context, but also understanding how the goals and strategies of the involved actors are enacted within a highly conventional form of texts as grant proposals. Most of these concepts will be useful to investigate other domains of institutional communication within science, like communication related to decision-making within universities about strategies and resources, respectively the communicative process around the design of research policy strategies.

Our intent was mostly programmatic and illustrative: while one of the authors, because of his professional experience, has a wide knowledge of grant proposal writing and communication, these concepts await for a deeper empirical investigation, conducted on a sufficiently large sample of texts to allow for generalization.

In this respect, we highlight two wide-reaching questions that emerge from the previous discussion. First, the tensions between conformity and uniqueness appear critical for proposal writing. By its nature, proposal writing is a highly formalized and conventional genre, in which the manoeuvring room of grant writers is strongly constrained by environmental affordances, like the conditions of the call, their research agenda and the available resources. At the same time, proposals need to be unique and distinctive in order to be funded, as only these characteristics will grant them a competitive advantage – the decrease of the success rates for proposals implying that, for most funding schemes, submitting a “correct” proposal would not be any more enough to be funded. On this matter, the literature adopted two extreme stances, considering either proposals as essentially conventional and focusing on their very generic characteristics (see for example Connor and Mauranen 1999) or as the unique outcome of individual negotiation between scientists and referees (Myers 1985).

In this chapter, we have introduced a number of analytical concepts that allow a more nuanced treatment of the relationship between conventionality and uniqueness, by distinguishing for example those moves that are generic to grant proposals as an interaction scheme from those specific to science (and even to specific disciplines). On the argumentation side, the concept of argumentative patterns, broadly defined as the constellation of argumentative moves used in particular situations to defend a standpoint (Van Eemeren 2016) would allow investigating how argumentative moves are combined and mobilized in specific contexts and whether they are effective within a specific dialogic interaction.

Second, a central, but yet unexplored question concerns the function of grant proposal writing for science in general, and research funding more specifically. We can broadly distinguish between three extreme stances, related to different scholarly traditions. (a) For most science policy studies, proposals are essentially a ritual process that allows funding agencies to be accountable and to claim that funds are attributed based on a rationale assessment and on good arguments, while in reality they are distributed based on social hierarchies in sciences and social networks (see for example Van den Besselaar and Leydesdorff 2009; Bornmann and Daniel 2004; Viner, Powell, and Green 2004). (b) For sociologically-oriented studies of science communication, grant proposal writing is a way to reproduce social conventions and standards in science, by linking resources to conformity by these standards, as assumed by the sociological literature (see e.g. Myers 1985; Latour 1987). (c) In the argumentative perspective that we have outlined in this paper, the context of grant proposal writing has been designed purposefully to enforce human reasonableness and to achieve the best possible result in terms of decision-making, i.e. selecting the best proposals based on reasonable arguments (Jackson 2015).

Addressing the question of the function and effect of grant proposal writing on the development of science would therefore help bridging different scholarly traditions around science communication and moving forward in understanding how the socio-institutional-structure of science (policy) co-evolves with its associated communication processes. While such issues have been extensively investigated for what concerns scientific communities and their epistemic development (see Merton 1968; Latour and Woolgar 1979; Bazerman 1988), they are still poorly understood for what concerns the institutional, socio-political and communicative infrastructure of science.

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### **III Science, scientists, and the public**



Wolf-Andreas Liebert

# 19 Communicative strategies of popularization of science (including science exhibitions, museums, magazines)

**Abstract:** The mediation of science is determined by many factors such as the actors, the addressee-related goals, the forms of knowledge and scientific traditions and paradigms, so that a uniform strategy of popularization cannot be described, as popularization is always relative to bundles of factors, which are referred to here as *prototypes*. Popularization strategies are always functionally linked to certain communicative goals that focus on addressees and their (knowledge) needs. For one of the respective prototypes, however, strategies of popularization can be described, which is carried out here using the example of mediation of science by a science journalist.

The changing communication landscape must also be taken into account: The mediatization associated with globalization is leading to a radical change in the popularization of science. Through the introduction of new media, recipients can become authors or co-authors and make their own claims to knowledge production. The late modern fragmentation of the public sphere is also creating increasing competition for attention, so that entertaining formats and news play an important role in the struggle for attention.

**Keywords:** science journalism – popularization – root metaphors – popularization strategies for science – popularization strategies for the humanities

## 1 Introduction

The concept of popularization has experienced many facets and changes. In communication science, it is classified as part of a communication model for science communication that can rather be assigned to the deficit model (e. g. Metag 2017; see also Chapter 5 in this volume). This model implies that successful science communication is considered to occur when experts make themselves understood by laypersons (i. e. those who have a deficit of knowledge) in such a way that they not only adopt the knowledge, but at best even increase their acceptance of science. In linguistics, the deficit model was criticized early on and the more complex model of the ‘relative layperson’ was applied (Biere 1989; Liebert 2002). This means that not only in the expert role, but also in the layperson role, it must always be indicated in relation to which domain of knowledge someone is a layperson. Thus a Nobel Prize winner in chemistry can also be a layperson, namely in relation to disciplines in which he or she is not an expert.

However, the popular not only serves as an input area for science communication, but also has its own dynamics (Feyerabend 1982). Here own forms of knowledge are generated, which are partly hybridized with scientific knowledge, partly also in explicit opposition to science with the claim to validity (Collins and Pinch 1993, 1998). The places of communication are diverse and range from film, print and social media to museums, science festivals and participative formats such as citizen science. The consideration of the complex lay concept and the popular thus multiplies the forms and manifestations of the popularization of science. A certain communicative strategy, which would be equally valid for all constellations, therefore cannot exist. Hence, communicative strategies of popularization can only be specified depending on the communication constellation, taking into account parameters such as actors, addressees, purposes or types of knowledge (e.g. sciences or humanities): that of the science journalist (see also Chapter 20 in this volume), who, through prior knowledge and in-depth research, has a knowledge advantage over his or her reader. It is important that this lead in knowledge lies in the nature of the matter and is not normatively proven, for example in the sense that the knowledge of the reader would be worse or deficient in any way, but is simply knowledge of a different kind. In the concrete reading situation, there is a constellation in which the reader wants to know, understand or experience something that the journalist has ahead of him or her at that moment.

This constellation can still be found in all possible reception situations, be it on YouTube (see e.g. Chapter 24 in this volume), in the children's university, reading a science magazine or watching a science show. However, the modelling has developed further, since the deficit model has proved empirically to be unsuccessful (see Chapter 5, this volume and Bonfadelli et al. 2017). In addition, communication situations have changed, since media use and reading (think of reader comments under online articles) today almost always include a feedback channel. Nevertheless, there is almost always the situation described above of a knowledge offer on the sender side and a knowledge search or a knowledge activation potential on the receiver side, say, one knows it, but hasn't thought about it for a long time and is happy to get it presented in a new context. It is at this moment that this text begins and analyses it from a linguistic point of view: What communicative acts are present here? How can they be characterized? Which acts can be identified as strategies of popularization?

## 2 Functional determinants of science popularization

In the following section, science popularization will be described by its communicative functions. It should therefore be asked for what purpose which (mediation) actors use which strategies for which addressees with which (knowledge) needs in which setting, in order to mediate which scientific knowledge of which domain and/or to acquire it?

The concept of *strategy* thus stands in a functional network of relations with actors, addressees, purposes, (knowledge) needs and much more, and cannot be viewed in isolation. In the following, the central variables will be characterized in more detail before we can talk specifically about strategies.

### 2.1 Actors

The generality of the above question allows not only scientists to act as mediators, but also actors who must first acquire scientific knowledge in order to convey it with a specific purpose. The concept of the actor was deliberately formulated so broadly as to cover not only scientists, but also non-scientific mediation agents and lay movements.

The first actors to be considered are individuals and institutions. These can be (relative) laypersons, professionalized intermediaries (e. g. science journalists) or genuine experts, i. e. researching scientists from the domain of knowledge to be mediated.

The concept of the layperson is therefore relative, not absolute: A quantum physicist may be a layperson in relation to a literary scholar and vice versa. The concept of actors used here is also open to the inclusion of non-human actors as mediators, as suggested by Bruno Latour (2004, 2013).

### 2.2 Addressees

Who are the addressees of science popularization? The determination of the addressees can initially be carried out in negative form: If one speaks of a popularization of science, then this presupposes on the part of the addressees the restriction that none of the addressees is at the same time recognized as a scientist of the domain which is to be mediated. This means that, conversely, there is a great heterogeneity in the origins and knowledge levels of the addressees, so that mediation actors can set relatively few prerequisites for mediation. This does not mean that scientists of the same domain would not or may not receive the products thus created, they are only *not addressed* to them, at least not in the first place.

The addressees are thus relative laypersons, to whom – as just explained – also belong persons who are at the same time scientists in a discipline and laypersons in relation to the discipline or domain of knowledge to be mediated.

By designating the addressees as non-scientists with regard to the scientific domain to be mediated, no mediation processes will be considered in the following which take place in the context of education or value creation, as they do, for example, in the implementation of scientific knowledge in technology and engineering, unless, of course, they would address a larger non-scientific audience – with regard to their domain – (e. g. with a press release).

### 2.3 Needs and communicative goals

The functionalization of communication presupposes certain knowledge requirements on the part of the addressees and certain communicative goals on the part of the mediators. Although it makes sense in principle to also ask about the needs of mediators, scientists and other stakeholders (see Born 2018), the relationship between the need for knowledge and communicative goals and the corresponding functional actions will be set out below. From a linguistic point of view, the following can be assumed as knowledge needs and communicative goals (see Liebert 2002: 79–84).

The addressees shall

- have a benefit, initial action pattern PRESENTING BENEFIT (e. g. advisor, consumer magazines)
- recognize a danger and protect themselves, initial action pattern WARNING (e. g. hygiene rules for epidemics)
- expand their knowledge horizon, initial action pattern BROADEN HORIZON (e. g. non-fiction books)
- experience beauty, initial action pattern PRESENTING FACTS AESTHETICALLY (e. g. planetarium, fractal visualizations)
- give legitimation, initial action pattern RECRUITING SUPPORT (e. g. open day, science festivals)
- control, initial action pattern INSTRUCTING (e. g. instructions for use, manuals)
- be entertained, initial action pattern ENTERTAINING (e. g. science shows)
- make political decisions, initial action pattern REASONING (e. g. hearings, expert opinions)
- satisfying their curiosity, initial action pattern REPORTING NEWS (science news on television and daily newspapers)

From this, the demand for knowledge about hazards and dangers, handling knowledge, orientation knowledge and general knowledge is to be examined more closely.

If there is a danger to life and limb or any other hazardous situation, e. g. in the event of an outbreak of a disease such as bird flu, the need for information on dangers and how to avoid them is high. Warnings are therefore an important part of science communication, not only when it comes to technological developments with a corresponding risk potential. The first experiences in dealing with warnings or omitted

warnings have rather led to a critical picture of science. This concerns the handling of radiation in the early phase of atomic energy, but also the handling of toxins in food and clothing. The case of the “omitted” earthquake warning in L’Aquila 2009 in Italy can also be cited: in this spectacular case, the strong earthquake that occurred in L’Aquila in 2009 was not publicly predicted. The public was outraged by the “failure of science” and criminal proceedings were brought against the scientists. The responsible researchers were initially convicted by a court for negligence, but later acquitted (Cartlidge 2015). The intervention of technological projects such as the cultivation of genetically engineered maize or reproductive medicine also creates a great need for knowledge about the risks of these projects. Since these are social debates that extend over a longer period of time and require a great deal of background knowledge, science museums are also taking on these topics, for example on climate change (Füßl and Trischler 2003: 435).

Handling knowledge is a transfer knowledge that connects technological products and users to “hybrid actors” (Latour 1993), so that they have the knowledge to use the device correctly. For example, a blood glucose meter requires specific medical and technological knowledge that allows the user to determine his or her own blood glucose values and to use them as a basis for medication. Due to the rapid technological change, this knowledge has experienced a great increase in importance. The functioning of basic technologies is also a topic of museums (Fehlhammer 2003; Füßl and Trischler 2003).

Orientation knowledge helps to understand one’s own situation in a rapidly changing world. Wilhelm Dilthey saw this as the central task of the humanities (Dilthey 2002). However, it is precisely the popularly mediated sciences that have always formulated a claim to orientation, which has increasingly come to the fore in recent years. Orientation knowledge can also be ideologically charged and functionalized for political purposes. This will be discussed at the end.

In addition to the specific knowledge needs, a general knowledge need must also be assumed, which primarily serves to broaden one’s own knowledge horizon. This general need for knowledge is rooted in human curiosity and in a radicalized and highly reflected form the basis of modern science. A large number of mediation formats address this general need for knowledge.

In addition to meeting information needs, entertainment needs were also on the agenda of the popularization of science from the very beginning. Already in the rhetoric we find the formula of *prodesse* and *delectare* (to please and to educate; see also Lobin’s contribution in this volume). The increasing division of labor and specialization of the modern sciences has led to a compressed and largely opaque technical language (von Polenz 1999), so that technical and scientific texts can no longer be received by an educated public without mediation; this applies in particular to scientific images (Flusser 1998; Liebert 2003, 2007). The reception of such texts and images is correspondingly richer in prerequisites and requires more cognitive and temporal effort. In addition, the public sphere of late modernism is increasingly fragmented, so



that a struggle for partial public spheres has also flared up (Franck 2005). Entertaining forms therefore play an increasingly important role. In addition to combining entertaining and informative elements such as *infotainment* or *edutainment*, there is also a *boulevardization* of science (see Biere 1997; Berg 2018).

The different knowledge needs were also described in the theory of *news values*. The theory of news values attempts to show on what basis news is selected and published as “valuable” (Galtung and Ruge 1965). These include morbid curiosity (delighting in the misfortune of others), anxiety, sex, love, health, fantasies of power (omnipotence and powerlessness) as well as curiosity (extraordinary, extreme, abnormal).

## 2.4 Needs, purposes, and text functions

The purposes and text functions of popular science communication now correspond to the aforementioned needs. Popular scientific communications can therefore serve the purpose of satisfying information needs by warning, instructing, orienting or educating. Or they serve the purpose of satisfying the aforementioned entertainment needs. Individual functions can also occur in combination. Thus, a warning in a hazardous situation can also receive concrete instructions. Conversely, the instruction text of a technical device may contain warnings. Usually, however, there is one main function in which the others fit. The information function can also be subordinated to the entertainment function, for example if the physiology of people with unusual extremities or diseases is described in an entertainment format with “objective” medical terminology.

## 3 Prototypes and varieties of science mediation

In the field of science mediation and popularization, there is a multitude of communicative configurations with very different settings, different mediation instances and addressees, different media, each of which opens up different options for action and design. Accordingly, the processes must also be described in different ways. Since not all variations can be covered here, a *traditional prototype* with a *ideal-typical mediator* and further functional determinants is to be defined for simplification purposes, which will then be considered further: Science journalistic contributions, as they were primarily used in journals.

In principle, a distinction can be made between a science-oriented and a public-oriented setting of science journalism. Science-oriented means an orientation towards scientific problems, actors and organs of publication and relevance within the sciences. Public-oriented, on the other hand, means an orientation towards the

relevance and problems of the audience or the addressees of the publisher or the information journal (see also Chapter 4 in this volume).

For this traditional prototype of the popularization of science, the following can now be assumed:

The mediator should be a professional science mediator (“science journalist”) who produces popularizing texts for a media publisher and who himself has a scientific background. She/he popularizes topics science-oriented with reference to the “scientific world”. The “scientific world” is intended to be an abbreviation for any actors and their relationships in one or more scientific domains. The media company should have a weekly newspaper with its own science section for readers who are generally interested in science. (For current developments in the field of new media see Chapter 24 in this volume.)

The roles within a media company alone are manifold. Colleagues, department heads, editors-in-chief with whom other communicative interests have to be negotiated. Publishers, for example, have a certain idea about the readership, what their information and entertainment needs are and how they can and should best be addressed. They also have the norms of the respective institutional writing culture at their disposal and are entitled to influence them. All these communications in these different roles and levels influence the creation of the concrete mediation text.

In an expanded understanding of actor (Latour 1993, 2004) also the popularizing text and – via its intertextual references – all further texts connected with it and the research objects mentioned there can be added as actors. In actor-network theory, everything that has power to act must be listed in the description. In actor-network analyses, for example, animals or the climate also appear as actors. The actor-network theory represents a separate branch of research, which cannot be further developed at this point (Latour 2004, 2013).

Within the science-oriented prototype, there are thus the actors: Science journalists, publishers (as clients and platforms), addressees (who can themselves become actors of mediation in new media), as well as the “scientific world”.

If we accept these actors in this setting for simplification, the following work flow results: The science journalist first orients himself towards the addressees and their presumed needs and then “scans” the “scientific world”. He then selects sources of interest for his purposes and, if necessary, conducts research in order to make these texts his own, together with parts of his own text. The quality criteria for the works thus created are, on the one hand, the adequacy of the addressee, i. e. the fulfilment of the promises of comprehensibility and the fulfilment of the above-mentioned needs, and, on the other hand, the adequacy of the subject, i. e. the fulfilment of the promise that the mediated also stands before the authority of the scientific world (see Biere 1989). In the course of these processes, she/he is in constant contact with colleagues and the publisher and coordinates the various standards and interests.

Essential elements of the prototype shown here can also be found in other mediation constellations. Further and other prototypes result from varying the basic com-

municative parameters. These include, for example, the chosen media, the available or unavailable multimodal resources, the use or non-use of certain mediation procedures, the participation roles, which are in a special way also associated with forms of interactivity, as well as influences through thematic specifications. In this way, the field of variants of science mediation can be reconstructed as a repertoire of prototypes, each with its own configuration of communicative, medial and sociological parameters.

## 4 Humanities and natural sciences as object of popularization

In the prototype assumed here, popularization is limited to the sciences. This prototype was not chosen arbitrarily, but corresponds to the practice of many science journalists: When one speaks of the popularization of science or science journalism, one often refers to a narrow concept of science in the sense of science; the humanities are hardly included in it. This is also due to the fact that the sciences on the one hand and the humanities on the other are dominated by different paradigms of thought. Paradigm here means a set of axioms as well as a *root metaphor* (Pepper 1966) which are made their basis by scientific disciplines (see Kuhn 1974). According to Stephen Pepper (1966), four different paradigms can be identified: The metric, the formal, the systemic and the contextual paradigm, each of which requires different forms of mediation, as explained below. In the metric paradigm, for which the sciences stand prototypically, the world is limited to the measurable; Pepper assumes a mechanism as a *root metaphor*, i. e. a generative causal model (sensu Maturana 2000, 2005), which describes the measurable world and can predict it with high probability. A scientific theory in the metric paradigm includes a causal model from which predictions can be derived and verified by measurements. By setting up metrically verifiable causal models, knowledge is provided that is capable of intervening in the world, making it controllable and manipulating it in a controlled manner. Max Scheler therefore spoke of *knowledge of domination* (Scheler 1960). By reducing the world to the measurable, scientific theories can operate with metric concepts. Mathematics plays a decisive role as a descriptive language.

However, mathematics is not only auxiliary science for the sciences or the metric paradigm in general, but – like formal logic and semantics – also has an intrinsic value because it focuses on analytical truths and their formal representation. Therefore, according to Pepper, it is assigned its own paradigm, the formal one.

The systemic or cybernetic paradigm is also original, since it has its own basic assumptions and its own root metaphor, namely that of the holistic organism. Formal, metric and systemic paradigms can be combined to a certain degree.

The “black sheep”, however, is the contextual paradigm. In the contextualist paradigm, context plays the decisive role. Here is the assumption that all phenomena are

contextualized, including the observing researcher. Therefore, an essential part of the research lies in the understanding of these contexts and the context integration of the examined phenomena. True to the basic contextualist assumption, the result of a research itself is again something that must be put into a context, namely into the respective discourse, in order to reinterpret it. In this paradigm, “progress” is the new interpretation of relevant phenomena and thus the destruction and production of meaning.

If we now consider possible forms of mediation and the aspect of Pepper’s four paradigms, it is clear that the metric and contextual paradigms, for example, require completely different forms of mediation.

Pepper’s concept of a paradigm and scientific discipline are also not in a 1:1 relationship. A paradigm can be shared by different scientific disciplines and a single discipline can also be dominated by different paradigms. The greatest difference between the sciences and the humanities is that the sciences share a single paradigm, whereas the humanities share several paradigms. If one looks at the field of social sciences or cultural studies as an illustration, it is dominated by various paradigms, i. e. researchers work within a discipline whose basic assumptions differ fundamentally but can be found in other disciplines. In linguistics, for example, formal, metrical and contextualist paradigms exist side by side and against each other: A structural and therefore also formal theory of language can be found as well as a statistically oriented corpus linguistics and an interpretive conversation analysis.

This paradigmatic representation according to Pepper makes it clear that it is difficult to apply uniform mediation formats. Dilthey’s proposal of equal rights for the sciences and the humanities and for the metric and contextual paradigms has by no means become a matter of course and has repeatedly become the subject of interdisciplinary and public debate (Collins and Pinch 1993, 1998). Particularly prominent were the so-called “science wars”, which arose at the end of the 1990s following a hoax article in a humanities journal (Sokal and Bricmont 1999).

At least some differences with regard to the mediation should clarify the problem.

While all research domains have a “mediation problem” due to increasing specialization, the sciences are highly dependent on internal specialist language competence due to the formal description language and the specific interest in predictive causal or at least probability models. At the same time, they produce knowledge of domination or disposal that promises power over objects of the world, so that mediation must involve a great deal of effort, but can always presuppose a certain relevance.

The humanities, which according to Dilthey can provide orientation knowledge, are fundamentally capable of being self-explanatory even without professionalized mediators, at least for an educated public, due to the contextual paradigm. But since they do not provide knowledge with which one can dominate the world, but can think about the world differently, they are under great pressure to legitimize themselves in a discourse marked by utility thinking.

In the following section, the prototype for scientific knowledge will be dealt with further and the specifics of knowledge in the humanities will be dealt with selectively.

## 5 On the specifics of scientific knowledge

One cannot speak of the mediation of scientific knowledge without characterizing this knowledge. Scientific knowledge has many – sometimes counterintuitive – peculiarities that make it impossible to convey it unreflectedly and directly, for example in an everyday mode of narration, without losing the fundamental character of this knowledge. This knowledge includes not only knowledge in the narrower sense, but also the knowledge of technical languages, technical images, processes, methods and research strategies. Therefore, some remarks will first be made on the specifics of scientific knowledge, in order to then deal with its mediation in the narrower sense.

As mentioned earlier, sciences work in the metric paradigm to construct causal explanatory models that allow metrically verifiable predictions (Maturana's *generative mechanism*, Maturana 2000). This world view is therefore about measuring what is measurable and creating models that define what is measurable, explain what is measured and make predictions about what is measurable in the future. An example of this is the Higgs boson theoretically postulated in elementary particle theory, whose existence could only be proven after decades and thus represented a confirmation of the adequacy of this theory (Boutas 2014). Even if the formal or the systemic paradigm is resorted to, it is only in order to create metric models from it again. Scientific activity in the narrower sense is therefore the establishment of models and hypotheses derived from them, experimentation, measurement, documentation of measurements and the correlating of measurements to hypotheses and finally to theory.

The central form of the representation of scientific knowledge in the scientific discourse is the scientific paper. Of course, many new requirements and formats have been added in recent decades. For scientifically recognized knowledge, however, the paper in specially designated journals is constitutive. In particular, a relatively sharp distinction is made between a descriptive and an interpretative area in which the data described are related to the model and the hypothesis derived from it. Knowledge gained in the sciences in the scientific paper is not narrative, but encyclopedically structured, i. e. it is not a matter of telling a certain story, but of creating a basis of certainty in the Cartesian sense, on the basis of which knowledge of domination (Scheler 1960) can unfold. This does not mean that stories and anecdotes did not play a role or should not later play a role in mediation – there are countless studies of “science policy studies” – but only that they are not a constitutive component of the scientific concept of knowledge in the scientific paper. This is particularly evident in the designations. Thus the term *atom* is not used for the “indivisible” like photons, but for objects that were initially thought to be such. In the course of the realization that other objects are more “elementary”, however, history was not continued in the naming. Units of measurement such as Newton or Faraday are also usually chosen posthumously after important natural scientists from this field as a tribute, and not to inscribe a narrative, such as how the concrete history of discovery proceeded. For calculating with these units, the narrative is irrelevant, even misleading.

Another component of natural science is controversy, which is also not a narrative, although controversies can be transformed into narratives for mediation purposes (see also Fritz's contribution on scientific controversies, Chapter 15 in this volume). The fact that controversies play an important role in the constitution of scientific knowledge was already shown during the pre-Enlightenment period (Dascal 1998). The fundamental structure of the scientific discourse as controversy is related to the assumption of the production of knowledge, which must be so robust that it must endure a permanent scrutiny by everyone, and which is then called "objective". This results in a requirement for controversy, and in order to make such a controversy possible as a requirement for transparency, it means that every proposal for inclusion in the knowledge base must be documented in such a way that, in addition to the properties of the metric paradigm described above, it is also verifiable in principle. The consequence of this is not only that the measurement procedures have to be documented, but also that the text is divided into a descriptive and an interpretative part. The descriptive part consists exclusively of the presentation of the results of measurement procedures, while the interpretative part links the described data with the theoretical assumptions and makes statements on model adequacy. The system of natural laws, natural constants, models, measuring methods, etc. that has developed over the centuries represents a frame of reference in the sense of Strawson (1959), within which the properties and behavior of objects and their metric recording in space and time are researched. However, a frame of reference is not specific to the natural sciences but, according to Strawson, a necessary condition for all human communication. However, the scientific frame of reference differs considerably from that of the everyday world and has little in common with it.

Science is therefore a cooperative and competitive enterprise (Bourdieu 1998). It is a complex system of cooperation and controversy within and between scientific groups, which can take place at different levels: Within or between scientific groups, consensus or dissent can thus prevail at the levels of data description, methods or data interpretation, or a combination thereof. In addition, there is a social environment characterized by increasing competition for resources, symbolic but also real capital (e. g. in the field of gene patents).

The specific characteristics of scientific knowledge outlined here and the related forms of knowledge and representation also have consequences for popularizing mediation strategies (Section 6) and mediation formats and media (Section 7) for scientific topics and objects.

## 6 Mediation strategies

As shown so far, no context-independent mediation strategies can be described, but only in relation to a mediation scenario. For the following explanations, we will therefore assume the prototype that has just been introduced, i. e. the popularization of science by a journal article by a science journalist. Looking at the relevant studies and textbooks for this area (Göpfert 2006; Könniker 2012; Weitze and Heckl 2016), a wealth of such mediation strategies can be found for this prototype, as this is a highly professionalized field. They can be classified into content-related, appellative and cultural-related strategies.

### 6.1 Content-related strategies

The scientific research process is not an algorithmic procedure, but is characterized by contingencies: The respective procedure of researchers and research teams follows a certain systematics, which is, however, ignored in individual cases in order to arrive at an innovation (Feyerabend 2010). However, this contradicts most journalistic genres that work with a narrative structure, a “story” (see Göpfert 2006). Within the framework of a narrative structure, the narrative parts must functionally interact in such a way that they form a meaningful whole. Discovery stories are therefore usually not a chronologically faithful reproduction of historical-chronological events; rather, fragments from the history of discovery are usually fitted into a narrative that does not exist in this way in the scientific domain (see e. g. Liebert 2002, 2003).

As a rule, the actual existing controversies are not traced, unless they can be placed as news value of the scandal “Science is divided” or “Science is wrong”. However, there are isolated formats that take controversies as a starting point for mediation. The narrative is then replaced by an argumentative-discursive structure that more closely corresponds to the scientific process.

Another variation is the use of strategies to convey the frame of reference of science. Earlier, with reference to Strawson, the concept of the frame of reference was introduced, by means of which concrete space-time objects and their meaning are classified in the existing knowledge. It is therefore implicit knowledge (Polanyi 1966) or background knowledge. One of the most important questions that the science journalist must answer is what background knowledge should be made explicit so that the findings that are to be conveyed can be understood. Therefore, strategies can be distinguished that serve to verbalize background knowledge or to make implicit knowledge explicit. It is known from specialist language research that scientists communicate in significantly different ways, depending on how professional they assess the situation and the addressees (see Roelcke 2010 for an overview). If there is a high degree of professionalism in the situation, for example in the publication of an article for one of the main journals, one will find a text with high knowledge requirements and correspond-

ingly little or no explanation of background knowledge. An explanation of knowledge that can be assumed from the readers of *Nature* or *Science* would mean an insult to the readers, as this would massively violate the cooperative principle of Grice (1975). If scientists are not trained to explain their fields of research outside of the peer situation, the peer gesture remains intact and the well-known phenomenon of the cryptic scientist who cannot express himself comprehensibly occurs. In socially controversial research areas, there are therefore corresponding offers for training in science PR. In order to obtain information that can be used by non-specialist addressees but is nevertheless scientifically adequate, the mediation situation must therefore attempt to verbalize background knowledge or “implicit knowledge” (Polanyi 1966). If one compares science journalistic publications for adults and children or asks scientists to answer the same question for addressees with clearly contrasting knowledge (science journalist, child), it can be seen that much more is activated from background knowledge if a less specialist addressee is assumed (Liebert 1997). Often metaphors and comparisons are cited which are rarely fixed in internal scientific communication or are fixed as scientific metaphors like “letters of DNA” etc. (Liebert 1995, 2008). However, it is precisely the fixed specialist metaphors that serve as starting points in the mediation situation, which can lead to a number of misunderstandings (Liebert 1999). A strategy for the activation of background knowledge and the elaboration of appropriate metaphors thus consists in imagining a less technical addressee (see Wormer 2008). Of course, this is only necessary if the scientist is not yet experienced in external communication.

## 6.2 Appellative strategies

In addition to content-related strategies, appellative strategies also play an important role, which are to be shown here as examples of attention economy and relevance to everyday life.

Every science journalistic article is a media product that finds itself in a competitive situation with other media products and must therefore win a place in the attention economy of its addressees (see Liebert 2002; Franck 2005; Könneker 2012: 16–17). A mediation text must therefore advertise itself. The first goal is therefore to attract the necessary attention so that the article or book is even noticed before a decision about reading or non-reading is made. In particular, images or paratexts such as headlines or, in the case of books, blurb texts or recommendations from prominent personalities play an important role. Their function is to represent the news value and relevance for the addressees in a drastically exaggerating way.

Appellative strategies can be found in particular when it comes to evaluating scientific findings and procedures in relation to the world in which the addressees live. Then, especially in a public-oriented setting, addressees, scientists or state and social institutions can be called upon to take action. Appellative strategies therefore serve in particular to determine relevance.



### 6.3 Culture-related strategies

As a third type of strategy, culture-related strategies can be identified, which thus convey science as cultural artefacts, i. e. including economic constraints and personality traits of researchers. This type of strategy is relatively new and has been inspired in particular by Science Policy Studies, which have focused on the cultural context of scientific knowledge genesis. These include reports on personal “skirmishes”, selfish and conceited motives of researchers, but also the contribution of laypersons to the advancement of research processes (Collins and Pinch 1993, 1998).

### 6.4 Other strategies

In addition to the three types of strategy mentioned above, there are also strategies that can appear as substrategies in all three function groups (content-related, appellative, culture-related). These include, above all, visualization strategies: they can be used for the constitution of content, for example in the form of charts or scientific imaging processes, but also for suggestion or for clarifying the cultural ties of scientific findings, for example in the form of caricatures. For the role of visualizations in popularization see Flusser (1998), Liebert (2003), Liebert and Metten (2007), Mitchell (1986), and Chapters 3, 11, and 24 in this volume.

## 7 Scientific mediation formats and media

Based on the prototypes introduced above, i. e. limited to the assumed wish of the addressees to expand their knowledge horizon, the communication media in which science is conveyed will now be examined. The following are to be selected from the great variety: Popular science books, monthly science magazines, columns in daily and weekly newspapers, museums, television and public lectures.

Popular science books continue to be one of the most important forms of communicating science. A distinction can be made between books written by scientists themselves (Einstein, Watson/Crick, Gel-Man) and books written by professional science mediators. The special nature of scientific knowledge, with its frames of reference, dimensions and sizes far removed from everyday life, makes this long form particularly suitable. Here also basic mapping procedures, methods and terms can be developed step by step in detail and slowly. The procedure is often of a historical nature. Stories of discovery, in the sense described above of an artificial chronology constructed for the popular narrative, play an important role here (see Liebert 2003). To a limited extent, there are also periodically published specialized scientific magazines. These are aimed at a large audience far away from the subject or a smaller,

close audience (e.g. *Scientific American*, *National Geographic*). Also in the columns of weekly newspapers and magazines as well as in daily newspapers one can find science mediating texts with education function.

Science is a special feature of the museum. The first science museums were established at an early stage of industrialization, initially as a collection of technical artefacts. Soon, however, basic knowledge and connections were also conveyed in the museum, for example in the form of experiments and historical reconstructions (for example by reconstructing the inclined plane of Galileo. In late industrialization, which Ullrich Beck characterized as a *Risk Society* (1994), the museum also increasingly takes up socially discussed questions of technological development such as genetic engineering or nanotechnology (see Fehlhammer 2003; Füßl and Trischler 2003). In the 1990s, the format of the Science Museum established itself more and more as a business model. For this purpose, the “direct experience” of science was worked out and presented in particular with so-called hands-on installations. Political-discursive effects are evident in popularization, as the history of discovery varies according to national location: “Technology museums in London, Paris, Rome and Munich also showed and show their very own history of progress in a comparable way” (Welzbacher 2017: 16; transl. by W.-A. L.).

A large number of science programs are present on television. The special feature of television is that dynamic visualizations can be used here, e.g. for model simulations. Central to this is the figure of the moderator, who must credibly stand for the adequacy of both the subject and the addressee (e.g. Ranga Yogeshwar, former moderator of “Quarks und Co.”, or Cara Santa Maria in “Talk Nerdy to Me” of the *Huffington Post*).

Public lectures are particularly visible when they are given by prominent personalities, either scientists or well-known science mediators (e.g. Richard Dawkins).

The field of science mediation and especially the mediation of scientific topics has been fundamentally transformed with the availability of digital, net-based media. Three trends determine this development: First of all, many traditional media offers can also be found on the Internet parallel to the original offer, e.g. TV contributions as archived podcasts. Secondly, entirely new mediation formats and strategies based on digital possibilities have emerged. Thirdly, the changed technical possibilities have led to a change in participation roles and interaction possibilities (e.g. in science blogs in which a contribution can not only be commented on, but in which discussions between the commenting readers and intertextual references to multimodal offerings outside the blog are also possible). The brief compilation of these tendencies shows that media technologies and the interactional, multimodal and semiotic resources available for them (Kress 2009) provide a framework that can be used flexibly for different mediation scenarios and in which consolidated presentation formats have developed.

## 8 Conclusion and further perspectives

The mediation of science is determined by many factors such as the addressee-related goals, the forms of knowledge and scientific traditions and scientific paradigms, so that a uniform strategy of popularization cannot be described, but is always relative to certain bundles of factors that have been described here as prototypes. The mediatisation associated with globalization leads to a further upheaval in the popularization of science. Through the introduction of new media, recipients can become authors or co-authors and make their own claims to knowledge production. The late modern fragmentation of the public sphere is also creating increasing competition for attention, so that entertaining formats and news play an important role in the struggle to be noticed. Knowledge of domination, as it was introduced earlier by Max Scheler (1960), plays an increasingly important role here, also in the natural sciences. The knowledge of domination that is imparted within the framework of a scientific education is often transformed in popularization only into mere contemplative knowledge. Recently, therefore, there have also been initiatives that have appropriated science as knowledge of domination and now carry out their own DNA tests or genetic manipulations as biohackers or carry out various gene experiments “in the garage” (Bromwich 2018). For this self-empowerment of scientific laypersons, popular scientific mediation is only interesting as mediation of knowledge of domination.

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## 20 Science journalism

**Abstract:** Although science journalism remains a potent actor in society, it has endured a number of transformations over the decades and is now undergoing yet another one as legacy media organizations – the science journalist’s traditional employers – decline and online channels proliferate. This chapter tracks the “story” of science journalists through their relationships with scientists, with fellow journalists, and with their own news organizations. It also explores the types of impacts that media science stories are likely to have on audiences and summarizes studies that are beginning to explore science journalists’ ventures into blogs and social media.

**Keywords:** science journalism – environment journalism – source-reporter relationships – medialization – social norms – primary groups – accuracy – objectivity – balance

In spring 1957, nearly 2,000 adults in the United States responded to a survey about their use of the mass media to learn about science. Sponsored in part by the National Association of Science Writers and led by Prof. Hillier Krieghbaum of New York University, likely the first science journalism professor in the United States, the survey asked participants about a number of specific science issues and included these two questions: “Have you heard anything about plans to launch a space satellite, sometimes called a man-made moon?” and “From what you’ve heard, what is the purpose of launching these space satellites?”

When Russia sent the world’s first satellite, Sputnik 1, into space only six months later, the survey team grabbed the chance to get back into the field to look for a link between media use and knowledge about science. They posed many of the same questions to a sample of more than 1500 individuals in spring 1958 and were particularly interested in the extent to which the media’s extensive coverage of Sputnik influenced public understanding of this new technology.

What emerged from the analysis was a surprise to the researchers but illuminated a pattern that – with few exceptions – holds today: media coverage led to greater awareness of satellites but to little in the way of knowledge gain. As the researchers put it in a 1960 article:

As would be expected, public awareness of satellites increased sharply when Sputnik I went into orbit [...]. However, this increased awareness was not accompanied by wide-spread agreement about the purpose of the satellites. While 27 per cent of the respondents attributed a scientific purpose to them, an equal number either knew no purpose or suggested an incorrect one (Swinehart and McLeod 1960: 584).

Mass media's ability to serve as alerting mechanisms remains critical to society. And their generally modest contribution to learning about science makes sense in what one might call a "free-range information environment", where users pick and choose among channels and then, typically, give those selections only a glancing blow before moving on. The impact of media science coverage can be much greater on certain audiences under certain circumstances, of course, and this chapter will tackle that complex landscape later in the narrative. But first, we turn to an exploration of the construction of science news stories with a focus on that most important actor: science journalists. More specifically, we will examine that process through the lens of relationships, first between science journalists and their employers, then among science journalists themselves, and finally between journalists and their sources, both scientists and public information personnel. This focus on relationships will not only allow an examination of patterns of coverage but also provide a window into some of the primary drivers of content. We will return to examine the impacts of these stories on audiences, followed by a brief look at the role of new media channels in this science journalism landscape.

First, though, a bit of historical context:

## 1 A (very) brief history of science journalism

Although one can find the occasional footprint of a journalist with a passion for science in 19th- and early 20th-century journalism, such as Britain's Mary Somerville (Brock 2006), Australia's W. B. Clarke and James S. Bray (Gascoigne and Metcalfe 2017), and Canada's Clément-Arthur Dansereau (Treatment of Science by the Media 2018), the specialty was driven largely by the 20th-century's two great wars. The devastation wrought in World War I by the use of new weapons, TNT and mustard gas, led a pair of individuals – one a newspaperman and the other a biologist – to establish a US-based science news bureau called Science Service, which distributed news to newspapers around the country. It also created a magazine, now called *Science News*, which thrives to this day.

In the aftermath of World War II and the shock of the atomic bomb, many countries began to fund scientific research on a large scale. In the United States, for example, the money pouring into research and development in physics and to fuel the space race in the 1960s led to a sharp increase in science journalists, as newspapers began to identify science as front-page news. Typically, a media organization tapped one of its existing reporters, who suddenly found himself (and this early cadre of reporters was overwhelmingly male) heading to Cape Canaveral in Florida to cover manned space launches.

Those journalists were often highly skilled storytellers but had little in the way of science training. Still, over decades of science reporting, many developed expertise

that rivalled that of their scientific sources. *The New York Times*'s Walter Sullivan, for example, began his journalistic career as a copy boy in 1940 and, after serving as a foreign correspondent, became science news editor in 1962. As fellow science journalist John Noble Wilford noted in Sullivan's obituary in the newspaper, "He wrote swiftly, hurrying to be off on the next article, but the authority of his articles impressed scientists. On at least one occasion, physicists said they did not fully appreciate the significance of their discovery until they read about it in Mr. Sullivan's article the next day" (Wilford 1996).

Over time, at least some formal science training has become a more common characteristic among science journalists, although many science journalists today still embrace liberal arts backgrounds (Bauer et al. 2013) and, as was the case in a recent survey of science journalists in Spain, believe that formal science training is unnecessary to the job (Cassany, Cortiñas, and Elduque 2018). A steady increase in the number of scientists-turned-journalists is transforming the occupation in the 21st century, as is the decline in newspapers and the rise of Internet-based vehicles. Science journalists are becoming, by necessity, increasingly entrepreneurial.

It is important to remember, however, that much coverage of science continues to be handled by general reporters, particularly in developing countries. In one recent survey of journalists in Ghana (Appiah et al. 2015), respondents identified the need for more training in science journalism as the most important factor that would lead to higher quality coverage.

## 2 Science journalists and the media organizations that employ them

The primary home for science journalists worldwide has long been print media, both magazines and newspapers. Even more specifically, the bulk of science writing jobs have been available at that subset of newspapers with substantial resources. As sociologists such as Gaye Tuchman (1980) have long noted, the default deployment strategy for daily news gathering has for many decades been geographical: reporters went to places where news ostensibly occurred, such as police stations, government offices, and courthouses. Only when a newspaper had resources to reach beyond that basic level of coverage did it hire specialty reporters, science writers among them.

Those specialty reporters, although focused on content very different from that of others in their organizations, remained tightly yoked to newsroom norms. The work of scholar Warren Breed, way back in 1955, illuminated a pattern still common today: regardless of background, a journalist quickly assimilates the norms of her newsroom (Breed 1955). For science journalists at daily newspapers, that meant stories with clear news pegs and, importantly, the use of objectivity and balance when covering contested science (see Amend and Secko 2012 for an overview of studies of story selection



and other factors among science journalists). Figueroa (2017) argues that the social structure of newsrooms is changing in response to economic and new channel pressures. But newsrooms remain intensely hierarchical, so normative pressure to align oneself with prevailing norms continues.

News values such as novelty, scale, and timeliness remain important to all of journalism. They proved awkward to apply in science coverage, as so much of what counts as science is an incremental process of generating and evaluating evidence, with few clear beginnings and endings. Science journalists handled that problem by “chunking” process into episodic stories tagged to such events as journal publication dates and scientific meetings. One unintended outcome of that strategy was that it gave the scientific culture the opportunity to dominate decisions about what is news, an issue this chapter will return to below.

Objectivity and balance come into play when truth claims are difficult to parse. Since science journalists sometimes do not have the expertise to evaluate competing claims and their audiences typically expect them to act as “translators”, not as “judges”, they have historically defaulted to this pair of norms. Objectivity demands that, if you cannot discern whose truth claim is most valid, then at least capture that truth claim accurately. This norm led to a strong focus on the accuracy of science news, both within journalism and within the scientific culture, and presented another opportunity for the scientific culture to exercise control over information; I return to this below.

Balance, on the other hand, mandates that, in the face of competing claims, a reporter provide at least a subset of those claims so that readers can be aware of the continuum of claims. In most cases, that continuum gets simplified into providing claims lodged at each end, the “he said, she said” story. Balance is meant to convey that “the truth is in here somewhere”. But in fact, it more often conveys that “nobody knows what’s true”, a clear misinterpretation of the journalist’s aim (for conceptual overviews of these norms, see Wien 2005; Skovsgaard et al. 2013; Priest, Goodwin, and Dahlstrom 2018).

Balance is such an important norm that one can find instances of science journalists employing it even when they know that some of the truth claims they are describing are invalid. In one iconic study, Dearing (1995) examined coverage of three issues where evidence was contested by lone scientists, whom Dearing characterized as mavericks. Although the journalists, in a survey, indicated that they were well aware that the mavericks were not credible, they still included their views in their stories as demanded by professional practice. Dearing noted, “Most of these journalists responded that they did not believe the mavericks to be credible. Yet the framing of their stories begets credibility” (Dearing 1995: 356).

Since contested truth claims are a common component of science, balanced coverage has become a highly salient issue for critics of science journalism. That critique is at its most visible in controversies where the science has become politicized, such as climate change and the vaccine–autism debate. Critics become most incensed when

the truth claims of individuals without scientific expertise are arrayed against those of the scientists. Those claims are not equal, they argue, yet balanced accounts portray them as such (see, for example, Grimes 2016; Chakradhar 2017).

That appears to be changing, at least for such issues as climate change, where the weight of evidence on behalf of anthropogenic warming has become overwhelming. For example, Rice, Gustafson, and Hoffman (2018) found that coverage of the issue in three elite US newspapers did not pit scientists against non-scientists but, instead, covered the divergent views of non-scientists (primarily government officials) who were arguing about legitimately uncertain factors such as policy actions. Today, most science journalists now privilege evidence-based claims in their stories, leaving climate deniers aside (Bolsen and Shapiro 2018).

Still, arguments about “false balance” consume the professional lives of many journalists whose editors struggle to remain committed to both accuracy and fairness (see, for example, Peters 2016). It is important to note that the practice has varied across countries (Skovsgaard et al. 2013) and over time (Brüggemann and Engesser 2017).

### 3 Relationships among science journalists

Although the number of science journalists worldwide burgeoned in the latter half of the 20th century, they remained anomalies in most newsrooms. Specialized reporters are too expensive for most media organizations to field, so the science reporter has usually been a singular presence in his newsroom. He believes that he has more autonomy than other reporters, as editors acknowledge that they know little about science, and his “beat” often requires travel to scientific meetings or to recurring events such as satellite launches.

Covering news in these more distant locales has historically thrown science journalists together on a regular basis, and those settings nurtured the creation of robust primary groups. Those relationships, in turn, figured prominently in decisions about what to cover. In the 1970s, I studied primary group interactions among some of the top science journalists in the United States. The venue was a meeting of the American Association for the Advancement of Science, where hundreds of journalists glean stories from symposia, press releases, and press conferences (Dunwoody 1979, 1980). Below, I identify a few patterns from those analyses that illustrate the power of such groups.

- *One strategy for maintaining strong friendships among colleagues who are also one’s primary competition is to shift the locus of competition from the individual reporter to the organizational level.* Friendships and competitive behavior are difficult to maintain simultaneously. The science journalists I studied pulled this off by defining competition as something that matters at an organizational – not an

- individual – level. That is, competition is a norm that motivates editors, leaving journalists free to interact as colleagues, not as adversaries.
- *Covering the same story, using the same angle, is a means of managing editors' perceptions of competition.* Although there is rarely a story of the day at large scientific meetings, science journalists can handle competitive expectations by selecting the same topic and covering it in similar ways. Such a strategy might lead journalists to opt into a particular press conference, for example, and to share information about their story intentions.
  - *Cooperation generates better stories than does competition.* Science is hard to cover, and specialty reporters with collegial ties to one another can benefit from the greater knowledge that stems from literally “crowdsourcing” a story. For example, at one large science meeting journalists attended a press conference where a scientist offered what he argued was evidence for a link between genes and violent behavior. Clearly unsettled by that claim, the journalists gathered after the press conference to share reactions; some ultimately volunteered to contact independent sources to vet both the claim and the scientist and brought the resulting information back to the group.

Although studies of primary groups among journalists are rare, they suggest that, when such affiliations form, they reflect not the geography of place but, rather, the pull of professional responsibilities. For example, Russo (1998) studied primary group identification and commitment among journalists at a large metropolitan newspaper. He found that reporters identified more strongly with the profession than with their newsroom.

One can see this professional allegiance among science journalists with particular clarity today. As changes in the science journalism business have made reliance on scientific meetings and other venues for interaction more intermittent, primary group affiliations have become the province of professional organizations. Groups such as the World Federation of Science Journalists and many national iterations (for a list of these groups, see <http://www.wfsj.org/associations/>) organize regular conferences to promote learning and commitment to the profession, and they use the Internet and social media to maintain the kinds of interactions crucial to primary group impacts. These professional organizations have become increasingly important to science journalists as media organizations have cut them loose, forcing many journalists to morph into highly skilled freelance writers (Brown 2014).

Training of science journalists has also evolved rapidly over the years. From taking the rare course or two embedded in generic journalism/communication programs, budding science journalists around the world now can earn certificates and graduate degrees. Participants in these programs have always been a mixture of individuals from journalistic backgrounds and those stepping into the career from formal science training. Most training programs welcome a variety of backgrounds, although it is increasingly common for programs to privilege science training among applicants;

the well-known Science Communication Program at the University of California Santa Cruz in the United States ([scicom.ucsc.edu](http://scicom.ucsc.edu)), for example, admits only those individuals who have not only a science degree but also research experience.

The value of any particular educational background remains uncertain, however, as one can find little evaluation of credentials that make a “good” science journalist. Some years ago, I went looking for studies that aligned assessments of science reporter quality with demographic characteristics and found that quality – most frequently (if poorly) operationalized as a reporter’s level of knowledge about a specific science issue – was only marginally related to formal science training but was robustly associated with number of years an individual had worked as a science journalist (Dunwoody 2004). As in most occupations, on-the-job experience counts.

## 4 Source-reporter relationships: scientists

Scientists probably functioned as the chief popular science communicators of the 19th and early 20th centuries. Journalism paid only scant attention at the time to science – then a novel way of employing evidence to search for patterns in nature – and scientists were not only keen to use the scientific method to thwart myth and superstition but also quick to grasp the link between visibility and resources. Many 19th-century scientific expeditions relied on popular support garnered by public talks and articles in the general magazines of the time.

But the professionalization of science in the United States, early in the 20th century, began to carve out a chasm between scientists and the public. One major goal of professionalization is to distinguish “us” from “them”, and scientists came under increasing pressure to distance themselves from the public. A productive exchange relationship between scientists and lay audiences deteriorated rapidly, and popularization became a four-letter word (Burnham 1987).

Scientists’ retreat from interacting with lay audiences may not have taken place simultaneously across the globe. Bowler (2009) argues that many British scientists remained actively engaged in popularizing science well into the 1960s, although he marks that moment as a turning point when scientists began to lose interest in non-scientists as relevant audiences.

For many scientists around the world, 20th-century professionalization brought with it a very different system of reinforcement: scientists began to be punished rather than rewarded for communicating science to the public. Scientific and medical societies devised rules that defined popularization efforts as something akin to “unethical advertising” and berated their members for even allowing their names to be used in newspaper stories. Scholar Rae Goodell profiled a group of “visible scientists” – senior scientists in the United States who engaged in extensive popular communication in the 1960s in spite of the scientific culture’s norms – and illuminates the

blowback that most of them endured from their colleagues throughout their careers (Goodell 1977a, 1977b).

The retreat of scientists from the public landscape threw open the doors to journalists, who became the main link between scientists and the public. Historians have tracked these efforts in the 19th and early 20th centuries (see, for example, Sommer 2006; Nall 2017), noting a rapid embrace of sensationalism as newspapers eagerly fielded stories about the canals of Mars, the discovery of early hominin bones, and other mysterious phenomena. Such coverage made it easy for scientists to disparage journalistic efforts. Even when coverage of science became more “mainstream”, however, with journalists covering scientific meetings and attending to the major science journals, scientists continued to devalue interactions with the media.

Journalists typically get work done through sophisticated exchange relationships with sources. Such relationships grow when the parties, who typically have different goals, find that they can realize those goals through the construction of a “shared culture”, a social setting characterized by a communal understanding of the rules and limitations that accompany the culture’s members (Blumler and Gurevitch 1981). That means journalists need to understand the norms of science and how those norms intersect with journalistic needs; for example, a shared culture requires patience with scientists’ reluctance to discuss their work before it has been accepted by a peer-reviewed journal. Scientists, in turn, need to understand the urgency of journalists’ daily publication schedules, among other work norms (see below).

With scientists in retreat from public communication, a shared culture proved difficult to build between them and the journalists keen to talk to them during much of the 20th century. A culture grows when participants need something that the others can provide, and scientists did not perceive a need for the kind of visibility that journalists offered. That, in turn, led to a power imbalance: scientists’ indifference gave the scientific culture a great deal of control over what became news about science. For example, journalists rely heavily on the publication of research in scientific journals despite the fact that major journals put in place embargo rules governing when a story can be published, typically on the day of journal publication (Kiernan 1997, 2003, 2006).

Scientists often press to evaluate the accuracy of a story before publication, behavior unique among sources, and some journalists accede to that demand. Although sensitivity to accuracy is not surprising, nor is the finding that accuracy is the most common complaint that scientists have about science stories, it is important to note that the assumed definition of accuracy is closely tied to the power imbalance between scientists and journalists. For a source, an accurate story is one that achieves a tight fit between the information she provided and that story’s details. That, in turn, means that an accuracy judgment is not one of validity but of reliability (Dunwoody 1982). Scientists have been quite successful at elevating accuracy as a professional concern and as a perennial research focus in the science journalism literature, but one might argue that this emphasis on goodness of fit (here’s that concept of “objec-

tivity” again) comes at the expense of giving proper emphasis to the actual validity of truth claims (see also Chapter 1, this volume). Hansen (2016) offers a thoughtful review of the accuracy literature, focusing on the changing nature of the definition of “accuracy” over time, while Kohring and Matthes (2007) note that perception of the accuracy of science stories serves as one factor in trust of news media.

In the late 20th century, this awkward exchange relationship between scientists and journalists experienced a sea change. Scientists began to rediscover the value of public visibility and have become increasingly sophisticated at working with journalists, as well as at communicating directly with publics themselves. Interest in public visibility has become so great that large scientific institutions, such as the American Association for the Advancement of Science (AAAS) and Wellcome in the UK, now offer resources and training, and science communication researchers have begun to explore the strategies of a thriving community of individuals who specialize in training scientists to communicate (see, for example, Besley et al. 2016).

Motivations that have precipitated this shift among scientists vary by study. However, there is ample evidence that public visibility is good for a scientist’s reputation, affecting even the credibility afforded to one’s work by other scientists (see, for example, Phillips et al. 1991), and scientists around the world now routinely report that interacting with journalists is good for their careers (Lo and Peters 2015; Peters et al. 2008a, 2008b). Recent surveys of scientists’ reasons for engaging with journalists and the public highlight the importance of such factors as feeling efficacious, that is, that one has the skills to communicate well (Dunwoody, Brossard, and Dudo 2009), and embracing goals such as defending science against misinformation and educating the public (Dudo and Besley 2016).

In recognition of this sea change in scientists’ attitudes and behaviors, scholars have begun tracking what they call the “medialization of science” (Rödger, Franzen, and Weingart 2011; Scheu and Olesk 2018). Closely akin to the “shared culture” concept of the 1980s, medialization posits that scientists’ increasing recognition of the social legitimacy conferred on their work by public visibility is leading to efforts to develop a mutually beneficial relationship with the mass media. And although scientists worry perennially about the impact of “popularization” on their credibility, experiments suggest that trust and credibility can survive even advocacy efforts (Kotcher et al. 2017). Dudo (2015) offers a useful review of the literature examining scientist-journalist relationships.

In yet another excellent overview of this relational literature, Peters cautions against seeing too radical a change in scientists’ behaviors. He argues that relationships between scientists and journalists have remained fairly stable over time: “Although there is more influence on public communication from the science organizations and more emphasis on strategic considerations today, the available data do not indicate abrupt changes in communication practices or in the relevant beliefs and attitudes of scientists in the past 30 years.” (Peters 2013: 14102).

The rise of new communication channels – particularly those that allow scientists to communicate directly with publics – may bring about more substantial changes in relationships in the future. This chapter addresses that below.

## **5 Source-reporter relationships: science organizations and public information officers**

Since science journalists' primary sources – scientists – are typically found in organizations such as universities, government agencies, and private industry, public information personnel (or PIOs) who are employed by these organizations have long served as important linkages (see also Chapter 22, this volume). Although journalists prefer to connect directly to scientists themselves, they are often alerted to possible story topics by PIO pitches in the form of press releases, tip sheets, or direct contact.

Scholarship examining this relationship in the science news world is limited, although communication scholars have studied the mass media's dependence on provided information – often called “information subsidies” – for many years. Those studies find that journalists generally rely heavily on these subsidies and that such information often accounts for a substantial percentage of stories that find their way into mass media (Turk 1986; Dunwoody 1993; Sallot and Johnson 2006; Chen, Chen, and Chen 2012; Kroon and van der Meer 2018). That percentage typically increases as the resources available to a media channel decrease; for example, small media organizations with few reporters may simply incorporate press releases wholesale into their news offerings. PIOs commonly complain about the small community newspaper that removes the press officer's name from the press release and then publishes the text as if it were generated by the media organization itself.

This carefully managed exchange relationship makes journalists' negative attitudes toward public relations seem odd on the surface. Journalists routinely express contempt for the public relations process even as they rely on its practitioners for story ideas. DeLorme and Fedler (2003) acknowledge this negativity and, looking back in time for causal factors, found many examples of unethical behavior among early PR practitioners, from bribery to faked events. Interestingly, they also document a steady flow of journalists into public relations beginning in the 1890s, a process that continues to this day among science journalists as their media homes cut them loose for economic reasons.

As Schäfer (2011) notes, scientific institutions began to extend their public relations efforts in the latter part of the 20th century, reflecting a growing concern about the perceived decline in the credibility of science in society and an assumption that such a problem could be solved by ramping up the volume of “good” science information pumped into the public domain. Advocacy-oriented and other nongovernmental organizations got the message, too, and in many cases have built formidable

strategic mechanisms to move their views through journalists and into public view. Lück, Wozniak, and Wessler (2016) describe one instance in which science journalists and environmental NGOs created a type of shared culture around coverage of the UN climate change conferences.

Calls to clarify the norms of the shared culture between PIOs and journalists and to build respect for both occupations abound (see, for example, White and Hobsbawm 2007; Macnamara 2014; Borchelt and Nielsen 2014; see also Chapter 22, this volume). But also on the increase is an awareness of the level of control that science PIO operations can exercise over what becomes news about science. Science journalist-turned-communication scholar Winfried Göpfert argues that, just as the scientific culture becomes increasingly sophisticated in its information control efforts, science journalism is entering a “weak phase” reflective of the decline of journalism generally (Göpfert 2007: 216). The rise of social media channels, he warns, offers scientists and their organizations even more opportunities to replace the work of science journalism with public relations efforts masquerading as journalism.

## 6 Science story impacts on audience

Recall the apocryphal impacts (or lack thereof) of media coverage of Sputnik I that opened this chapter. While media accounts succeeded in alerting Americans to the launch of the world’s first space satellite, that extensive coverage did little to bolster audience members’ understanding of what satellites actually do. In fact, science’s assumption that more information about science in the media will increase public understanding of science has never panned out in a substantial way over the decades, a pattern common to all types of news across time and space (see also the account of the “deficit model” in Chapter 5, this volume).

Still, a growing literature looking for message effects does find them, contingent on a variety of individual and societal factors. In this section, we will take a brief look at a number of them.

### 6.1 Why NOT an impact on knowledge?

A lot depends on how one defines “knowledge.” In the case of science, that definition has been driven largely by studies of science literacy. A recent examination of the concept by the U.S. National Academy of Sciences, Engineering and Medicine (2016: 2) identifies its most common attributes:

- (1) the understanding of scientific practices (e. g. formulation and testing of hypotheses, probability/risk, causation versus correlation); (2) content knowledge (e. g. knowledge of basic facts, concepts, and vocabulary); and (3) understanding of science as a social process (e. g. the criteria



for the assignment of expertise, the role of peer review, the accumulation of accepted findings, the existence of venues for discussion and critique, and the nature of funding and conflicts of interest).

In addition, Friederike Hendriks and Dorothe Kienhues discuss pedagogical and psychological research about science literacy and information processing in Chapter 2, this volume.

Not surprisingly, those components are often given short shrift in news accounts focused on communicating briefly about episodic events in science. So even if an individual engages in effortful processing of information gleaned from a media science story (all too rare an occurrence; we humans are overwhelmingly superficial information processors!), it is unlikely that the learning that takes place would map well onto the science literacy components identified above. Those studies that do uncover a link often find their results dependent on such factors as the type of media channel used, print or broadcast (Wade and Schramm 1969; Nisbet et al. 2002), individuals' socioeconomic status (Viswanath and Finnegan 1996; Wei and Hindman 2011), and perceived need for information (Yang et al. 2010; Yang et al. 2014).

Some scholars suggest that one might find a more robust media-knowledge link if the definition of science literacy were modified to better match the contours of media coverage. Brossard and Shanahan (2006), for example, isolated 31 scientific and technical terms that occur regularly in media science accounts and, in a pilot test using undergraduate students, found that the students better understood those media-derived terms than questions from a classic science literacy test, although media exposure could not be linked to those outcomes.

So what do media science stories reliably accomplish? Here is a brief but potent list of impacts:

## 6.2 Science stories as alerting mechanisms

One of the most important functions of media stories generally is to signal when something is worthy of attention. Among the gratifications sought by audiences from news media generally, "surveillance" is high on the list. We have a strong need to monitor our environment and are particularly energized by information about something going wrong. Thus, science stories that share timely information about new, unusual, or suspicious occurrences, particularly involving conflict, send us into processing mode. Science journalists know this and privilege information that can be packaged in these ways.

### 6.3 Reinforcing beliefs

One of the most powerful impacts of media information is that, under the right circumstances, stories can strengthen existing beliefs. This pattern has been well known for many years, having surfaced at least as early as World War II. The Allies hired filmmaker Frank Capra to create a series called “Why We Fight” to convince new military recruits that the cause deserved their commitment and sacrifice. Social scientists were able to implement a field experiment (quite novel at the time) in order to measure cognitive and attitudinal outcomes of the series. The films did enhance recruits’ knowledge of the war, at least for a few months. But most importantly, the dramas generated little in the way of attitude change. Instead, those viewers with already established beliefs about the war believed even more intensely that their opinions – whether pro or con – were correct (Hovland, Lumsdaine, and Sheffield 1949).

This use of information to intensify one’s existing beliefs, sometimes labeled “motivated reasoning”, has become a popular arena of study in science communication as topics such as climate change, GMO foods, and the purported risks of vaccines become highly politicized and publicly contentious (Hart and Nisbet 2012; Kahan 2016; Carmichael, Brulle, and Huxster 2017). The pattern is incredibly stable and resistant to informational interventions (Drummond and Fischhoff 2017). That has not stopped efforts to find work-arounds (see, for example, van der Linden et al. 2015; Cook, Lewandowsky, and Ecker 2017; Feldman and Hart 2018), but changing such beliefs remains a daunting challenge.

### 6.4 The power of storytelling

Stories that “transport” us can lead to change in knowledge and beliefs. The concept of transportation is related to a reader’s/viewer’s ability to get lost in a story. Jones describes it as “the familiar process by which we are all moved to temporarily suspend our engagement with the world around us to fall into a story” (Jones 2014: 648). We are tempted to suspend skepticism in order to fully inhabit this narrative world, and it is that lowering of analytical defenses that may give narratives much of their persuasive power (Green and Brock 2000; Green 2006).

Characteristics of narrative that promote transportation include vivid characters, ideally similar to the reader herself; a plot that involves tension, conflict and, ideally, a resolution; and a narrator, or point of view. Dahlstrom (2014), in an overview of the narrative effects literature, notes that use of narrative strategies makes texts easier to understand and increases audience engagement with the information. And although narrative characteristics are more common in fiction than in news accounts, scholars argue that journalists have become effective implementers of narrative devices over the course of many years (Zelizer 1990; Hartsock 2007).

## 6.5 Using media information to make inferences about others and about oneself

Perhaps one of the most interesting research domains for communication scholars today encompasses studies of the ways in which audiences use journalistic stories to make inferences about themselves and others. This domain suggests that media science stories are interpreted in ways that may have little to do with actual content. Here are just a few examples:

- We regularly assume that media accounts influence others more than they do ourselves personally, leading us to underestimate the impact of information on ourselves. Called the “third-person effect”, this pattern is most likely to emerge with stories that offer negative news. For example, in one recent study Dahlstrom and Rosenthal (2018) asked individuals about the power of climate change messages and got the classic third-person response: respondents perceived those messages as more likely to influence others than themselves.
- Media science stories, which necessarily simplify explanations of concepts and processes, may lead readers/viewers to become over-confident in their ability to understand the science, resulting in less reliance on the expertise needed to manage a highly complex world. In a recent experiment, for example, Scharrer et al. (2017) asked participants to read both texts aimed at scientists and texts designed for lay audiences. They found that reading the popular science articles led participants to agree more with the knowledge assertions in the text and, importantly, to feel more confident about their interpretations of story meaning.
- People may use media science stories as surrogates for what other people think and do. We humans are constantly monitoring the attitudes and behaviors of others. Such tracking is important as we seek to align our own feelings and behaviors with our peers, particularly in ambiguous situations where appropriate attitudes and actions are harder to discern. This is the world of social norms (Nyborg et al. 2016), and media accounts can play a major role in these monitoring efforts. For example, studies have demonstrated that policy makers use media coverage to judge the public salience of science issues, often reacting to such stories as if they had, instead, been hearing from constituents (Trumbo 1995). Others have examined the normative impact of media accounts on such behaviors as binge drinking (Yanovitzky and Stryker 2001). The point is that the simple visibility of an issue, via repeated coverage in the mass media, can lead to inferences that the topic is important (one important corollary of agenda setting) and, over time, even to changes in individuals’ attitudes and behaviors.

## 7 Science journalism and new media channels

The channels upon which individuals historically relied for science news – newspapers and magazines – are being superseded in the 21st century by television and the Internet. In the United States, the Internet had become the primary channel for science and technology information for 55 % of Americans in 2016, up from 47 % in 2014. Internationally, television remains a dominant channel for science news; however, in nearly every country where data are available, the Internet now plays a major role in both searching for and exposure to science news (National Science Board 2018).

While most Americans go online for science news, they have not forsaken legacy media organizations. A 2017 survey of U.S. adults by the Pew Research Center found that most got their science news from mainstream news outlets, probably online. The survey also found that Americans were lukewarm about getting their science news via social media. Only about a quarter of Americans in the survey said they follow science-related pages, and only about a quarter of social media users say they trust social media platforms to deliver accurate and unbiased science news (Pew Research Center 2017).

Research suggests that their concerns are warranted. Studies of the diffusion of verified versus false news online suggest that the latter spreads far more quickly than does the former. One recent study of the spread of information via Twitter from 2006 to 2017 found that, while robots accelerated the spread of both verified and false news at the same rate, people were far more likely to share false news, perhaps because of its novelty (Vosoughi, Roy, and Aral 2018).

Science journalists have been moving steadily online, both for information-gathering purposes and to follow their audiences. Although research on these newer channels remains very much in “start-up” phase, a number of preliminary patterns have emerged:

- Individual science news stories online appear to be structured in ways similar to that of news in more traditional channels; for example, they focus on similar topics and employ traditional news criteria. But channel differences also appear in comparative studies. While Painter, Kristiansen, and Schäfer (2018) found that legacy media covered the 2015 climate change summit in Paris much more intensively than did online media, the opposite pattern emerged from a comparative analysis of nuclear power and nanotechnology stories. Cacciatore et al. (2012) found a steady increase in those stories available via Google News over a five-year period but a sharp decline in stories in newspapers during the same period. And in a comparison of science stories in legacy media and tweets, Büchi (2017) noted differences across platforms in the information conveyed for some science topics but not for others. It is clear, the researcher concluded, that content differences between these classes of channels depend to some degree on the nature of the science issue itself.

- Science journalists are broadening their channel repertoire, moving into self-publishing via blogs and personal websites. Fahy and Nisbet (2011) note that such journalistic products increasingly compete with science content from other actors – scientists, scientific organizations, NGOs – who can now aim information directly at specific audiences. While such a landscape offers a rich “science media ecosystem” to readers/viewers, the researchers warn that it may seriously diminish the role of science journalists as impartial disseminators of science, encouraging journalists to adopt more novel roles, such as information curators, analysts, and watchdogs.
- Relationships with sources and audience members are becoming more collaborative in the online world. While many science journalists react warily to science content that comes from other “players”, such as blogs written by scientists (see, for example, Colson 2011), they have quickly adapted to an environment in which potentially credible information can emerge quickly and in real time via a host of online channels. One well studied example occurred in 2010, when a group of scientists published a paper online claiming to have discovered and cultured bacteria capable of living and growing using arsenic (the full published paper is here: Wolfe-Simon et al. 2011). Skepticism quickly grew among other scientists, and initial critical blog posts by a small number of scientists garnered attention from their peers and from science journalists. Yeo et al. (2017) found that discussion on blogs and Twitter posts in the days, weeks, and even months following the announcement served as a kind of “informal process of post-publication peer review” that helped to debunk the original study in a very public way. And an analysis of online media stories about the “discovery” found that “gee whiz” reactions to the study quickly morphed into stories that were dominated by critical reactions, which Vestergaard (2017) assessed as heavily reliant on blog content.

Reader comments and questions are also becoming salient pieces of information as science journalists explore how to use audience capabilities to “talk back”. While some science journalism sources have barred comments in the face of the kind of cruel, ad hominem attacks that are way too common on many sites (La Barre 2013; Anderson et al. 2014; Ellis 2015), Secko et al. (2011) take a more optimistic view and propose the concept of the “unfinished” science story that can be reinterpreted and supplemented over time by audience comments.

Research on the growth, roles, and impacts of new media channels on science journalism proceeds apace. For further overviews and analytical reflections, see Brossard (2013), Peters et al. (2014), and the National Academies of Science, Engineering and Medicine (2017).

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Holger Wormer

## 21 Teaching science journalism as a blueprint for future journalism education

**Abstract:** This chapter discusses concepts of science journalism education and its localization between the education of journalists in general and different fields of science communication curricula. Science journalism curricula usually include elements of natural sciences (including medicine) and – to a smaller extent – of cultural and sociological sciences, general journalistic skills as well as aspects from communication science. Despite some convergence with institutional science communication, a special status of teaching science journalism as a logical truth-seeking partner of science itself is recommended. As a perspective, it is suggested that all media sections have to become more scientific in the sense of evidence-based reporting in a data-driven and fake news endangered world. Skills as they can be especially taught in science journalism curricula offer a great potential to establish journalism as a “new knowledge profession” (cf. Donsbach 2014), delivering a saleable added value to the gratuitous information that any user can get by himself via Google or social networks. Therefore, concepts of science journalism teaching may have great potential as a blueprint for other fields for journalism teaching. However, the demarcation from rather marketing-oriented fields of science communication as well as concepts to pay highly educated independent journalists seem to be crucial in the future.

**Keywords:** science journalism – journalism education – data-driven journalism – evidence-based journalism – public relations – future of journalism

### 1 Introduction

“Reporting is one of the most difficult professions, requiring much expert knowledge and serious education. [...] improperly trained men have seriously misled a whole nation. It is habit rather than preference that makes readers accept news from correspondents whose usefulness is about that of an astrologer or an alchemist.” What seems to be a very current citation is nearly one hundred years old, given by Walter Lippmann (better known for his idea of news values) and cited in a recent work on journalism education (Lippmann cited in John 2013: 283). Lippmann did not refer specifically to science journalism. However, the citation already includes aspects that refer to similarities between science and journalism which may be closer than many people would have thought spontaneously. Forms of journalism dealing with scientific issues are commonly described as a “relatively recent vintage” (Friedman, Dunwoody, and Rogers 1986: xii; see also Chapter 20, this volume) or even a “delayed section” of the media (Hömborg 1990) founded mostly long after the classical media sections

such as politics, economics, culture, local and sports (for a brief encyclopedical definition of science journalism: Wormer 2008a). Different to other sections, popularization was seen as the main task of science journalism in many countries (cf. Kohring 2005: 58–62; 158–180). However, in the last twenty years of the 20th century, the role of science journalism as a critical observer has increasingly developed (see also part 2 of this chapter) and science journalism has become a common part of media reporting (e. g. Elmer, Badenschier, and Wormer 2008). However, there are at least three aspects that make science journalism (and therefore science journalism education) slightly different from the classical sections of the media such as the news or political section:

- The distinction between science journalism and other fields of science communication, either from scientific institutions or from popular books, articles and blogposts by scientists themselves often seems to be more blurring than for other issues in the media. Therefore, it has to be asked which skills taught in science journalism programs could also be relevant for these other fields (and vice versa).
- Many topics in science journalism are more complex, require a deeper understanding of the subjects addressed and are often less easy to explain (or at least to sell) to a broader public compared to realms like sports, culture or politics. Therefore, it has to be asked to what extent science journalism education needs a higher degree of specialization than teaching for other media sections.
- Science journalism is closer than other fields of journalism to tools and (data) technologies that may also be an instrument to guarantee an added value to all kind of journalistic investigations in the future. Such an evidence-based journalism (cf. Allan 2011: 773) goes beyond the “he-said-she-said”-journalism (just citing two different opinions in an article without appraising their evidence) and the kind of information that ordinary users may meanwhile easily find by themselves via Google or their personal social media community. Therefore, science journalism teaching has even greater potential as a blueprint for other fields for journalism teaching in the future.

Following these particularities of science journalism, this chapter describes first the position of science journalism between other forms of science communication, before an overview of different areas of teaching the field and their suitable weighting is given. The final section illustrates the special role that science journalism education could have for other forms of journalism teaching because of its closeness to emerging new technologies that affect media and information seeking in a digital world. However, besides its particularities, science journalism is part of the journalistic system as a whole. Therefore, many questions concerning journalism education in general are relevant for science journalism as well. Following the recommendation of Deuze (2006: 23; 28), the chapter does not just concentrate on detailed curriculum issues. Rather it tries to describe different contextual factors influencing a final curriculum – which finally depends in its details also on the differing needs of different societies as well as on the specific teaching framework at every single journalism school or faculty.

## 2 Teaching science journalism – just a specific field in science communication?

Surprisingly, the history of science journalism has not yet been systematically analyzed in a long-term perspective (Daum 2008: 155). However, the same author at least gives a first overview of the field with a focus on German-speaking countries since the 17th century (Daum 2008: 155–175). Boyce Rensberger, former director of the Knight Science Journalism Fellowship programme, delivers a compact historical analysis of the localization of science journalism in the world of science and science communication (especially in the US) over the last 100 years:

Science journalism has undergone profound changes since its origin more than a century ago, some more radical than most journalists of today are aware. Although there are legitimate complaints that some current reporters are too close to their sources, or otherwise unable to deliver a disinterested analysis of the field, it is salutary to reflect on how far the profession has come since its beginning. (Rensberger 2009: 1055)

According to Rensberger's analysis, initially science journalism was not so different from what we would describe today as public relations or just marketing for science. For example, in the US the association for science journalists did not even have the term "journalist" in its name, and the members rather called themselves "science writers" when they founded the National Association of Science Writers in 1934. Only in the 1960s and 1970s, after the appearance of Rachel Carson's book *Silent Spring* which described the problems of DDT and the beginning of the environmental movement, did journalists become more willing "to be critical of the work of scientists" (Rensberger 2009: 1056) and to also address the potentially adverse effects of science and new technologies. Or, as other authors put it, the environmental movement "focused journalists' attention on science's social, economic, and political contexts" (Friedman, Dunwoody, and Rogers 1986: xiv) whereas it is regarded as "not enough to focus on the science itself" (Blum, Knudson, and Henig 2006: vii). For the "digital age" Rensberger (2009: 1056) summarizes: "Science journalism has moved from working for the glory of the scientific establishment to taking back its independence and exercising a new responsibility to the public."

However, in some countries the emancipation of science journalism from other fields of science communication shows various indicators of flashbacks in recent years. Regarding the US Jerome wondered already in the mid-1980s if – after a more analytical and policy-oriented period – there had been a kind of "wholesale return to the 'gee-whiz' school of science writing" (Jerome 1986: 147). And after a peak of science journalism also outside the science sections (e.g. Elmer, Badenschier, and Wormer 2008), messages of editorial cut-offs (the most prominent example being the entire Science, Tech team at CNN (Brainard 2008)) and "equally contentious moves" (Allan 2011: 773; see also Brumfiel 2009) have emerged.

However, nowadays journalistic sources seem to still have the biggest influence on opinion formation concerning research issues in society and science itself (e. g. Allgaier et al. 2013; acatech et al. 2017: 27; for a recent international overview of media usages in different countries see Reuters Digital News Report 2017). According to the German Science Barometer 2016, 44 % of 1006 surveyed use the Internet (obviously including journalistic offers) “often or sometimes” as an information source for science and research, 67 % use television, 54 % read printed articles on scientific topics in newspapers and magazines. However, science journalism (as well as journalism in general) has lost parts of its role as a gatekeeper. In the digital world (science) journalism is now in direct competition for attention with other offers of science communication: From the public relations of scientific institutions, scientists (Neuberger 2014: 317), and we should add, as well as from sometimes well-informed “lay scientists” but also pseudoscientists. As all German Science Academies summarized in an analysis:

[...] the boundaries between professional and general audience are blurring. Former gatekeepers can be partially bypassed. Generally speaking, the Internet and Social Media present new possibilities of dissemination with (at least potentially) broad reach, which is equally open to all actors (as well as citizens interested in participation). On a single platform, for example a blog portal, journalists, scientists, PR people, and interested laypersons can communicate with each other, without their respective role (educating, enlightening, persuading) becoming visible. (acatech et al. 2017: 21)

From a professional perspective, the mostly public-funded science communication efforts of scientific institutions often imitating independent journalistic products have to be addressed. The background of this development has been described intensively as “new governance of science” and “new public management” in the literature (for an overview: Marcinkowski et al. 2014: 56–60; acatech et al. 2014: 10). Hence, in most OECD countries universities and other scientific institutions have transformed into entrepreneurial organizations facing an enormous pressure to demonstrate their legitimacy and becoming more publicly visible. “As noted in the literature on university public relations (PR), scientific organizations perceive an increased urgency to attract positive media coverage and to minimize negative publicity” (Marcinkowski et al. 2014: 59). Weitkamp (2015: 3) states a “large growth in the science public relations industry over the past 30 years”. As a consequence, even mid-size scientific institutions have sometimes a dozen or more people working in their public relations and marketing departments. Although exact measurements of the real staff structure of science public relations are difficult, the output side paints a rather clear picture. To give an example, our own study of more than 300,000 press releases from German speaking scientific institutions shows that even some smaller universities are used to sending a press release to the world on every workday (Serong et al. 2017: 162), not to mention numerous other online and social media activities or at least a couple of print products, in some cases even trying to compete directly with journalistic print publi-

cations in kiosks and book shops, as examples of the German Leibniz-Gemeinschaft (2012) or even mid-size universities show (see Figure 1).

For the Average Joe, especially the online offers of science journalistic media are very often not easily distinguishable from public relation products of scientific and other institutions. Journalistic selection criteria (at least if they fit their own interests) and forms of presentations are widely adopted by the public relations departments. However, some basic journalistic virtues and standards (such as criticizing or hearing a second opinion in the sense of “*audiatur et altera pars*” concerning a certain research result) are usually ignored or violated (Wormer 2017: 443; a proposal to include such critical quotes in the future is given by Brown Jarreau 2014).

Another frontier between journalism and public relations becomes less visible in the perspective of the user. As many media houses suffer from editorial job cuts and are increasingly lacking time and money for investigations, the situation gets even worse: Very often the public relations material, such as press releases, has a growing influence on the way a journalist reports, however, often just leading to a reproduction of its failures and pitfalls, too (cf. Schwartz et al. 2012; Yavchitz et al. 2012; Sumner et al. 2014). Or, as Geoff Brumfiel summed up about a decade ago in *Nature*: “Whether directly or indirectly, scientists and the institutions at which they work are having more influence than ever over what the public reads about their work” (Brumfiel 2009: 275). Russ-Mohl (2012: 108) claims that among all tendencies of convergence in the media, the convergence of science public relations and science journalism has to be regarded as the furthest progressed among all (see also Weitkamp 2015).



**Fig. 1:** In a book shop and kiosk of a train station in the northwestern part of Germany in 2018, the mid-size University of Regensburg (located in the south of Germany) tries to sell its research magazine *Blick in die Wissenschaft* just in between professional popular science magazines such as *bild der wissenschaft*, *P.M.* (Gruner+Jahr) and *Spektrum der Wissenschaft*. (Photograph: Wormer)



What does this mean for teaching science journalism? On the one hand, the extension of science communication efforts by scientific institutions themselves means a growing second job market for science journalists, whereas jobs in journalistic media are often cut off (e. g. for the US: Brumfiel 2009: 275). Obviously, well-educated science journalists who can keep things easily understandable, who are used to working under the pressure of daily highspeed journalistic media and who are furthermore well-connected within the journalistic media landscape are in great demand from the public relations departments of the scientific system. However, the localization, function and role model of science journalism in relation to other forms of science communication must be made extensively clear to the students. This does not only help to clarify the potential tasks and importance of science journalists and other actors in the daily work but also makes it easier to switch to similar fields as a potential working opportunity. However, after two decades of science journalism education, we observe that science journalists very often move into the field of public relations whereas a change vice versa from public relation officers into science journalism is rare, last but not least, because of a lack of trust and acceptance in PR people among leading editors in journalistic media houses.

Fig. 2 gives an overview of the roles mentioned above as they were issued by the Germany Academies of Sciences and as they are, for example, used in our own introduction courses for science journalism students at TU Dortmund University.

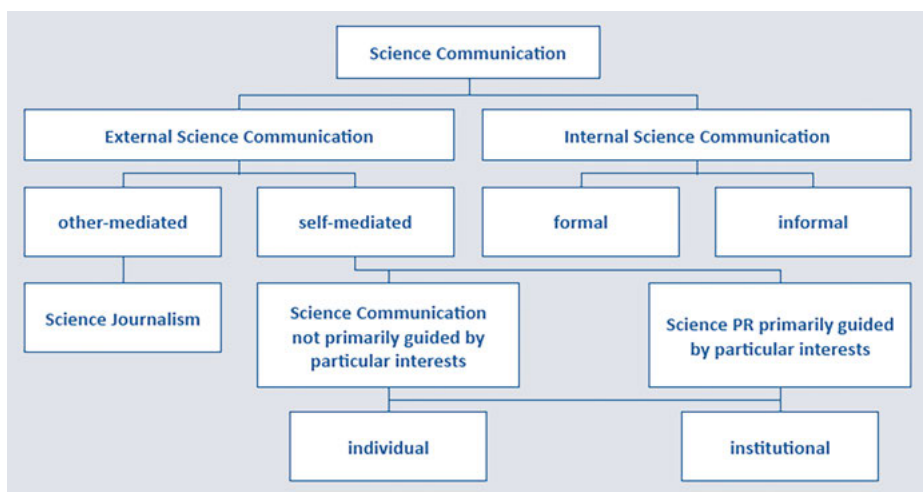


**Fig. 2:** Essential elements of the traditional localization of science journalism in relation to different fields of science communication (figure, further sources and explanation in acatech et al. 2017, 21). For science journalists, teaching the special role of journalism as an observer from outside in contrast to the increasing field of self-mediated and self-observing forms of science communication seems to be crucial.

It is obvious that many skills that have to be taught to science journalists are also of great importance for other fields of science communication. This seems to be especially true for the means of “good presentation” meaning comprehensibility as well as dramaturgical techniques of making things exciting by telling good stories, as well as good writing and good visualization (for an overview of quality criteria in science journalism see, e. g. Rögner and Wormer 2015; Nitz 2015 and projects such as [www.medien-doktor.de](http://www.medien-doktor.de) or [healthnewsreview.org](http://healthnewsreview.org)). But additionally, sectors of science communication increasingly giving themselves the appearance of producing journalism (as drafted above; also described by Weitkamp 2015: 1–2) and trying to communicate directly with a broader public are also well-advised to adapt quality standards concerning their content (cf. Wormer 2017: 444–445). One example is a recent debate about the question of whether a press officer writing a press release, a blog post, or similar should think about including a second opinion or even results from other scientific institutions which contradict the findings of the scientists in his own institution (cf. Wormer 2017: 441–442; Brown Jarreau 2014; see also Weitkamp 2015: 6). As a consequence, some quality standards from science journalism are incorporated in only recently developed standards for the public relations of scientific institutions as presented, for example, by the Bundesverband Hochschulkommunikation (2014).

Beside all kinds of convergences, Fig. 2 illustrates that science journalism retains at least one unique selling point: Different from other kinds of science communication in a democracy it has to fulfill the role as a critical observer from outside, as a watchdog of the scientific system (cf. Dunwoody in this volume). For that purpose, professional science journalism teaching has also to include the elements, strategies and tools of investigative reporting that go beyond the investigation techniques which are merely needed to be a good “explaining uncle” telling nice stories about the world of science. In this context, a profound knowledge of the dependencies inside the scientific system, of its reviewers and opinion leaders, of the advantages and disadvantages (such as the emerging of “predatory journals”) of open access and of different funding sources as well as of the political and economic framework of science in general are crucial. Or, to put it in the words of Rensberger:

[...] Scientists too can use the web, bypassing journalists altogether and taking their science – and their agendas – directly to the public. It is becoming increasingly difficult for readers to tell which sources are disinterested and which have an axe to grind. If science journalists are to regain relevance to society, not only must they master the new media, they must learn enough science to analyze and interpret the findings – including the motives of the funders. And, as if that were not enough, they must also anticipate the social impacts of potential new technologies while there is still time to make a difference. (Rensberger 2009: 1056)

In this sense good journalistic practice and ideal journalistic virtues (such as its truth-seeking function in democracy) are much closer to good scientific practice than to any rather marketing-oriented form of science communication such as public rela-

tions. Therefore, science journalism is seen here as the natural (nonetheless critical) partner of science itself and any curriculum in this field should be oriented alongside this overall concept. What this means for the practice of science journalism teaching will be discussed in the following section.

### 3 A complex mixing console: the different ingredients of teaching science journalism

Because most countries lacked academic science journalism programs for a long time, the traditional way to become a professional science journalist was studying a scientific subject (e.g. biology, physics, chemistry, medicine or engineering) first and learning journalism afterwards in a journalism school, at university or in structured internships or similar education programs directly in the media houses (such as a “Volontariat” of between 1½ and 2 years in German media). In a “best-practice study” for the Bertelsmann Foundation Rager and Hassemer (2003) looked for academic science journalism programs worldwide in order to prepare the development of the first bachelor course in science journalism at a German university in Dortmund in 2003. A similar program was established at a similar time at the University of Applied Science in Darmstadt. Prior to this, in Germany only a postgraduate study course at the Free University of Berlin existed (again, only for students with a first degree in the sciences). For 2002, Rager and Hassemer (2003: 5) identified 121 universities worldwide offering a specific science journalism program, most of them in the United States. (Among those the programs of the University of California-Santa Cruz, the University of Wisconsin-Madison and Boston University were ranked among the top ten with the highest reputation in a survey with more than 300 professors, students, freelancers and science editors (Rager and Hassemer 2003: 9).)

Since then the amount of similar academic programs has increased. In 2007 the European Commission (2007) even published a *European guide to science journalism training* providing some basic information (structure, length etc.) of different programs and organized a specific conference on science journalism. The *Global Science Journalism Report* gives an idea on the level of education of science journalists from an international perspective. According to the answers of  $n = 591$  respondents in the report (Bauer et al. 2013: 15), the training background of 36 % in this poll is “a university degree and training on the job; 26 % have a university degree with a specialist science journalism training; 19 % hold a university degree and have undergone general journalism training; 9 % went to journalism school and 11 % were trained on the job.” Furthermore, the “level of formal education among science journalists is generally higher in Europe, USA, Canada and Asia, than it is in Latin America, the Middle East and Sub-Saharan Africa. PhDs [...] are far more common in Europe (32 %) and in USA and Canada (31 %) than in other world regions.”

However, science journalism programs are often not clearly distinguished from more general science communication programs which can also focus on science education in museums or simply public relations. Nevertheless, some basic structures in the curricula are similar. For academic science communication programs offering a full degree Mulder, Longnecker, and Davis (2008) identified four supporting disciplines as pillars supporting the discipline: Science, Educational Studies, Social Studies of Science and Communication Studies (see Fig. 3):

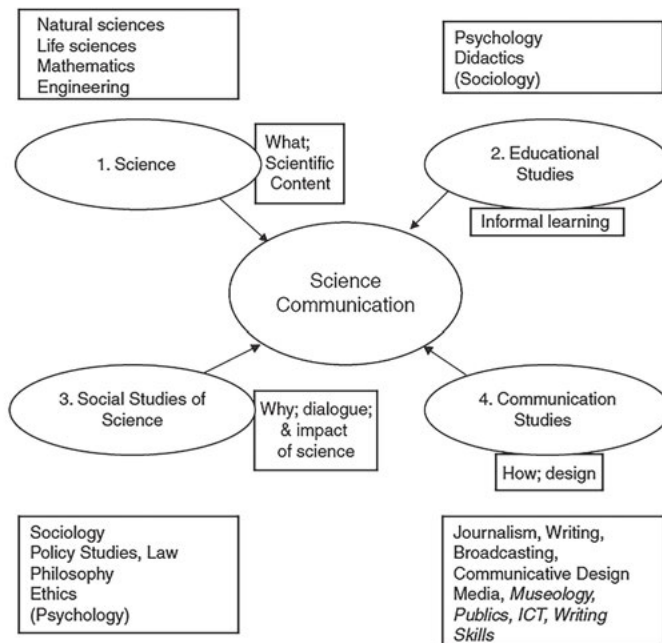


**Fig. 3:** In 2008 Mulder et al. identified “Four Areas of Study That Support the Discipline of Science Communication” which are more or less valid today. However, the question remains which weighting each field should get in a curriculum, how they can be connected and if on the other side the tendency to mix up science journalism with rather public relation and science marketing-oriented fields in “communicology” programs (as criticized by John 2013: 284) is really a model for the future.

This structure is widely in line with concepts of science journalism education that are rather derived from journalism education programs in general. Usually these were structured into elements of subject knowledge (about the subjects to be reported on) and special knowledge (about journalistic skills and techniques). The journalistic competences themselves are usually framed – at least in academic programs – between elements of journalism handicraft and results of communication or psychological studies

(such as reception studies) that have direct consequences for journalistic practice. The structuring in “subject competence” and “journalistic competence” traces back to the 1970s (e. g. Donsbach 1978: 11–112, cited from and discussed in Streitböcker 2013: 222) and can also be found in the tradition of journalism schools in the US as “knowledge” and “craft” (2013: 228). In practice it has also been adapted in the description of the general job profiles of journalists from journalism associations (such as the “Deutscher Journalistenverband” (German Journalists’s Association – DJV) (Pätzold 2008: 12–13)). Among others, the following qualifications are described here: broad general education and competence as well as the willingness to acquire the subject competence for the relevant fields; a structured training for journalistic and presentation competence including investigation techniques and journalistic genres as well as knowledge basics in media law and fundamentals in economic competition of the media. In his more recent work Donsbach describes journalism as a “new knowledge profession”, he distinguishes “five basic fields of competence” to be taught:

A journalist should (1) possess a keen awareness of relevant history and current affairs, as well as analytical thinking, (2) have expertise in the specific subjects about which he or she reports, (3) have scientifically based knowledge about the communication process, (4) have mastered journalistic skills, and (5) conduct himself or herself within the norms of professional ethics. (Donsbach 2014: 667)

But although most educators will probably rather agree on general structures of a curriculum as proposed by Mulder et al. and/or by Donsbach, it seems to be much more difficult to decide which weighting each pillar (and finally each single course) should get in the practical teaching: How much and which kind of expert knowledge or subject competence of the scientific disciplines probably to be reported on in professional life later is necessary? How much (and how many) basic journalistic skills of investigation and presentation is (are) crucial? What should journalists know concerning the audience and its perception of science news? Which technologies and which media channels (radio, television, print, online, social) have to be taught to what extent? As described in an earlier publication on science journalism education, the adjustment of all these different elements can be regarded as a complex “mixing console” (Wormer 2008b) where adding one ingredient will mean that another element has to move into the background.

### 3.1 Teaching which kind of subject competence – and how much?

Traditionally science journalism is mainly focused on the reporting on issues related to disciplines from the medical and natural sciences and engineering (cf. Wormer 2008a). Although the importance of other scientific disciplines for the science sections of the media is an ongoing debate (cf., e. g. Volpers and Summ 2015; Summ and Volpers 2016), in the editorial everyday life they are still covered rather by other sec-

tions (such as the culture or “feuilleton” sections for art and cultural studies or the business pages for economic studies). In any case, this begs the question again which kind of basic knowledge from which discipline is crucial. The proportion of reporting may give a first orientation of the importance of different scientific disciplines. Summ and Volpers (2016: 782) count 21 % of science coverage for social sciences and behavioral sciences, and 20 % for medicine, followed by biology and agricultural sciences with 18 %. Our own findings (Elmer, Badenschier, and Wormer 2008: 885) focusing on the classical disciplines of science journalism, that is, excluding social sciences and humanities from the counting, show about 28 % for medical issues and about 13 % for biology. Although most content analyses of science reporting are difficult to compare because of different definitions of science journalism constituting the basic population for the sampling and also because of differences in the chosen categorization of disciplines, it seems to be internationally consistent that medicine is among the most dominating disciplines (cf. Elmer, Badenschier, and Wormer 2008; Bucchi and Mazzolini 2003; Clark and Illman 2006), often followed by biology. Despite the described difficulties Volpers and Summ (2015: 252–253) even talk about some constants of science reporting (“Konstanten der Wissenschaftsberichterstattung”) over the years. In contrast, disciplines such as chemistry or mathematics seem to be neglected with amounts around 3 % or less (Elmer, Badenschier, and Wormer 2008) – at least compared to their prominence in the scientific world itself. Of course, it is difficult to define a kind of expectancy value for a reasonable amount of reporting on a certain discipline because every discipline already differs in size of the number of scientists as well as the scientific publication output. However, it has to be noted that, for example an extensive research field such as chemistry receives disproportionately less attention.

Again, the question of what this means for science journalism teaching remains. On the one hand, we may argue that disciplines which are highly present in the actual reporting of journalistic mass media also deserve more attention in the curriculum in order to satisfy the existing market. On the other hand, we may argue in a more normative way that disciplines which seem to be underreported have to be taught more in order to ‘cure’ a potential deficit in the reporting. Furthermore, studies looking at the real interests of users suggest the possibility that the interest of the audience concerning some disciplines may be underestimated by the editors (cf. Artz and Wormer 2011). And beside the editorial reality of today’s preferred disciplines, science journalism teaching should also anticipate the need of certain subject competence that has to be extended in the future. One example is the field of data science and informatics which was rarely in the main focus of science journalistic coverage. But as it is gaining increasing importance in everyday life and in society as a whole, these disciplines are candidates for an increased teaching of these subject competences (even apart from the fact that these disciplines belong to an emerging field for journalistic research and production itself, as will be analyzed later this chapter). For issues concerning the technical and engineering domain, for example, many science editors from our coop-

erating media partners of the bachelor course in science journalism at TU Dortmund University complain about a lack of competent (science) journalists who would be able on the one hand to evaluate the truth concerning a promised innovative character of the latest smartphone brand and on the other hand to estimate the official risk assessment of a 40-year-old nuclear power plant in the neighborhood.

Clearly connected with the question which and how many disciplines have to be taught in the pillar of subject competence is the question of how deeply a certain discipline has to be understood. As most science journalists cannot afford later in their daily job routine to cover just a single scientific field, following the given editorial structures there are usually several disciplines to be integrated in a curriculum. In many editorial offices there is at least a distinction in responsibilities for 'harder' sciences (such as physics, astronomy etc. and engineering) and for 'softer' sciences (such as medicine, psychology, biology and environment). Accordingly, in the science journalism bachelor program that we offer since 2003 students can choose today between a specialization in life sciences & medicine, physics, technical journalism (with a focus on engineering sciences) or data journalism (with a focus on statistics). Having started with a distribution of about 60 % subject competence teaching in the curriculum and 40 % journalistic competence, the proportion has shifted to about 50:50 in recent years (external internships in media houses not included). Rager and Hassemer's international analysis (2003: 80) has still found a common distribution in the curricula worldwide of about 70 % for the subject and 30 % for journalistic competence. The shift towards an increasing emphasis on the journalistic competences is in line with the observation that the time is over where some popular media followed a motto such as "If you don't have a PhD in Physics or similar you should not apply for a job as a science journalist in our house". However, a general problem of education persists: Often advanced topics (such as the latest news concerning Einstein's theory of relativity or gravitational waves) are attractive for media reporting. Such issues cannot really be taught without some basic knowledge (such as Newton's law) as a precondition. But taken for itself this kind of basic knowledge is often of rather limited interest in the media.

One helpful approach to gain time for teaching enough subject competence in a curriculum is to cut off time-consuming practical lab elements as they exist in pure science curricula to a minimum. A science journalist has to get an idea what laboratory (or clinical etc.) work means in reality. Therefore, he or she should have some basic practical experience during education. However, he or she will not have to run his or her own lab experiments or do clinical surgeries later in the job.

Again, Donsbach (2014: 668) puts the goal of teaching subject competence in a nutshell: "While the level of this knowledge journalists have will rarely compare to the level that the experts in the respective field have, it has to be sufficiently deep so that the structure of the field is understood and the main actors are known." In this sense finally one field of subject competence in science journalism that has been neglected for decades deserves closer attention: The knowledge about the structure of

the scientific system itself, including its institutions and their financing, the scientific publishing procedures (from peer review, open access and predatory journals to scientometric issues, from the journal impact factor to the H-Index), as well as courses on good scientific practices, ethics and problems of scientific fraud. Interestingly, these (in comparison to, let's say, vivid interview training, for the students initially rather boring) structural issues are constantly mentioned in personal communications and evaluations in the practice field as most important by our own former students of science journalism. One reason for that may be that many science journalists sometimes already working for decades in the field have never received a systematic education concerning science policy issues such as research funding or publication policies because they were usually career changers coming from a purely scientific education in physics, biology or similar into science journalism later.

## **3.2 Which kind of journalistic and which background competence?**

### **3.2.1 Applied research as a bridge to investigation and presentation skills – and to the social sciences**

Although the schematic separation of four different areas as proposed by Mulder et al. (2008; Fig. 3) is helpful for structuring the field, it is recommended for the implementation in a concrete curriculum to not separate theoretical and empirical findings too much from practical skills. This guarantees that journalism teaching can be evidence-based as much as possible and relying less only on the beliefs of former generations of journalists. One example is the widespread belief that citing experts makes an article more vivid and readable whereas reception studies have shown that such citations often disengage readers, hindering them from reading further. Regardless if it concerns the teaching of journalistic styles and narrative approaches, special interview training with scientists, aspects of media law or economics or reception (latterly including debunking of misinformation), science journalists should learn practical skills as often as possible alongside the evidence of the corresponding scientific disciplines, for example from reception studies in communication sciences or in psychology. Or as Donsbach says (2014: 668):

If journalists know about, for instance, socio-psychological factors and group dynamics, they might resist more of the drives of 'pack journalism' and its often irrational decision-making. If journalists know more about audience research, they will be able to present their messages in a way that might maximize not only attention to news but also, if employed in a responsible way, its cognitive processing by the audience.

For science journalism teaching, such an approach also implies another advantage: The connection between theory and empirical findings from sociological, communi-



cation and journalism research, etc. to journalistic practice also increases students' knowledge in these fields which are usually a smaller component in the teaching of (usually rather natural sciences focused) subject competences. If such knowledge and teaching is consequently integrated into the curriculum and science journalism students also have to write a related Bachelor or Master thesis (e. g. in order to develop projects evaluating their own journalistic products), such an approach will also be a bridge between sciences and humanities.

However, such an approach must not dilute the clear science journalistic focus. Such a tendency has already been criticized regarding many academic journalism curricula (John 2013: 284):

Journalism scholar Barbie Zelizer has recognized 'the ascent of academic curricula in communications that took over journalism training programs,' a simple statement that too easily summarizes the great hegemony of generic 'communication,' which is itself an outgrowth of old speech and rhetoric departments. The sad result of the subsequent dissolution of professional journalism education has been graduates steeped in 'communicology' who carry degrees stamped 'journalism' or 'mass communication,' but who are unable to gather facts in an interview, discern fact from propaganda in the exchange, or write a good sentence to describe it.

Similarly, general science communication programs can probably not replace a distinct science journalism curriculum, including the above-mentioned skills of investigative reporting as well as the competence of embedding research results in social, ethical and legal contexts. Such competences, crucial for highly independent observers of the scientific systems from outside, seem not to be demanded very strongly in the science communication departments of scientific institutions. In contrast, there are stronger intersections on the side of presentation techniques and the distribution of scientific information.

### **3.2.2 From single channel journalists to cross media jugglers**

Probably the biggest shift in science journalism teaching in recent years was the movement from educating primarily for one or often two types of media to a complete cross media approach (including online, print, radio, television and social at the same time). Especially online journalism teaching, 15 years ago regarded as second class journalism, is now tagged often under buzzwords such as "online first". However, the decision if there should be still a certain kind of specialization on at least one nucleus home medium with all the others surrounding it or if an "everything equal"-approach is the better one seems to be answered differently by different educators. In any case, we have to keep in mind that especially the social media channels underlie an ongoing diversification, a continual coming and going of new platforms and technologies, which requires a certain flexibility. Also, Donsbach (2014: 669) points out:

With the technological changes brought about by digitalization, journalists must also learn to work across different media platforms to convey their messages to the audience. However, if the goal is simply to provide skills training in the latest technology, the training may ultimately fail, because media technology is constantly changing. The instructional goal should be the strengthening of students' adaptive capacity – coursework that will enable them to respond effectively to changes in technique, platform, and perspective. Medical school training is an instructive example. Although medical students are properly taught the latest techniques, their training centers on the acquisition of knowledge that will enable them to adjust to whatever changes occur in medical technology and practice.

The comparison of academic journalism schools with “teaching hospitals” makes sense and can also be found among other authors (e. g. Mason 2015: 25). One strategy to fulfill the demand for flexibility and openness in an appropriate education is to offer tailored courses combining skills of journalism and science at the same time and not just teaching one after another. As a recent survey among journalism educators in four European countries (asking for the future skills to be taught for the next generation of journalists) concludes, there is no need for journalism education “to follow every trend, that journalism education should not try to include and embrace every new development in the industry, but teach core competences and only those trends that are significant. The role of journalism educators rather should be that of critics who observe developments in the media and implement new skills and tools in their teaching only if relevant” (Bettels-Schwabbauer 2018: 90). Furthermore, according to the study most institutions ask their students to gain practical experience not only in editorial, investigating and writing etc. exercises at the university but also in internships in the mass media – a recommendation which seems to be a broad consensus also among the media houses.

## 4 Teaching science journalism as a bridge to new tools and technologies for journalism

In an all-embracing digitized media world the potential of science journalism education, rather on the fringes of journalism education in the past, has finally to be seen also on a broader scale. Similarly, as recently discussed for the field of data journalism (Wormer 2018), science journalism may be considered as a potential bridge between data science and journalism. There are at least three reasons to consider contents and concepts of science journalism curricula for other programs as well:

- 1.) Especially science journalists may be seen eligible in the tradition of Walter Lippmann and Philip Meyer (see pages 455–456) to fulfill the thinking and requirements of an evidence-based journalism. Such a kind of journalism offers an added value to media users beyond their own possibilities to gather and evaluate information in the digital world.

- 2.) As science journalists are used to report on such issues they should also be more open for data issues and new technologies – both skills which are of increasing importance for nearly all media houses. These include different areas from investigation tools, to new possibilities of interactive presentations up to internal evaluation tools in the field of audience analytics and research.
- 3.) Science journalists have a great potential to better understand developments and phenomena in a data and technology driven world which becomes more and more important in everyday life.

Arguments such as the third one have always been popular to illustrate a probably increasing importance of teaching science journalism. However, their significance could gain more weight now in a time of an omnipresent smartphone in everyone's pocket. Data science and modern information technology influence every part of the daily life now, starting with the online buying of everything or the use of a search engine for anything. Recently, data manipulation, data sharing and data security, "filter bubbles", "echo chambers" or the distribution of "fake news" via "robot tweets" or the questionable use of Facebook algorithms have left the purely scientific discussion and started to become a mainstream issue spreading from talk shows to political debates (for a literature overview on "filter bubbles" and "echo chambers" cf. acatech et al. 2017: 23–24). However, these issues are barely understandable without enough knowledge both of the basic technologies behind and the understanding of media and their audience on the front end. Both fields of knowledge (the technological and computer science side as well as the communication science side) can be easily implemented not only in a two-branched science journalism education but on this basis also in journalism teaching in general.

The second argument concerns both investigative and presentation skills of journalists. The dimension and complexity of investigative journalism projects such as the Panama Papers have finally forced many non-science journalists to realize that probably in the future the most relevant investigations may often not be handled without scientific and technological methods (an observation that also some authors of the Panama Papers themselves admit (cf. Wormer 2018: 236–237)). The same is true for the presentation of journalistic media products which is already increasingly becoming technology-based in the newsroom. Everybody who wants to generate a modern interactive and colorful journalism, including a kind of individual news value generator for every user (cf. Wormer 2018: 228) which promises higher attention and better page impressions, will need a certain level of data, programming and technology knowledge. Also implementing internal live web metrics that improve the range and marketing of the journalistic products needs editors who are at least open-minded to science and technology developments (cf. Nguyen and Tien Vu 2018; an overview of possible technological developments in the future of the media can be found in Webb (2017)). Or, as Nguyen and Lugo-Ocando (2016: 6–7) put it:

[...] whether they like them or not, it is the journalist's duty to learn, master and use statistics competently, for at least two broad reasons. For one thing, the emergence of the 'big data' society means daily newswork itself is based more on 'number crunching' than any time in the past. Many digital newsrooms today are inundated with live web metrics, erecting large data boards for reporters and editors to constantly monitor what audiences are doing with their news sites and apps, where they are from, where they go to, what they read/like/share/tweet/retweet the most and so on. These numbers behind the news are diverse and complex – for example, some tracking software could produce several hundred variables and even pin down the advertising income that a news story can generate. If journalists have the ability to handle these metrics, they can harness them into an excellent, unique tool for more pertinent, more engaging and perhaps more viable news products. But if they do not have the statistical reasoning skills to understand and use web metrics wisely and calmly, journalists might risk falling in the trap of 'the sentiment of the crowd' at the expense of their professional judgement. In this new 'click-thinking' culture, web metrics could easily deepen one of journalism's already severe crisis – the dumbing down of news – and bring newsroom tensions and conflicts to a new height.

Because of such reasons, the need to establish data, science and technology literacy on a broader scale in journalism education seems to be evident. Although (following the observation in our institute and also in other schools of journalism) journalists in general have rather chosen their job because they wanted to deal with language, pictures and telling stories, they should at least be able to communicate and cooperate with data and technology experts, regardless if in limited projects or in a permanent editorial team. And who should be better prepared to build bridges between journalists and scientific expertise than well-educated science journalists?

But the arguments for a basic understanding of science, data and technology issues go even beyond the purely technical needs in the newsroom itself and lead to the idea listed as number one in our list on the second page of this chapter: Going beyond a "he-said-she-said"-reporting providing a journalistic fact checking that is worthy this name leads back to ideas of a kind of journalistic thinking as it was already demanded by some intellectual prophets (but interestingly not science journalists at all) in the 20th century (Nguyen 2018: 5):

Lippmann argued ardently in *Public Opinion* for the integration of scientific rigour into journalism, calling newsmen to bring to their truth-seeking and truth-telling function the objective method of science, which is 'based on exact record, measurement, analysis and comparison' (Lippmann 1920: 138). 'It does not matter that the news is not susceptible of mathematical statement,' he said. 'In fact, just because news is complex and slippery, good reporting requires the exercise of the highest of the scientific virtues' (1922: 49). This means, as he pointed out in an earlier book, *Liberty and the News*, journalists would have to possess the ability to '(scribe) no more credibility to a statement than it warrants, a nice sense of the probabilities, and a keen understanding of the quantitative importance of particular facts.' (Lippmann 1920, 82).

However, that does not necessarily mean that journalistic and scientific knowledge are identical but rather that they could be regarded as complementary according to Spinner (1985). A similar idea is also described as "precision journalism" which Philip Meyer (1973) proposed as an inquiry method that uses "quantitative social science

research methods [...] to gather news” (Demers and Nichols 1987: 10–11). According to the same source, this kind of journalistic thinking has its origin some decades earlier: “Precision Journalism is already described for some journalistic investigations in the 1930s.”

Science journalism curricula seem to fit perfectly for teaching such kind of an “old new” idea of journalism. Science journalists are routinely taught to deal with new research and technologies and to identify and talk to scientific experts from different disciplines. The advantage of two-branched science journalism programs is that they usually attract students who feel from the very beginning comfortable both with language and other purely journalistic skills, but are not worried about studies, complex theories and statistics. This strategy helps avoiding a problem pointed out by Hewett (2016: 132) in a similar way for data journalism education that “despite promising job prospects, data journalism risks being rejected as unappealing by potential students with an arts or humanities background”. At the same time, the two-branch approach has also a second effect for bridging the gap: It often attracts students from the natural sciences, engineering, medicine or statistics to approach, on their part, the world of journalism and media.

## 5 Conclusions and perspectives: towards a new knowledge profession and a public understanding of journalism

In his already cited article on the future of journalism education, Wolfgang Donsbach has described journalism as a new knowledge profession “with the core societal functions [...] validation and shared reality” (2014: 661). Donsbach refers to Philip Meyer recommending that

journalism students receive instruction in the process of knowledge-tested reporting. Such training would educate journalism students to be truth-seekers in a scientific sense and provide evidence that is always tested against alternative explanations. Philip Meyer has long argued that journalists need to apply the logic of the scientific method to their work – for instance, applying the technique of replication so that other journalists can ‘get the same answer’ [...]. As in the sciences, ‘true objectivity,’ Meyer says, ‘is based on method, not result’ [...]. (Donsbach 2014: 668)

Notably, Donsbach was not talking about science journalism but about journalism education in general. This is even more striking if we compare Donsbach’s proposal with Rensberger’s (2009: 1056) claims for science journalism (already cited on page 441): “If science journalists are to regain relevance to society [...] they must learn enough science to analyze and interpret the findings – including the motives of the funders.” If we take Donsbach’s and Meyer’s approach seriously, journalism

has probably to become more scientific in the future without abandoning journalistic virtues and time-tested (e.g. narrative) forms of presentation. Interdisciplinary double-branched study concepts in science journalism could be a blueprint here for journalism educators to tailor programs for the corresponding needs in other media environments in the future. Science journalists and science journalism teachers should also encourage journalists from other fields to approach this field of science and technology sometimes appearing as a “strange” one. They understand by training the language and culture of journalists as well as of scientists. Science (and similarly trained) journalists being used to building bridges between different professions are valuable as translators; or even as leaders to manage and direct interdisciplinary teams but at least to bring people with different qualifications together. Similar to the success of the big Internet companies (which is built on the knowledge of science and technology on the one hand and of knowledge of the media on the other) the successful *journalistic* media will have to anchor on these two branches. Perhaps just with the help of well-educated science journalists.

Ideally, the skills of science journalists in a narrower sense should enable them to fulfill their role as critical observers of science and society in a similar way as is usually claimed for political journalism: Science journalists of today have to be educated, in the sense of Rensberger (2009), not as “cheerleaders” but as “watchdogs”. On the other hand, scientists and journalists share a normative responsibility for truth seeking (see Chapter 1, this volume), fact checking and strengthening debates and opinion formation in a modern democracy as it was formulated in the recommendation of the German Academies of Sciences (acatech et al. 2014: 2):

Science and journalism are among the essential pillars of a democratic society. This is why Article 5 of the German constitution (Grundgesetz) guarantees freedom of the press and scientific freedom. Despite their necessary mutual independence and their often divergent purposes, both freedoms also fulfill similar functions. They supply policy-makers and society with a diverse array of information that is as reliable as possible, reinforcing the education and knowledge of the population and stimulating democratic discourse. They should also provide a basis for reasoned political, economic and technological decisions.

In this sense, substantial journalist-scientist collaborations seem to be one important strategy for the future. Such cooperations can help to ensure quality (e.g. with verification tools to detect “fake news”) and, in general, to generate the needed added value of a journalistic product that might persuade media users to pay for news. Again, science journalists could help here to build such bridges between science and other fields of journalism. A recent activity in this direction is the annual conference SciCAR which has started in 2017 and is dedicated especially to such cooperations. It is organized by the Science Media Center Germany, the German Association of Science Journalists (wpk) and the chair of Science Journalism at TU Dortmund University and funded mainly by the Volkswagen Foundation ([www.scicar.de/index.php?article\\_id=1&clang=1](http://www.scicar.de/index.php?article_id=1&clang=1)). Individual teamwork between journalists and scientists

in specific fields (e.g. sharing specific methods and knowledge) is not contradictory to the general role of science journalism as a critical observer of the scientific system.

However, there are also a couple of obstacles to overcome for the future of journalism and science journalism education. First, as Jeffrey Alan John (2013: 283) describes in his article “One way to save Journalism and Journalism Education”, journalism must regain more respect for its profession. Although recent data (cf., e.g. for Germany: Ziegele et al. 2018) indicate a temporary recovery of trust in journalistic media, there should be no doubt that this goal will remain important in the long run. That also means that the qualification of seriously trained journalists and science journalists must also become more visible for the users. John (2013: 285) discusses the possibility of a kind of certification for journalists and sketches a suitable curriculum for that as follows:

Accordingly, a journalism education that meets those recommendations would strive to create a reasonably uniform, rigorous curriculum of about five or six years in length. It would include practical training from professionals, and education in principles and theory as presented by experienced minds of our time. At its conclusion, the graduate would be launched holding an appropriate appellation, say, “credentialed journalist,” indicating to the world that the holder has been suitably prepared. (John 2013: 285)

At the same time, he admits that “the idea of a journalist holding a certified “professional” standing is wholly alien to our culture” (John 2013: 285). The proposal of such quality labels seems to be not very popular in the social media world as the experience of the author of this chapter and of the other speakers of the working group of the German Academies of Science has shown after having proposed such labelling or at least a code of conduct for the web and social media in their (already mentioned) recommendations (e.g. acatech 2017: 9). However, probably the idea of such labels is not so far-fetched as it may sound if we don’t talk about certification but rather a branding of quality in science journalism. This can be done to a certain extent by science journalists themselves, making more transparent what their quality criteria, standards and working procedures for investigations are in order to guarantee a certain level of evidence of their reporting (an example of how such criteria can be developed systematically is given in Rögener and Wormer 2015). Such labelling can be added at the beginning and the end of every journalistic piece. And, why not, it may be at least worth thinking about a construction – even on the institutional level – of how a kind of certification or approval could be organized somewhere between journalistic media and associations and academia. Or as John (2013: 284) asks: “Why not follow the lead of our brethren in medical, veterinary, and law schools [...] who enter professional life only after certifying their qualifications?” In any case, an education and/or permanent training of the highest quality seems to be crucial for such attempts as well as a cooperation between “academia and the profession”. As already pointed out before, this is also an argument for John to speak in favor of a clear profile of journalistic education instead of “communicology programs” without a clear profile. The “need to acknowl-

edge journalism as an independent discipline” is also one of the conclusions of the cited survey in four European countries asking for the future skills to be taught for the next generation of journalists; “only then would it be possible to teach journalism adequately and to provide future journalists with the professional skills their careers require” (Bettels-Schwabbauer et al. 2018: 91).

Furthermore, every science journalist himself or herself should explain more offensively in everyday life and in an everyday language why his or her products (investigated with professional methods and routines) are usually more credible than other pieces of information that could be found somewhere in the web. As a consequence, we have already included in our courses respective role-playing discussions with both journalism skeptics and science skeptics to train the explanation of one’s own profession as a science journalist. Additionally, on the institutional level it seems to be time, about 20 years after the Public Understanding of Science movement, to support Public Understanding of Journalism campaigns (cf. Wormer 2017) that could be funded by foundations, NGOs but also scientific institutions.

A second obstacle to overcome concerns especially science journalists of the kind described in this chapter, being highly qualified both in certain fields of science and the media world equally: It is the obstacle of adequate payment. The problem for such professionals is comparable to one known on the job market for highly qualified software developers or similar: Carefully and broadly educated science journalists should have to be paid adequately also by journalistic media houses. However, the cut-offs in salaries especially for freelancers are meanwhile often so dramatic that many highly qualified science journalists earn amounts of money that can neither guarantee their survival nor their independence from other (such as public relations) sources of income. Although a rather idealistic than materialistic attitude seems to be a good requirement for the profession, a minimum level of salary is needed to remunerate a reasonable effort of inquiry or even up to investigative journalism. Therefore, programs to support a truth-seeking journalism have to be further developed, for example oriented on the kind of (journalistic) peer review based funding that we know from the scientific system. Whereas the education of highly qualified science journalists can and should be paid by public money, the financing of highly qualified journalists in the profession is a core question for the future of science journalism and its teaching. If their challenging qualification cannot be paid adequately on the journalistic job market, valuable science journalists will increasingly migrate to other fields of industry, marketing and public relations, in some cases at least to the well-being of a scientifically informed society, but in many other cases mostly for defending the interest of a particular stakeholder.



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Charlotte Autzen and Emma Weitkamp

## 22 Science communication and public relations: beyond borders

**Abstract:** This chapter applies an overall *communication constitutes organizations* (CCO) perspective to explore the relationships between science communication and public relations. In the context of increasing institutional interest in public relations and science communication, the chapter asks whether public relations from research institutions should be seen as a subset of science communication or a discrete role. It argues that communication is essential to the constitution of organizations and challenges ideas of science communication as value free and neutral. In doing so, it considers the rise of institutional public relations and considers how these “new” players in science communication serve the interests of the scientific community. Finally, the chapter considers the implications of taking a CCO perspective on how we understand the relationships between scientific organizations, scientists and the public.

**Keywords:** public relations – science communication – organizational communication

### 1 Introduction

Many science communicators may not [...] recognise their role in public relations. However, they are in the business of building relationships through communication and they are the guardians and promoters of their organisations’ reputations. That, in my opinion, all makes them far more complete public relations practitioners than some who use the title but who only carry out basic publicity functions. (Sue Wolstenholme, CIPR President, CIPR, 2014)

For more than a century news media have been the central arena where people learned about new developments in science, making news media a natural habitat for communication about and with science. This context provides good reasons for science communication scholars to focus attention on media and over the years, research has shed plenty of light on relations between scientists and journalists and likewise on relations between science and society, as these unfold in contemporary medialized society (Hjarvard 2008). Nevertheless, one key actor remains underexposed and under-researched in the science communication equation: namely the organization. Where social scientists from various perspectives in the last decade have discussed the impacts of larger scale societal changes (globalization, marketization, etc.) on universities and science in general (e. g. Mazza et al. 2008; Whitley and Gläser 2007), only a few have paid attention to these changes with regard to how science communication is practiced by different actors. When we ask whether communication of new research

findings in academic press releases should be labeled as science public relations (PR) or as science communication, we struggle to find answers that illuminate our understanding of this growing contemporary science communication practice, at least as long as we see these two labels as inherently contradictory and stick to the perspective that scientists and journalists as individuals are the key participants in mediated science communication. If, however, we consider that organizational communication is comprised of these individual communication efforts, and that the organizational perspective is an inseparable part of individuals' communication, we see the distinction between science PR (which we might see as emerging from organizations) and science communication (which could be seen as comprising the wide range of ways that research emerges from the academy) blur. Thus, we argue that a focus on the role of research organizations as communicators will deepen our understanding of the ways that research emerges from the academy and the role organizations do and could play.

From the perspective of this chapter, we focus our attention on public facing communication of science emerging from universities and other research based institutes (i.e. the non-commercial organizations) and publication channels, especially the academic journals that facilitate dissemination of research amongst the scientific community. We take an inclusive view of the term "science", taking it to comprise both natural and social sciences. While in some cases practices differ in the humanities, the discussions and issues also apply across these disciplines. As such, we are primarily interested in communication activities that are initiated by scientists, research organizations and academic journals. Further, we are interested primarily in web-based activities that are designed to generate media or social media coverage, rather than outreach activities aimed at formal education (for example). Both media and outreach activities typically form part of researchers' public communication and engagement activities: activities which fall under the umbrella of Broader Impacts (in the US), Pathways to Impact (in the UK) and Expected Impacts (in the EU).

Society's expectation of scientists regarding public communication of their research is nothing new. What has changed though, is the context that frames these expectations. Over the past few years, there has been growing pressure on researchers to undertake public engagement (e.g. to inform citizens, to stimulate interest and support for research more broadly) and to consider ways to generate impact from their research, be this economic, policy or other societal benefits. This emphasis on identifying the impacts of research places pressure on scientists to create and share such impacts and this might be seen as yet another driver of institutional commitment to and support for public engagement. Critiques of the focus on impact highlight negative consequences for scientific research and scientists, including reward systems for scientists and universities who undertake media activities (e.g. Marcinkowski and Kohring 2014). Weingart (2017: 114), for example, argues that certain forms of current reward systems are "putting a premium on attracting attention" and this in turn may encourage scientists to "hype" research findings. We do share concerns about the

public's ability to learn about, discuss and influence what goes on in science, and we acknowledge the complex and intertwined relations between the different incentives of different actors to communicate. However, we argue for a more thorough look at the organization to better our understanding of the reasons why scientists choose to communicate their research achievements in public and the means that they use to do so.

## 2 A “communication constitutes organizations” perspective

We adapt Krücken and Meier's (2006) idea of an “organizational turn” in higher education to account for how we see organizations emerging as key participants in science communication and then apply the concept of organizations being constituted in communication (Schoenenborn and Vásquez 2017) as an overall perspective which can usefully inform analysis of science communication practices that includes scientists and universities as actors, not least the dialectic interplay among these. We take the position of methodological collectivism and identify universities as corporate agents in the sense that they can be attributed actions and states (e. g. beliefs, intentions, desires) that are not reducible to the mere sum of actions and states of individuals (Tollefsen 2002, 2015). This line of thought has come to be known as communicative constitution of organizations (CCO); it takes a constructivist position and builds on the assumption that: “communication is the key process for the emergence, perpetuation, and transformation of organizations” (Schoenenborn and Vásquez 2017: 1). This means that communication and its functional background is foregrounded as the essential modality that constitutes organizations (Taylor and Van Every 2000) and communication is further understood as the primary mode of explaining social reality at large (Craig 1999). This position opposes a longstanding conceptualization of universities as organizational shells hosting researchers from different disciplines (see e. g. Weingart and Maasen 2007: 84) and instead understands the university as continuously constituted in communicative events performed by various actors, including the actor that following Krücken and Meier's (2006) idea comes to be constituted as the organization itself. Davies and Horst (2016) also point to science communication as essential to the construction of “identities for science, scientists, and scientific organizations” (Davies and Horst 2016: 57) and argue that any particular communicative event may be a mix of different purposes and take part in the identity constitution of the scientist and the scientific organization at the same time.

To understand the role of research organizations in communication, Krücken and Meier (2006) suggest that organizations such as universities should be ascribed organizational actorhood and therefore must be considered as key players with their own and distinct reasons and means for communication. To Krücken and Meier, an



organizational actor is an “integrated, goal-oriented entity that is deliberately choosing its own actions and that can thus be held responsible for what it does” (2006: 241). Krücken and Meier ascribe organizational actorhood to universities as a way to explain how universities adapt to the current era of globalization processes by turning “into organizational actors, which are able to act strategically and position themselves with regard to their competitors” (2006: 242). As pointed out by Weingart and Maasen (2007), who drew on Krücken and Meier’s concept of organizational actors to investigate elite universities in Germany, this means that we will see universities think and act like competing companies in two markets: “one is that of students, the other is that of knowledge” (Weingart and Maasen 2007: 79). Thus, research findings and especially the communication of research findings are the primary commodity for universities and “have the potential to influence the university both financially and in terms of its research ranking” (Wilkinson and Weitkamp 2016: 6).

As a theory of communication, CCO can help us shed light on how research organizations such as universities come into being and how they come to exist across time and space in communication. If we adapt the idea of organizational actorhood, then communication of research findings becomes essential, not just to the constitution of the individual research organization but to the constitution of science as a social institution; the scientist becomes a central actor in both contexts. In CCO, the unit of analysis is always actual communication events (e. g. a press release, a website text) situated in local practices that enable the researcher to “consider the larger space-time framework in which the communication events are inscribed” (Schoenenborn and Vásquez 2017: 4). Instead of asking what kind of communication a text generated by a university is, a CCO perspective highlights the performative dimension of communication and asks how the actual text is talking the organization that communicates into being. This gives us new opportunities to explore relations between researchers, their universities and the public communication of research without having to decide beforehand how we understand reasons, means and roles in the communication we analyze.

### 3 Changing contexts of science communication

Although there is a long history of public communication of science and technology, external pressure on scientists to communicate about research findings largely springs from the influential Royal Society Report commonly known as the Bodmer Report (1985). In the intervening 30 plus years, we have seen a move away from so called “deficit” approaches to science communication which employed a unidirectional approach to transfer information from science to society, to a multitude of approaches which seek to facilitate multi-way communication (see also Chapters 4 and 5, this volume). This emphasis now includes the entire research and innovation chain, under

the umbrella of Responsible Research and Innovation (RRI), which seeks to ensure that the public is not just informed about scientific research, but able to participate in research governance and to influence the direction of research and innovation and associated policies (Owen, Macnaghten, and Stilgoe 2012). While there is still much science communication that takes place in venues outside research organizations (such as museums) or which is designed simply to provide information, this shift in focus from a one-way to a multi-way approach to communication (where there is an explicit assumption that the public will contribute in meaningful ways to governance and policy) has been accompanied by considerable discussion about the role of both scientists and institutions in communicating to and with public groups (Holliman and Jensen 2009; Jensen and Holliman 2016), the roles of publics themselves within science communication (Barnett et al. 2012; Sturgis 2014) and the rationales for promoting public engagement with science (Stilgoe, Lock, and Wilsdon 2014). Regardless of how the role of the scientists, or that of the public or intermediaries in the communication process, is conceptualized, it is clear that there has been a growing pressure on scientists to communicate their work with the public and increasingly to do so in ways that allow some sort of interaction.

While much current debate about how scientists should engage with the public focuses on dialogic approaches, the role of the media and mediated science communication has not escaped scrutiny (Peters 2012; Dudo 2015; Yeo and Brossard 2017). Weingart (2001; cited in Peters 2012: 217) introduced the concept of “medialization of science” which Peters describes as comprising two parts: “first, the increasing media attention for science, and second, adaption to or even anticipation of media criteria within science as a response to the increasing necessity of legitimating science by means of public communication” (see also Chapter 5, this volume). Within the context of medialization of science, Franzen (2012) points to high profile science journals including media attractiveness as one of the criteria for publication acceptance, suggesting that such motivations may lead scientists to overstate findings (see also her chapter in this volume).

Within the broader literature on science media studies, research points to a tricky relationship between scientists and science journalists, one in which the rise of professionalized institutional public relations may be seen as shifting the balance of power toward scientific institutions, accentuating the need to understand organizational actorhood in science communication. As Peters et al. (2008: 271) observe: “Overall, the strategic component in the self-presentation of science has grown, and science probably controls its media image more effectively than ever before.” Peters et al. (2008) argue that scientists’ communication with the media has become institutionalized, something also seen by Wilkinson and Weitkamp (2013) who found a majority of researchers worked with press offices to disseminate research findings to the wider public. Marcinkowski et al. (2014: 75) find a series of feedback loops, whereby scientists active in the media sphere become “attractive addressees”, sought out by journalists and university press offices in search of “publishable statements”.

This points to a cadre of scientists who are both willing to engage in media activities and have become skilled in doing so.

Both Marcinkowski et al. (2014) and Peters (2012) highlight an increasing institutionalization of media interaction. This is driven, in part, because universities are under increased pressure to attract positive media coverage while at the same time minimizing negative coverage (Marcinkowski et al. 2014), leading to provision of public relations support. Professionalization and introduction of formal structures (e.g. press or PR offices) are central elements of the emergence of global organizational actorhood and follow according to Krücken and Meier (2006) from the organization's need to pursue self-defined goals and external demands for accountability.

Zooming further in on the role of the organization and its need to communicate, we find that the emergence of universities as actors in science communication inevitably generates new internal demands for scientists to communicate to support the organizational business. Organizations like universities need acceptable framework conditions (funding, legislation, etc.) to thrive. In creating, and not least, securing such conditions, management is exposed to various kinds of external pressures that the organization must address through communication. Here the role of scientists and their research achievements become central. In conducting their research, scientists become owners of the university's most valuable storytelling content, the organization's primary commodity, knowledge. So, when a university needs, for example, to argue against government cutbacks this can be more easily done on the basis of a reputation as a strong research organization.

That contemporary science communication is seen to communicate scientific ideas as well as organizations can create tension between the two purposes of the communication (Hauser et al. 2019). The need to build and maintain a good reputation will inevitably put pressure on scientists to communicate to help maintain, protect and strengthen the organization. However, since, at the organizational level, it is mostly management that experiences these external pressures, the pressures to communicate are not as visible to scientists as the demands put directly on them as part of the public discourse surrounding science communication. As such, the organization's need may not be recognized or accepted by all scientists. As Weingart and Maasen (2007: 85) state, for most scientists: "Loyalty to and interest in promoting the image of the entire university is limited". To them, the department and scientific discipline will often be a context to which they relate more readily. However, a key point arising from the CCO perspective is that an individual scientist's perceptions and motives to communicate "makes no difference" when it comes to the constitution of the organization. When a biology professor is quoted in relation to a new research finding in a university press release, this communicative event brings this university into being (yet another time) regardless of the scientist's perception of the role he or she played in the communication. Likewise, journals that disseminate research and quote researchers are continuously constituted in the peer reviewed articles they publish as well as in the press releases they issue. Schoenenborn and Vásquez (2017: 17) explain that "[I]t is through

communication that organizational members will (or will not) negotiate and create consensus on who (or what) is authorized to speak on behalf of the organization”.

That scientists may not recognize the importance of communicative events to their employers can give rise to competition and conflict between press offices at universities and press offices at journals. Within larger projects, different universities may wish to frame and own press coverage of a new finding, as may the journal publishing the original research. The individual scientist might be fully satisfied with or even prefer a press release issued by a journal representing the scientist’s field of research, though this is unlikely to satisfy the university that employs the scientist. On the other hand, organizations and scientists that do recognize the market value of a specific communication event can use this to control who is entitled to speak on behalf of a collaborative research project or organization and who must remain silent, at least as long as the research finding has what resembles journalistic news value. Good reputations are built step by step through communication about, for example, research findings and scientists are the only authentic communicators a research organization can use to do this. It is therefore important to note, that an enhanced focus on the research organization as a distinct actor in science communication, as argued for here, by no means removes the equally important focus on the scientist as central actor. Research is still conducted by scientists who speak for themselves as well as on behalf of their research projects and organizations and as Davies and Horst (2016) point out, many and parallel purposes will co-exist in public communication.

In a study of scientists’ different perceptions of the roles they play when they represent research in public communication, Horst (2013) identified the well-known role of scientists as experts and as educators representing specific fields of knowledge and science as a social institution, respectively. Horst (2013) however, also identified a less well-recognized role emerging, namely a role where scientists purposefully represent the organization they are affiliated with when they represent research in public communication. That we now see a different and more strategic communications role gradually entering the stage of science communication corresponds well with the need for communication to position the organization in the marketplace as reflected in the organizational actorhood ascribed to universities, proposed by Krücken and Meier (2006).

Critics of PR (e. g. Weingart 2017; Nelkin 1995) prefer to maintain an arm’s length between the scientific organization and the public when it comes to communication of science and will argue against the emergence of a role for scientists as organizational actors. Among the arguments against such a role is that organizations that conduct the research are not sufficiently critical of their own research when undertaking science communication and by making strategic choices to promote certain research areas they may turn out to be tainted by vested interests. In this context, communication initiated by news media and independent science journalists is typically viewed as most likely to offer critical and independent communication of science; a position also increasingly contested (e. g. Göpfert 2007; Murcott and Williams 2013). The changing

media ecosystem, for example, puts pressure on journalists to produce more content for more channels (Macnamara 2016; Williams and Clifford 2010), reducing the time available for critical reporting (see also Chapters 20 and 21, this volume). Furthermore, studies highlight a problematically close relationship between science journalists and both their subject and sources (Schäfer 2011), with most studies pointing to the challenge science journalists face in maintaining their independence (e. g. Nelkin 1995; Williams and Gajevic 2013). Gandy (1982: 86) goes so far as to label this a “convenient fiction of journalistic objectivity”.

In such an imperfect world, we argue that considering the organization as an actor in the science communication space, and thereby embracing the public relations function, allows a fresh perspective on what stands out as an intricate, contemporary practice within science communication where it is increasingly difficult to separate the means and motivations of science communication actors. It is a perspective that can add to the rich picture already developing of the roles and motivations of scientists in an increasingly mediatized society. Further, we do not wish to argue that this stance implies that all science communication is mediatized nor that all communication from organizations necessarily is marketized. As outlined below, we argue that the CCO perspective offers new ways to conceptualize the role of public relations within organizations, opening up new spaces where organizations can contribute meaningful and socially valuable science communication, though this does not imply that scrutiny of such behaviors is not required.

## 4 Rise of institutional public relations

Cornelissen defines public relations as: “The function or activity that aims to establish and protect the reputation of a company or a brand, and to create mutual understanding between the organization and the segments of the public with whom it needs to communicate” (2017: 292). As has become the case for science communication, public relations is both a practice and a field of research and the interaction between theory and practice in both fields raises challenges about how best to act when relating to different publics. Grunig and Hunt (1984) introduced a four-model typology of public relations, which has become the dominant paradigm in public relations theory. The typology consists of the press agency/publicity, the public information, the two-way asymmetric and the two-way symmetric models. Even though this typology to some extent reflects a historical development, where the norms of public relations activities (much in line with norms in science communication) over the years have moved from linear one-way communication towards two-way symmetrical relations, later studies have shown how successful companies tend to combine different types of public relations activities (one-way as well as two-way communication) to achieve their goals (Grunig, Grunig, and Dozier 2002; Grunig 2001).

The emergence of the different types of PR activities and thinking (as expressed by the four models) has not led to replacement of one by another, but for them to exist in parallel. At least this goes for activities informed by the linear public information model and the two-way models (the asymmetrical and symmetrical, respectively): in other words, they are not mutually exclusive. In contrast, organizations adopting public relations informed by the earliest PR model, the press agency/publicity model, find it hard to also undertake activities informed by the three other models because it has very different underlying values. The press agency model values publicity over complete truth; it seeks media coverage regardless of the price and is therefore typically perceived as propaganda. In contrast, the public information model values truth and the purpose is the dissemination of information, not necessarily with a persuasive intent. The public relations person functions essentially as a journalist in residence, whose job it is to report objectively information about his organization to the public (Grunig and Hunt 1984: 21).

Definitions of public relations that focus on mutual understanding and two-way exchange of information as in Grunig and Hunt's two other PR models, are not unlike the aims espoused in science communication, which seeks to engage in discussion, involving the public in a two-way dialogue, so that understanding is mutually developed (Trench 2008). The definition of public engagement provided by the National Coordinating Centre for Public Engagement (NCCPE) in the UK highlights how closely related the vocabulary of public relations is to that of contemporary science communication:

Public engagement describes the myriad of ways in which the activity and benefits of higher education and research can be shared with the public. Engagement is by definition a two-way process, involving interaction and listening, with the goal of generating mutual benefit. (NCCPE n.d.)

Taking a CCO perspective to focus on the role of organizations in the science communication equation though, brings us beyond the dominant paradigm in public relations. Where Grunig and Hunt's four model typology is helpful in illuminating our understanding of the many different approaches to communication seen in contemporary science communication, its instrumental focus and the fact that it springs from an American historical context also limits its use. Critical public relations scholars (e.g. L'Etang 2005, 2008) talk about a discursive turn in public relations and argue for a better understanding of public relations as a social practice. As such, public relations can be understood as the collective communication emanating from an organization (Falkheimer and Heide 2018). This means that those actors involved in communicating (e.g. scientists) may not perceive their communication as strategic or indeed even as being undertaken on behalf of an organization. Nevertheless, all communications are guided by an intention to achieve something (for example to make accessible new research findings or meet expectations from funders), and in this sense, all communi-

cation originates with a purpose (and therefore could be considered strategic). To us this is an important reminder regarding the function of communication. Whether we choose to understand communication from the academy as science communication, public relations or journalism, this can never be neutral or value free.

When we discuss institutional public relations in science, academic press releases are the most visible output. However, the growing number of press releases (Serong et al. 2017; Autzen 2014, 2018), which are often seen as comprising science PR in its entirety, are in fact just one of several dimensions of public relations in science that should be considered – which would also include, for example, public lectures, community events and even activities linked to RRI. Furthermore, to build relationships through communication, organizations must establish and maintain identities to which others can relate. Wehmeier and Winkler further suggest we see organizations as: “the evolutionary result of intertwined internal and external communication processes” (2013: 283). From a CCO perspective, we find that as organizational texts, press releases not only speak on behalf of an organization already existing, but due to the co-constructed nature of communication and sense making processes involved they also talk the organization into being when different actors engage in the communication. In that sense they play roles much more intrinsic to the research organization than just “selling science” and promoting universities in mass media, the aspect of science communication (and public relations) practice which is both most recognized and criticized.

As a means of communication, press releases were developed at a time when news media were the primary way to reach broader publics: as a tool to “transfer news to journalists so that it can be made public” (Cornelissen 2017: 165). But as recently pointed out by Anhäuser and Wormer (2016), press releases issued by academia seem to have gradually transformed from a “for the press” release to a “for all” release. Trench (2007) points to the Internet as crucial to explain how research organizations have become more independent of traditional news media when it comes to science communication. For example, universities and journals can now create their own newsrooms on institutionally controlled websites and make science news stories available online to everyone, including important stakeholders, without having to ask journalists and news media for help by means of a press release. Equally, researchers increasingly use Internet facilities, such as websites and blogs, to communicate research findings directly to readers. However, this does not imply that science news stories posted on organizational websites are no longer posted as press releases on news sites for journalists (e. g. EurekAlert!, AlphaGalileo, Informationsdienst Wissenschaft) or sent directly to journalists by email. This just means, that these texts do more than one thing and that these different purposes coexist in public communication (Davies and Horst 2016).

Examining academic press releases further, we find that the “for all” should be understood literally in that they also reach internal publics. In fact, Lynch et al. (2014) find that these internal audiences are often favored over journalistic audiences, in that

research press releases often contain considerable didactic material with less consideration of journalistic expectations. Alongside other organizational texts posted online, these “for all” releases also help make sense of the organization, that is to say, they are part of the communicative constitution of the organization. As noted by Trench: “For research centres, a web presence is essential – without it, the centre in some sense does not exist” (2009: 167). The continued telling of stories about research and related matters on organizational websites constitute research groups, centers, departments and whole organizations (over and over again). We do not imply though, that organizations did not exist before the Internet and that organizations are closed circuits where only (positive) communication by organizational members is part of the constitutive game. It is rather a reminder of the fundamental changes in means of communication brought about by the Internet that affect organizational communication including science communication. In the present conditions, universities can use science communication to promote themselves and build brands by means of well-planned strategic corporate communication. However, this does not take place unchallenged, in that organizations are also exposed to online phenomena such as social media “shit storms”, where critique (external as well as internal) can attempt to alter the reputation and may succeed if the self-presentation of the organization turns out to be problematic or does not reflect how the organization is otherwise acting. “Obviously, an organization that describes itself as a responsible corporate citizen does not emerge as such simply by talking this way” (Christensen et al. 2013: 375) which reminds us of the close relationship between talk and action. The point made by Christensen et al. (2013) is that when we take a CCO perspective, we see that:

the ways organizations talk about themselves and their surroundings are not neutral undertakings, but formative activities that set up, shape, reproduce and transform organizational reality. Communication, thus, is not something an organization does once in a while, in between other important activities, but is constitutive of all organizational life and sense making (Christensen et al. 2013: 375).

Research organizations’ increasing interest in public relations and science communication is watched with some concern both from science journalists and social scientists, and whenever we talk about science PR, the prevailing understanding is that public relations in science is somehow problematic. We find this PR skeptical stance problematic, in part because it seems to rely on a rather narrow understanding of public relations as primarily propaganda. Following Grunig and Hunt’s (1984) typology, a view of science PR as propaganda corresponds to a type of public relations where hype, exaggerations and downright lies are all legitimate means to gain attention, things that in an internal scientific context would otherwise be labeled as flaws or even misconduct. This type of public relations activity may take place in science, but it cannot lead to sustainable public relations for science and scientific organizations in the long run, nor does it correspond well with scientists’ perceived norms such as a desire for objectivity and truthfulness (see also Chapter 1, this volume). By



choosing to focus on propaganda, PR skeptics seem to imply that public relations is something that research organizations could (and should) choose to avoid. This is simply not possible, since scientific organizations and science as such have no choice other than to relate and build relationships through communication.

In the case of science, Borchelt and Nielsen talk about the PR function as “managing the trust portfolio” (2014: 62) and in line with Cornelissen (2017) stress that PR must be understood as “a function of entire organizations, not just science communicators or scientific officers” (Borchelt and Nielsen 2014: 67). This corresponds particularly well with the idea of ascribing organizational actorhood to universities (Krücken and Meier 2006). Borchelt and Nielsen further unfold the PR function at four different levels inside the organization (program, functional, organizational and societal levels) that need to be managed in accordance with each other in order to contribute to a successful organization. In this context, “successful” means being trusted and being able to achieve acceptable framework conditions (funding, legislation, collaborators, etc.) to conduct research and teach. To repeat Cornelissen (2017), an important point here is that this has to be achieved “in mutual understanding” which is quite different from propaganda.

When taking a closer look at the four levels of the PR function described by Borchelt and Nielsen (2014), we find explicit science communication activities such as academic press releases and media relations to be at the program level, and “the overall communications and PR function of the institution, typically including all of the individual program-level units” (Borchelt and Nielsen 2014: 66) is found at the functional level. These two levels are also where the organizational intermediaries (Public Information Officers (PIOs), in-house science journalists, etc.) enter the equation. At the (upper) organizational level, PR is defined as part of the management function of universities and seen from that point of view, PR activities should contribute to the running of the business, not just to gain press coverage. This means that science communication professionals must plan and conduct PR activities at the program and functional level that identify and relate to strategically important stakeholders in ways that are meaningful to them as well as to the organization at the management level (mutual understanding). PR at the societal level can be seen as the individual organization’s contribution to the ongoing (re-)negotiation of society’s license to operate for science as a social institution. It is at this meta-level of science PR that it becomes highly relevant to talk about trust in science as such and where society’s engagement, dialogue and RRI agendas are rooted. The two upper levels in science PR (organizational and society) are where organizational actors respond to external pressures exerted on institutions from governments, funders, etc. How well the PR function on the upper levels is managed and how well aligned it is with the actual communication activities planned and executed at the two lower levels (program and functional), will both depend on the status and skills of the communications functions in the organization as well as the management’s view on communication and public relations in general. If we accept the role of science communication as sense

and identity maker for the organization itself and that communicative events have multiple purposes, a better understanding of how research organizations apply and combine different types of PR for different tasks might further discussions about how science could and should be shared with and negotiated in society.

## 5 Implications for scientists, science PR and society

A CCO perspective brings new insights to the ways that we might think about the relationships between scientists and society. It allows us to consider how and why current drivers for public engagement have led to a growing science PR industry (Autzen 2014) and to consider what the effects of this trend might be on scientists, their employers and wider society. Pressure from funders to produce research with impact, necessarily leads to communication, but this communication can take a wide range of forms. The CCO perspective suggests that all these forms, whether a conversation with stakeholders or a planned media activity, can be seen as part of constituting the organization and contributing to its success. Everything you say on behalf of the organization, builds (or diminishes) that organization's reputation: every employee, through their communicative acts, creates the organization and scientists are no exception. In this context, science PR is not solely confined to interactions with journalists, but might be seen as any communication which links the speaker to their employer.

In this situation, a public relations team able to help craft a media-friendly message and facilitate its dissemination to journalists could be seen as crucial to organizational success in a highly competitive research environment. However, in contemporary large-scale science projects, scientists from different organizations collaborate. If media coverage of new research findings is seen as important by research organizations, feeding into the scientific business, then who is entitled to speak on behalf of a project or organization becomes important. Here science PR becomes tricky not just for society but for science itself, raising questions about whose voice is heard (senior or junior researchers as well as prestige levels amongst collaborating institutions), how those decisions are made and whether this process is transparent to the researchers involved, the organizations they represent and society at large.

From the perspective of society, press releases and other short news articles published on institutional websites are an important source of scientifically produced knowledge. Not only are they used by science journalists, but they may also be an important source of information for wider publics. An increasingly important role of PR professionals will therefore be to act as quality controllers, producing press releases of good quality that can almost stand on their own. Good, in this context, might mean, for example, placing new research into its wider scientific context as well as supporting interaction throughout the RRI process with a view to brokering mutual understanding between researchers and stakeholders. Furthermore, social

media has enabled research institutions to combine different activities into one united communicative effort. Whether academic press releases are understood as science communication or strategic communication, an increasing number of research institutions are present on diverse platforms to maximize their return on investment by reusing content from science news stories (press releases) on all channels possible. As already pointed to, online technologies (Internet-based communication of any kind) have made research organizations independent of journalists and traditional news media, so that these are now seen as “just one of the channels” through which institutions can reach relevant publics.

The rise of science PR, alongside the emergence of a wide range of digital channels that allow institutions and scientists direct access to the public (e.g. via social media), suggest a need to consider what constitutes ethical science communication. Weingart (2017) highlights German guidelines for good science communication which stress that: “Good science PR sticks to the facts” and “It does not exaggerate when presenting research successes, nor does it trivialise or conceal risks” (*Wissenschaft im Dialog* n.d.). In a call for an ethical turn in science communication, Medvecky and Leach (2017) ask where science communication should look for a code of ethics. Is it to science? To journalism? Or to communication fields more broadly? In the context of public relations, science PR can and arguably should consider the ethical codes applicable to public relations more generally. For example, the Public Relations Association of America (PRSA, n.d.) has a code of ethics, which emphasizes honesty (including accuracy and truthfulness in communication) and responsibility to the public interest, but recognizes that PR professionals work on behalf of organizations and as such urges that members act as “responsible advocates for those they represent”. But for those working in science PR within universities, research institutes and for the professional associations and journals involved in the dissemination of scientific information, a broader range of ethical considerations might be appropriate, such as those raised in journalism codes of conduct which include consideration of potential “public harm” from making information available or aspects raised in the study of communication ethics which consider how communication can be a force for good (Medvecky and Leach 2017).

## 6 Future research directions

Despite the observed and criticized institutionalization of media interaction and increased interest in strategic use of science communication from research organizations our knowledge of how well science communication activities at the program and functional levels of PR contribute to success at the organizational and societal levels is still limited. As pointed out by Borchelt and Nielsen (2014), the extreme focus on media relations has not shed much light on how media coverage and online communication

of science actually contribute to the running of a contemporary university business, which must account for its actions through a range of communication mechanisms, such as annual reports, and even less light on how well such activities are operated by a typical research organization. Knowledge about how research organizations select and frame the science they choose to communicate publicly on websites, in social media channels and as press releases, might further discussions about this increasing practice and its effect on public understanding, involvement and trust in science.

Thereto, our knowledge about the role of public information officers (PIO) is limited. Up to this point, PIOs or PR practitioners have mostly been thought of as intermediaries (boundary spanners) between individual scientists and journalists. But as addressed by Cardwell et al.:

[...] public relations practitioners often must navigate complicated internal communication processes before, during and after developing and executing strategic external communication plans (2017: 154).

To gain more insights into how management and PIOs influence or perhaps even take part in decisions of which content scientists communicate publicly on behalf of the organization, it might prove useful if we also think of PIOs as acting as internal boundary spanners between the scientists and the “organizational actor”.

Finally, we propose that future studies of relations between science communication from research organizations and independent science journalism might benefit from the CCO perspective. Rather than seeing journalism as objective and value free communication, and as such the untainted ideal when it comes to communication of research from the academy, investigations of science journalism and news media through the lens of CCO might open new avenues of research much needed in these times of blurring boundaries and changing media ecosystems.

## 7 Conclusions

The CCO perspective adds a formative and a strategic dimension to scientists’ public communication that goes beyond public legitimacy and gives the individual research organization an increasingly significant role in science communication. Such a role should not be ignored when we aim to understand different practices of communication and the roles these play in contemporary society. Polino and Castelfranchi (2012) take this a step further and talk about a “communicative turn” in science communication where communication can no longer be separated from scientific knowledge production. “Public communication of science and technology (S&T) has transformed into a structural value within the core axiological pluralism of contemporary technoscience: journalistic values, persuasion, publicity, opinion, etc. converge within the axiological core of techno-science” (Polino and Castelfranchi 2012: 3). This view fun-

damentally challenges what science is and should be, i.e. the values of science and who should define such values. What defines science is no longer just about principles for proper scientific knowledge production and as such a matter for scientists only. It is as much a matter of how science relates to contemporary society through news, public relations, etc. To see public communication of science as “a structural and structuring feature” (Polino and Castelfranchi 2012: 7) in our view bridges the needs for communication experienced by organizational actors (Krücken and Meier 2006), multiple purposes of communicative events (Davies and Horst 2016) and the more classic role of science communication as providing information to and for society.

To gain mutual understanding in matters of science remains a tricky challenge though. To engage in dialogue still requires that often complex and complicated matters are first made understandable. Scientists can do this job themselves or they can communicate with help from intermediaries, either internal staff (PIOs) or external journalists. The one-way public relations model, “the public information model” is in many ways familiar to science communication, even though this may not be acknowledged by critics of science PR. For example, Weingart (2017) argues that universities have shifted from information provision to public relations and marketing and that such marketing and PR has become an industry in its own right (implying that public relations necessarily has propagandist tendencies). The purpose of one-way PR models is to provide information and in that sense, it mirrors deficit model thinking, which is still prevalent in much science communication.

In his critique of science PR, Weingart also highlights that PR advances the organization’s interest. But all organizational communication advances an organization’s interest, including information provision. To that end, science PR has been present as long as the academy has told science stories in public and we might dare ask whether we should turn the picture upside down and begin to perceive science communication as public relations rather than to see public relations as a subset of science communication. At first sight, this position might seem rather radical, but with organizations emerging as key actors in science communication, this might prove to be a fruitful approach to study science communication initiated by scientific organizations.

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Philipp Schrögel and Christian Humm

## 23 Science communication, advising, and advocacy in public debates

**Abstract:** Traditional scientific policy advice used to happen behind closed doors in advisory bodies as a dialogue between scientists and policy-makers. The respective models for the interaction are basic linear arrangements assigning clear roles and primacy to one of the sides. However, these processes have been opened up following public pressure for more participation and deliberative decision-making models. Today, increasingly complex policy-decisions, like the assessment of climate change and the necessary actions to be taken, require more scientific input. At the same time, the medialization of politics and science has led to an intensified, more diverse multi-actor communication landscape. Correspondingly, also science communication does not happen in an isolated sphere, but takes place in the middle of political and societal debates – science communication is seen by some as political communication. The questions presented here are not new, but still intensely debated: What constitutes neutral science communication or policy advice and what partisan advocacy? Can so-called “scientific facts” and values be separated from each other at all? To which degree should scientists actively advocate for policy-decisions – or should they not do so? While the discussion is primarily led normatively, empirical evidence on the effects of scientific advocacy on citizens and on politicians is sparse and not painting a clear picture in this respect. This article portrays the development of the science–policy nexus and presents an overview on empirical research and the different perspectives on science advice and advocacy.

**Keywords:** science advice – policy advice – science advocacy – public participation – science policy – political communication – science communication – activism – politics

### 1 Introduction

The first March for Science in 2017 – thousands of scientists in the United States and in many other countries taking it to the streets and protesting for more evidence-based policy making, valuation of the scientific method and more general support for science (cf. Reardon et al. 2017) – brought back the debate about which role the sciences and the humanities *should* play in our societies. One central point in the discussion was and still is the question whether scientists should actively position themselves in public debates and advocate for science – e. g. for specific science-based policy decisions or for the support and funding of science per se – or if that would impair scientific objectivity and get scientists entangled in ideological fallacies.

Media coverage echoed this fundamental debate. Emily Atkin for example reported, that “some scientists fear that by participating in a march that appears even slightly anti-Trump, they will feed a conservative narrative that scientists are inherently biased and manipulate data for political ends” (Atkin 2017). Robert Young (2017) feared that the March for Science “will serve only to trivialise and politicise the science we care so much about, turn scientists into another group caught up in the culture wars and further drive the wedge between scientists and a certain segment of the American electorate”. On the other side, Kramer (2017) called these arguments “bullshit” because “it’s all well and good to say that science shouldn’t be political, but the reality of the situation is that it is”.

The American public was divided about the March for Science, too. In a poll by the Pew Research Center, 44 % of the respondents said that the march will help public support for science while 44 % expected it to make no difference and 7 % even assumed that it will hurt public support for science (Funk and Rainie 2017). The support for the March for Science’s goals was split sharply along party lines: While a strong majority (68 %) of Democrats supported the goals, only 25 % of Republicans did.

The March for Science advocacy for “science as such” might be new in its scale, but there have been many scientists in the past speaking publicly “for specific investments in science and recommendations on specific applications of science in societal contexts” (Scheufele 2014: 13585). While societies today are increasingly facing complex societal and technological challenges, scientists are also more often involved in addressing these problems and scientific studies frequently become central arguments in public debates. At the same time, at least in the US, there is an increasing number of science policy groups (e. g. Brugger 2018) and a recent poll in Germany showed that a majority thinks science has too little influence on politics while vice versa politics has too much influence on science (see Fig. 1 below).

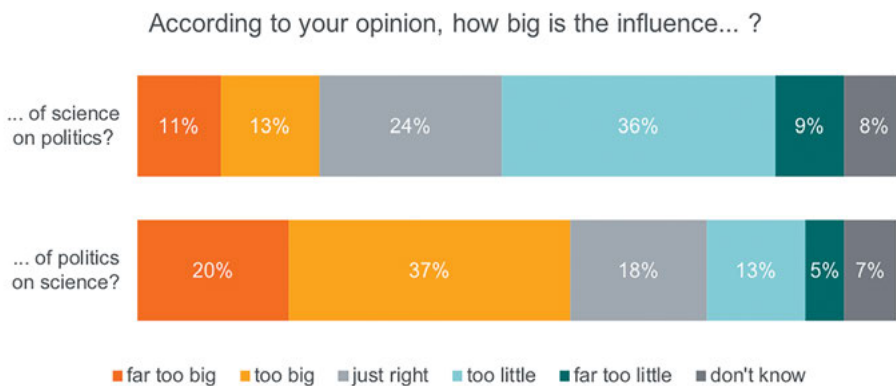


**Fig. 1:** Data from the representative survey (percentages are rounded;  $n = 1.007$ ) science barometer 2017 in Germany on public opinion regarding the interface between science and politics (see Wissenschaft im Dialog and Kantar EMNID 2017).

## 1.1 Advice, advocacy, and science communication

Debates around the legitimacy and boundaries for the role of scientists in policy-making often revolve around the presumed friction between seemingly objective policy advice and partisan policy advocacy. Clear definitions for *advice* and *advocacy* are rarely presented in studies and statements. Both concepts are sometimes used interchangeably or with overlapping meanings. A distinction with regard to the degree of institutionalization (individual communication, groups or formal institutions) or the target group (politics, administration, public) of the communication does not contribute to a definition, as it can apply to both advice and advocacy.

However, some defining aspects can be identified. Scientific advocacy is distinguished from advice primarily by its partisan character as the “active, covert, or inadvertent support of a particular policy or class of policies” (Lackey 2007: 12). Policy analysis and advising are in contrast described as the “formal assessment of the consequences and implications of the possible options for addressing a policy problem” (Lackey 2007: 12; c.f. Rürup 2009: 182). Traditional understandings see policy advice as a simple matter of “speaking truth to power” (cf. Wildavsky 1980), without any involvement in the actual decision-making. However, this is an idealised distinction that might not hold up in reality and other authors see the analysis and assessment of policy positions as a part of advocacy because it “routinely entails important yet obfuscated promotion or refutation of a policy, even when the assessor is unaware of such affects” (Nelson and Vucetich 2009: 1091).

Similarly, *science communication* is often used with different connotations. Science communication can have various goals, from education or the recruitment of next generation scientists to creating public support for the scientific system or supporting policy-making (cf. Bucchi 2008; Stocklmayer 2013) and has been framed in different concepts implying different understandings of science itself and paradigms for communication, from *Public Understanding of Science* to *Public Engagement with Science and Technology* or *Public Science* (Bauernschmidt 2018). While these different concepts highlight a certain aspect of science communication or imply a normative goal, generally speaking it is a rather broad umbrella term, comprising “all forms of communication focussed on scientific knowledge or scientific work, as well within institutionalised science as also external, including its production, contents, application and effects” (Schäfer, Kristiansen, and Bonfadelli 2015: 13, see Chapters 4 and 5, this volume). Although it is still a prevalent opinion by several scientists and communicators, science communication is never purely objective and value-free, but always happening in socio-political contexts, influenced and framed by assumptions and values (cf. Nisbet 2009; Scheufele 2014; Nelson and Vucetich 2009, see Chapters 1 and 2, this volume).

For this article, the following idealised working definitions shall be used for a basic understanding, although it has to be kept in mind that the distinction between advice and advocacy in practice depends on the individual assessment and perspective:

- *Science communication* is any communication on scientific contents, independent of its form, addressee, sender and purpose.
- *Science advice* is science communication presenting scientific information and science-based policy-options relevant for decision-making without a recommendation.
- *Science advocacy* is science communication supporting or suggesting a specific science-based decision or policy-option.

Looking back in history, the concept of scientific (or expert) advice for decision-making is not new. Scientific policy advice and advocacy behind closed doors and therefore without involvement of the public at large, has been common since ancient times and is mentioned in various historic works: “Therefore a prudent prince must hold to a third mode, choosing wise men in his state; and only to these should he give freedom to speak the truth to him [...] then he should decide by himself [...]” (Machiavelli 1998: 94).

While this understanding was also prevalent in democratic systems over the last 70 years (Weingart 1999: 152), we can observe today that medialization and greater demands for transparency and participation lead to significant changes in the relation between politics, science and the public. There seems to be a trend away from the established models of well-regulated scientific policy advice to more public, deliberative and advocacy-centred forms. Nowadays it is quite common for scientists to be involved – voluntarily or involuntarily – in potentially contentious policy debates in and with the public (Oppenheimer 2011). Weingart (2015: 17–18) called these developments “scientification of society” and “socialization of science” (see also Chapters 4, 5 and 22, this volume). They reflect a general participatory/collaborative opening of the science system, which is described – with different core aspects – from various perspectives under different names, be it *mode-2 science* (Gibbons 1994), *transdisciplinary science* (Mittelstraß 1998), *post-normal science* (Funtowicz and Ravetz 1994), *knowledge co-production* (Jasanoff 2004), *quadruple helix* (Carayannis and Campbell 2009) or *responsible research and innovation* (Owen, Macnaghten, and Stilgoe 2012).

One common aspect of all these models is, that there is rarely a pure inner-scientific discourse today, which is decoupled from public debates (see Chapter 22, this volume). Scientific information and new publications are available online to anybody anytime and are also immediately used in public discussions, especially when it comes to controversial topics. These developments pose chances as well as risks for science in general and for science communication in particular (for Germany see for example the statement of the Siggenger Kreis (2015) – a science communication think tank – addressing the dissolution of boundaries between established systems). So nowadays a great many actors are engaging in policy advice and advocacy with the help of scientific information – NGOs, think tanks, politicians, specialised bodies of parliaments and government, scientific institutions and of course individual scientists themselves. While they all are following their own rationale and are in one way

or another shaping public debates, this article focuses on individual scientists and scientific institutions like universities or research institutes.

## 1.2 Outline of this chapter

This chapter discusses the current state of the scientific debate on the intersection of science communication, advocacy and policy-advice. It draws on theoretical concepts, normative essays and empirical evidence, covering perspectives from political sciences to social sciences and communications.

We first discuss the different theoretical models for scientific policy advice and the roles scientists can play in it. They may seem too simplistic and therefore obsolete, but are still relevant for understanding today's debates. The next section addresses the formal opening of advisory processes through participatory forms of technology assessment and deliberative forums on controversial science (policy) topics. We then extend our scope beyond these formalised participatory processes to the public communication of science and the influence of medialization, which builds the context for public advocacy by scientists. This public advocacy and its role in shaping public debates is the object of the final chapter, including an assessment of its risks and benefits and a discussion of what we consider as reasonable science advocacy.

## 2 Established understandings of the relations between science and politics

Scientific policy advice is a well-established research area and there are a number of models and theories trying to describe the (ideal) interaction between science and politics. Two main approaches can be differentiated:

- The traditional models are concerned with the big picture and the power relations at play (cf. Habermas 1968; Weber 2018; Weingart 1999; Edenhofer and Kowarsch 2015a; Schenuit 2017).
- The typology presented by Roger Pielke Jr. (2007, 2015) is focused on how the individual scientists involved understand and fulfil their role.

While it may seem that such basic and somewhat dated models are too simplistic and no longer relevant in today's networked world, scientists and policy-makers often build their understandings on the interfaces between science, politics and society on these concepts. The public debate on preimplantation genetic diagnosis from 2011 in Germany shows this in an exemplary way. After a number of academies of science in Germany issued a joint statement on the topic (Leopoldina – Nationale Akademie der Wissenschaften et al. 2011), several high-ranking scientists, science representatives

and politicians argued in a series of newspaper opinion-articles about how scientific policy advice ought to be organised (see [https://www.sueddeutsche.de/thema/Politik\\_und\\_Wissenschaft](https://www.sueddeutsche.de/thema/Politik_und_Wissenschaft), accessed 1 August 2018). The opinions presented there can be traced back to the different key versions of these basic models discussed in the following, for example when the former president of the Bavarian Academy of Science, states that “academies should deliver facts and don’t engage in politics” (Willoweit 2011) and the former speaker of the German Bundestag emphasises that “politics is not an executive body for scientific recommendations” (Lammert 2011).

## 2.1 The Pure Scientist Model

The first model does not include an actual interface between science and policy making and is only briefly listed here for the sake of completeness. The *Pure Scientist* described by Pielke (2007: 15) is focused solely on their research and does not consider practical applications or possible societal problems. In this regard, the model describes non-communication between science, politics and society and thereby is reminiscent of the communication problems between different systems described by Niklas Luhmann. These systems operate with different codes and can therefore not communicate directly with each other (Luhmann 2017).

## 2.2 The Decisionist Model

The oldest model is the so called *Decisionist Model*. It dates back to Max Weber’s strict distinction between science and politics (Edenhofer and Kowarsch 2015a: 88; Weber 2018). It is based on the assumption that political decisions are ultimately not rationally justifiable, but are decisions “between competing systems of values and beliefs where coercive arguments don’t exist and which are not accessible to a binding discussion” (Habermas 1966: 130; this and all following quotes from German sources were translated by the authors). Therefore, politicians should define the problems for which scientists then research the best instruments or solutions (Edenhofer and Kowarsch 2015a: 89–91). These solutions are then implemented by the political system in accordance with its actors’ (irrational) political values and interests (Schenuit 2017: 3). Thus, policy decisions based on this model “suffer from a rationality deficit” (Weingart 1999: 154).

This model has two important implications: First, science is governed by politics, with the assumption of “a clear distinction between ‘objective knowledge’ and ‘subjective values’” (Weingart 1999: 154), and, second, communication with the public plays virtually no role in this model. This might explain why it is still very popular, especially with scientists involved in policy advice processes (Edenhofer and Kowarsch 2015a: 90).

In Pielke's (2007: 16–17) typology, the corresponding role would be the *Science Arbiter*: Scientists are addressing concrete questions posed by politics, but are not concerned with overarching aspects or the development of alternative options.

## 2.3 The Technocratic Model

The counterpart of this conceptualization is the *Technocratic Model*, which became popular in the so called “technocracy debate” in the 1960s and 1970s (Weingart 1999: 153), but can be traced back to Max Weber and his warning of a modern rationalised bureaucracy trapping politics in a “steely cage of dependence” (Weber 1972: 834–837). In this model science is the dominant player, setting the goals as well as the instruments to reach them. Politicians and the bureaucracy are limited to implementing these instruments as science reduces “the range of options to an objectively determined singular best decision” (Weingart 1999: 154; see also Habermas 1966: 131). In short: “[...] the politicians become fully dependent on the expert. Politics is replaced by a scientifically rationalised administration” (Weingart 1999: 154). So according to this scientific worldview, science is supposedly rationalising politics as a whole (Edenhofer and Kowarsch 2015a: 92).

This understanding implies that democratic discussions and decisions are superfluous, because “the notion of a quasi-natural, one-dimensional direction of scientific and technical development” (Weingart 1999: 154) limits politics to the role of a servant (Habermas 1966: 131–135; Schelsky 1961: 25–31; Edenhofer and Kowarsch 2015a: 91–94). Thus, “technocratic decisions suffer from the lack of legitimating public consent” (Weingart 1999: 154). Furthermore, just like in the decisionist model, the public is left out of the equation.

Even as this model does not have many open proponents, Edenhofer and Kowarsch (2015a: 93–94) state that it is widely spread in the reality of policy advice. Which might not be a surprise as it consorts well with the still popular yet empirically unsupported “knowledge deficit models” of science communication (Scheufele 2014: 13587, see also Chapter 5, this volume).

Pielke (2007: 15–16) describes this role for scientists as *Issue Advocate*. The scientist is trying to set agendas and priorities in accordance with his or her professional expertise in combination with values, ethical judgements and interests. The *Stealth Issue Advocate* (Pielke 2007: 7; 2015) is a special manifestation of the issue advocate described above. She or he is doing the same as the issue advocate but masks the advocacy as purely scientific and hides underlying interests or agendas. It is worth noting that the underlying motivations and reasonings are not relevant in this model. Even presumably noble intentions like educating the public on an issue or propagating an ethically or somehow otherwise “best” solution according to expert opinion would be considered stealth advocacy, when the values, interests and assumptions are not stated.



## 2.4 The Pragmatic Model(s)

As a critique of the shortcomings of the decisionistic as well as the technocratic model, Habermas (1966: 134) proposed an alternative, the so-called *Pragmatic Model*. Instead of a clear hierarchy between the scientific and the political sphere and a linear process between them, he assumes that both spheres influence each other through a critical and reiterative communication process: “the development of new technologies would be directed by interpreted value systems, and, at the same time, the interests reflected in these value systems would be controlled by examining them in the light of technical possibilities and the strategic means of their satisfaction” (Weingart 1999: 154).

In contrast to the models described above, the public plays a significant role. For Habermas (1966: 135), a successful implementation of scientific advice into political practice needs the intermediation of the political public. According to Habermas, this is because the communication between scientists and policy-makers has to take up the interests and values present in the public discourses of the general public. However, he sees the appropriate translation between the sciences and the public as the main problem of this communication process.

Based on the rather basic assumptions of Habermas, various scholars proposed their own democratic-pragmatic models (cf. Edenhofer and Kowarsch 2015a; Jasanoff 2004, 2011; Schenuit 2017: 5–11). Weingart, for example, criticised the pragmatic model for being too idealistic and based more on philosophical reasoning rather than on empirical findings. As a consequence, he proposed the similar yet different *Recursive Model*, according to which the relationship between politics and science is a recursive and reciprocal process:

Perception of the problem may come either from the scientific community or from policy-makers. In the political process it is transformed according to political criteria of relevance. As a political programme funding research for further clarification of the initial problem, it is handed back to the scientific community. The scientific community, in turn, executes the pertinent research whose results become the basis for continuous adaptation of the initial problem perception (Weingart 1999: 157).

More important, in our context, is the assumption that “the media play a decisive role in amplifying and thereby structuring the supply of knowledge” (Weingart 1999: 160). However, the broader public is not mentioned explicitly.

With the *Pragmatic-Enlightened Model* (Edenhofer and Kowarsch 2015b) the public’s role becomes more defined. The starting point in their model is the scientists’ “close scientific problem analysis together with politics and the public” (Edenhofer and Kowarsch 2015a: 99). Then, again together with societal groups and politics in a participatory process, the goals are defined that follow from the problem analysis. Science now has the task to research feasible ways to fulfil the goals with a focus on possible effects, limitations, unwanted implications and synergies while at the same time communicating associated costs, risks, benefits and knowledge gaps in

the public debate. Decision and implementation lie in the hands of policy-makers, a following evaluation leads to a refined analysis of the problem and the whole iterative process starts again. For Edenhofer and Kowarsch scientists should play the role of cartographers showing the navigator (i. e. politicians) possible pathways and their pros and cons: “Instead of suggesting a science free from value judgements, which cannot be achieved anyway, the ethical aspects should be discussed openly – and ideally again in the form of alternatives and their implications” (Edenhofer and Kowarsch 2015a: 101).

The corresponding role for scientists – to the various versions of democratic-pragmatic models above – in Roger Pielke’s (2007: 17–18) typology would be the *Honest Broker*. In this role, the scientist is well aware of political constraints and requirements as well as of the omnipresent possibility of conflicting interests and values, implicit assumptions or ethically laden scientific models. The described goal for the honest broker is to maximise the scope of action for policy making by presenting a selection of options. These options reflect scientific knowledge as well as value judgements. Thus, the Honest Broker increases the options for policy-making in contrast to the rather narrowly focused Science Arbiter.

### **3 Public participation in science policy making – a deliberative arena for advocacy and opinion forming?**

The public is rarely considered in the classic models for advice, and even when so (e. g. in Habermas’ pragmatic model) the specifics of the interaction are not spelled out in detail. However, the world has seen a development towards more public participation in policy making. From the 1970s on, technological and scientific developments and policy decisions were increasingly challenged in public discourse, based among others on a “crisis of experts” (Hennen, Petermann, and Scherz 2004: 19). The traditional models in which experts control technology developments and pass their knowledge on to the public in a “‘trust us, we’re experts’ science–society relationship” (Chopyak and Levesque 2002: 155) were no longer universally accepted. Pushed by the growing environmental movements and civil society activism around the world, decisions on environmental issues or technological infrastructure projects in particular became more and more difficult to push through from planning to implementation without public involvement and participation (Beierle 2010; cf. Dietz, Stern, and Panel on Public Participation in Environmental Assessment and Decision Making, National Research Council 2008).

The societal push for more formalised public deliberation and a “democratization of science” (Durant 1999; McCormick 2007) led to a subsequent establishing of

“invited” forms of public participation through administrations as well as scientific institutions (Wehling 2012). This “current trend of public participation in science and technology [which] has a new dimension and is much more widespread” (Chopyak and Levesque 2002: 158) and presents different connections between society, science as well as politics. The participatory development not only took place in Europe and the United States, but was also seen in many other countries, for example in Zambia (Mwale 2006), Taiwan (Fan 2015), Chile (Ureta 2016), Australia (Einsiedel, Jelsøe, and Breck 2001) and New Zealand (Goven 2003). However, Rowe and Watermeyer (2018) have summarised a series of critical points about (invited) participatory formats, e. g. the limited actual impact of participatory formats with regard to policy-implementation, the improper timing and the relevance of the topics opened up for participatory contributions, while pressing issues are still decided on in closed processes.

Besides the stated participatory demands, the current science and technology policy questions and decisions themselves call for a participatory opening. The complexity of the challenges surrounding issues such as the transition to renewable energy technologies cannot be addressed solely by experts or scientists or by one discipline. They require an inter- and transdisciplinary approach, which not only considers technical complexity but also ethical, legal and social implications (cf. Gibbons 1994; Macnaghten, Kearnes, and Wynne 2005; Pohl 2008). Therefore, a key element of engagement concepts on science and technology is that they “incorporate non-technical knowledges and values [...] which will ensure that they are not just scientifically but also socially robust” (Davies and Selin 2012: 121). Assessments of science and technology by means of public engagement offer the possibility of contextualization so that these “forms of knowledge [...] would gain robustness from their embeddedness in society” (Jasanoff 2003: 235). Socially robust knowledge has been defined by Nowotny et al. (2001: 168) as knowledge which “remains valid outside these ‘sterile spaces’ created by experimental and theoretical science” because it is more highly contextualised (embedded with other parts of society) and therefore likely more reliable.

Public involvement can take on many different forms – from community-based participation workshops or focus groups to consensus conferences – and range from the local and national to the global level (cf. Joss and Durant 1995; Chopyak and Levesque 2002; Rowe and Frewer 2005; Voß and Amelung 2016). Ideally public participation formats offer lay-people the opportunity to engage in the decision process as “experts for everyday life”, expressing and formulating their most pressing questions and problems. How far the involvement goes and what impact demands expressed by lay-people can have, for example on the political level, depends on each case and is difficult to evaluate, since processes within decision-making remain complex. Yet the inclusion of “the public” and its ideas, worries and expectations can offer a level of (normative) assessment, “lay-expertise” processes can be regarded as new elements of policy advice concerning upcoming and complex decisions (Hennen, Petermann, and Scherz 2004: 12; Dietz 2013).

Regarding the differentiation between advice and advocacy, special consideration is necessary for the interaction between scientists and citizens in public participation formats: “Public participation has been proposed as a mode of science communication that can, at least in principle, lead to better decisions by addressing both facts and values” (Dietz 2013: 14081). On the one hand, this disentanglement of values, so-called facts and interests brings underlying conflicts and disagreements on the table to be discussed. Wilsdon and Willis (2004: 24) formulate as goal for public engagement “to make visible the invisible, to expose to public scrutiny the assumptions, values and visions that drive science”.

On the other hand, an equal, respectful and fair dialogue is the general aim for all participatory approaches. In theory, this should be no problem for citizens and especially not for scientists, but practical experiences paint another picture:

In scientific discourse, we expect reasoned and balanced arguments and a willingness to shift from a currently held position when evidence refuting it accumulates. We know from historians, philosophers, and sociologists of science that the evolution of science is a bit bumpier than this ideal image (Dietz 2013: 14082).

Engagement in serious participation exercises requires training and professional support and planning, respect for the subject-matter expertise of scientists as well as respect for interests and opinions of laypersons. For fair deliberation, it has to be ensured that the presentation of scientific content does not mix the layers and depict solutions within the hierarchy of status and expertise, which actually would be up to a judgement of values and interests (cf. Renn 2004: 303). At the same time, one has to be aware that there is no “neutral” presentation of facts: “communication is not simply a translation of facts – it is a negotiation of meaning” (Nisbet 2009). The framing of information (cf. Scheufele 1999) is essential for enabling a meaningful interaction: “scientists – like any other actor in the policy process – must strategically ‘frame’ their communications in a manner that connects with diverse audiences” (Nisbet 2009).

Evaluations of participatory processes on science and environmental issues show that it is difficult to draw general conclusions – most formats work within their boundaries like a limited set of participants, a limited amount of time or a focused topic (Scheufele 2014: 13587; Renn, Webler, and Wiedemann 1995; Chess and Purcell 1999; Rowe and Frewer 2000). However, it is important to keep the general limitations of participatory processes, as described by Rowe and Watermeyer (2018), in mind.

## 4 Medialised science communication as political communication

One prevalent shortcoming of most public engagement approaches is, that they “cannot reach broad cross-sections of the citizenry” (Scheufele 2014: 13587). Besides quantitative limitations, several societal groups are excluded and not reached. Examples are people with a lower socio-economic background, single parents, people from rural areas, the disabled or people with different ethnic backgrounds (Schrögel et al. 2018). Thus, “the majority of encounters that members of the non-scientific public have with scientific issues – outside of formal educational settings – do not involve any form of direct public engagement” (Scheufele 2014: 13587). Instead, they get into contact with scientific issues through the mediated realities of mass media, be it online or offline. In an increasingly complex and medialised world these realities “heavily influence both public perceptions of science more generally – fact-based or not – and public understanding of scientific topics” (Scheufele 2014: 13588; cf. Weingart 1999: 160) and therefore necessarily public debates too.

At the same time many developments in modern science – be it nuclear energy, Artificial Intelligence, CRISPR/Cas or nanotechnology – “pose ethical, legal, moral, and political challenges” which “do not have scientific answers” (Scheufele 2014: 13586). As a result “public communication about modern science is inherently political, whether we like it or not” (Scheufele 2014: 13586).

The various phenomena of the changing media landscape and its effects on science and science communication are summarised as “medialization of science” (Weingart 2015: 244). The exact components and effects of medialization, also referred to as mediatisation (cf. Krotz 2001; Birkner 2017), are still debated to some degree (cf. Adolf 2011), but Schäfer (2008: 207–208) defines three basic dimensions of medialization: 1) extensification of communication – more media coverage and mediated debates, 2) pluralization of actors – i. e. politicians, “alternative experts” from NGOs also get media coverage on scientific issues and 3) polarization – a more critical media coverage and public debate on scientific issues, which also includes social implications, priorities and interests. Even if the degree of medialization can vary significantly across different scientific fields and topics (Schäfer 2008: 209) it has consequences for the science-politics-nexus.

First, public science communication cannot be seen isolated but instead is embedded in a web of related (mediated) messages with which citizens are confronted, forming “socio-political contexts” (Scheufele 2014: 13589). This observation can also be applied to understand political science communication, where direct channels of advice between scientists and policy-makers are now accompanied by mediated (public) discussions and advocacy influencing the policy process (see Fig. 2).

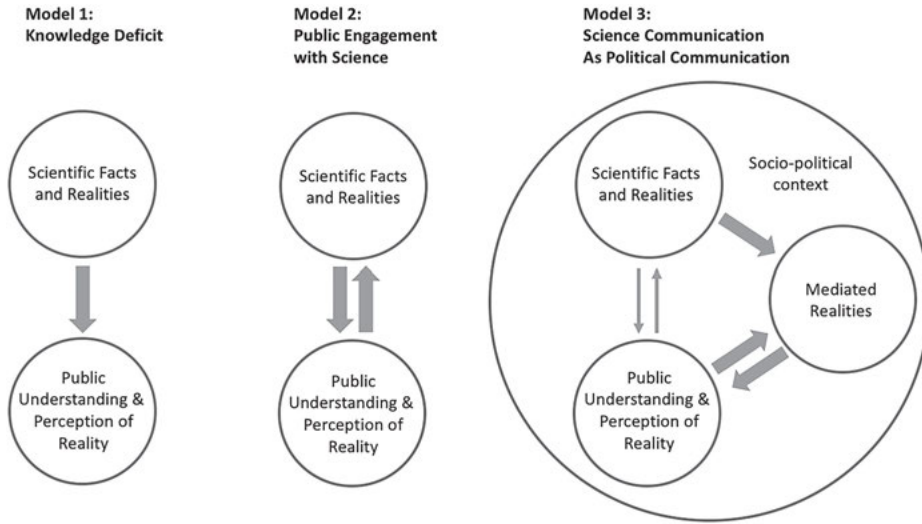


**Fig. 2:** Development of science communication models as proposed by Scheufele (2014: 13587).

Second, the peculiarities of medialised communication – e.g. agenda-building, priming, framing and the “spiral of silence”, which is the tendency to a self-enhancing conformity among the public (Scheufele 2014) – are influencing science communication, too (see Chapters 4 and 5, this volume).

This is especially relevant for topics which are at the centre of a public debate and have become strongly medialised. One example is the communication on the risks and benefits of genetically modified organisms (GMOs). NGOs are seen as counter-balance to industry-interests and established hierarchies by some (cf. Gerasimova 2018). Pieter Maessele (2009: 69) states: “local NGOs are found to perform a role as alternative science communicators who wish (1) to instigate an epistemic shift to an uncertainty-oriented approach in risk assessment, and (2) reframe the (values at stake in the) debate”. However, this reframing of values can also be problematic. NGOs are focusing their campaigning against GMOs on local stakeholders and donors in rich countries with general ethical concerns, not addressing the other ethical problem of global distributional justice for agriculture in other countries, as Robert Paarlberg (2014: 228) argues: “Using scare tactics to block the planting of GMO foods would be harmful enough; using wilful deception cannot possibly be justified.” Going further, John Davison (2010: 95) states that NGOs are “using pseudo-scientific justifications” in their campaigns against GMOs.

Generally, the increasing involvement of NGOs in communicating science is seen as a positive development by some (cf. Greenberg, Knight, and Westersund 2011; Slingsby and Barker 2005; Yearly 2008), while others raise general concerns:

[T]he widening appeal of corporate PR tactics and their establishment in the activist and NGO sectors may also be accelerating the process which Habermas described as a ‘re-feudalization’ of the public sphere, a process which sees public communication transformed into an instrument for the strategic pursuit of organized interests thereby damaging possibilities for meaningful discussion across political or sectoral lines (Greenberg, Knight, and Westersund 2011: 77).

Last but not least some scholars fear that with the increasing importance of Social Media stealth advocacy becomes more and more difficult to distinguish from transparent issue advocacy “given the ubiquitous and brief nature of many public statements” (Schmidt and Donner 2017: 344). This new media landscape alters the process of medialization, with scientists no longer orientating themselves on the journalistic selection criteria of traditional mass media and instead taking part in public debates directly via Social Media (see Chapters 28 and 30, this volume).

## 5 Public advocacy: scientists contributing to public debates

The medialization of science (and politics) dissolves the borders between the systems and multiplies the number and types of actors involved in forming the public understanding and perception of scientific issues. In this diversified and ambiguous science communication landscape, public advocacy by scientists and scientific institutions is a common phenomenon.

Science advocacy not only takes place when scientists acting as lobbyists try to influence politicians but can also happen in schools, public assemblies, via media, petitions or demonstrations (Carney 2014) as long as it is “more than merely conducting research and communicating results through primarily scientific venues” (Nelson and Vucetich 2009: 1091). While scientists can advocate covertly or behind closed doors the focus here is on *public advocacy* directly shaping public debates. Thus, by being directed primarily to the public it implies that this kind of advocacy mostly takes places outside the formalised processes of policy advice and public participation and thus in the medialised environment described above.

### 5.1 Examples of public science advocacy

There are many examples of scientists campaigning for certain policies based on (their) research findings: In 1939 Leo Szilard and Albert Einstein wrote a letter to US President Franklin Roosevelt warning him about the possibility of a German atomic bomb and urging for intensified research (Dannen 2017). While this is an example for classic private advocacy, later Einstein, together with eleven other prominent scien-

tists, signed the Russell-Einstein Manifesto which called for the peaceful resolution of international conflicts in the face of total annihilation of mankind in an atomic war (Russell and Einstein 1955). Although this change of mind seems to contradict the idea that scientists produce transtemporal truths, it didn't hurt Einstein's credibility as a scientist in the long run.

Two years later, a group of German atom researchers ("Göttinger Eighteen") published a manifesto in a number of national newspapers protesting against the planned nuclear armament of the German Federal Armed Forces and at the same time calling for support for the peaceful usage of nuclear energy with all means (Bopp et al. 1957). They saw their manifesto as a political neutral document founded only in their ethical responsibilities – a view which was "largely naive" (Seitz 2018). Instead, the manifesto was a clear affront against the government at the time and served as a catalyst for the emerging anti-nuclear movement, thus showing that such communicative acts can have unforeseen consequences.

Beside these ad hoc and temporary interventions, (public) scientific advocacy has been institutionalised by groups like the Union of Concerned Scientists in the USA, who claim to "share information, seek the truth, and let our findings guide our conclusions" (Union of Concerned Scientists n.d.) since 1969. There are other long lasting cases, like the Doomsday Clock which "warns the public about how close we are to destroying our world with dangerous technologies of our own making" since 1947 and shall be "a reminder of the perils we must address if we are to survive on the planet" (Benedict 2018). Interestingly the *Bulletin of the Atomic Scientists* tries to frame their Doomsday Clock as unpolitical and nonpartisan by arguing that "[e]nsuring the survival of our societies and the human species is not a political agenda" (Benedict 2018). Nevertheless it has attracted criticism for – allegedly – being not scientifically enough, spending "decades falsely claiming that their position as scientists gives them special license to dictate security policy" (Hopper 2018) and thus acting as a scaremonger. There are a lot more examples of scientific advocacy (cf. Scheufele 2014: 13585), so arguably scientific advocacy exists as long as scientific advice.

Advocacy for the support of science, the scientific institutions or specific parts of science are occurring regularly on different scales, too. One more widely known example is a public letter published in 2001 by several US scientists, including 80 Nobel laureates, to then President Bush arguing for supporting the use of embryonic stem cells for research (Stephens 2001). Even further, in the presidential election in 2004, several high-ranking scientists in the United States, this time including 48 Nobel laureates, publicly endorsed candidate John Kerry against sitting president Bush with the hope that he will "restore science to its appropriate place in government" (Brumfiel 2004: 4). Another example is the development in Canada in 2012 with the government under Prime Minister Stephen Harper ordering scientists not to talk to the media about findings (especially on climate change) and cutting funding to research institutes and environmental programmes. This led to a country-wide protest wave, gathering support also outside of science (cf. Turner 2013).



The developments in the United States under the presidency of Donald Trump since 2017 resemble much of the Canadian experience described above (cf. Donner 2017: 431). This led to the March for Science, which gained also supporting momentum in many countries outside of the United States.

## 5.2 Do or don't?

With all these examples one question remains: Does (public) issue advocacy, to follow Pielke's typology, "corrupt[s] both the political process and scientific enterprise" (Lackey 2007: 16) and should therefore not be pursued with scientists "avoiding direct involvement in policy development" (Ruggiero 2010: 1179; cf. Lackey 2007)? Or is an active engagement in public debates and advocacy for policy options a duty for scientists (cf. Ruppertsburg and York 2016)?

Coming back to the example of the March for Science and the political climate in 2017 – Norah MacKendrick (2017: 896) even stated that "[w]e are witnessing a unique moment". This moment triggered a new, broad discussion within the scientific community on the politicization of science and the question whether active advocacy and contribution to the public debate is necessary and/or problematic. A series of commentaries in the "Sociological Forum" as a response to the initial essay by MacKendrick (2017) depicts the diversity of opinions on the question: from a call to activism combined with (sociological) research (Frickel 2018) – a proposal which corresponds to the existing concept of participatory action research as pointed out by Shostak (2018) – to the "obligation to assess and challenge vested interest research" (Ruane 2018), to the discussion if the March for Science really is different from other activist groups and who participates (Fisher 2018) and what is actually meant by "science" (Whooley 2018) and to more critical comments on the method of advocacy (Brulle 2018). While this series of commentaries is only a microcosm within the broader discourse, the set of opinions and aspects raised can also be found in earlier discussions on the issue of science and advocacy. The underlying question, if scientists should formulate normative statements on policies, leads back to the fundamental controversies around the issue in the social sciences at the beginning of the 20th century, with Max Weber and his understanding of policy advice as one central figure: the so-called *Werturteilsstreit* (cf. Schurz and Carrier 2013). One more recent example of the still ongoing debate would be a series of comments on the boundaries between science and activism in 2015 in the *Journal of Science Communication*, with the intent to explore "how the (apparent) separation between 'value laden' activism and 'value free' science is in fact very thin, and how science communication can play a key role in ensuring reflexivity and self criticism in science" (Bandelli 2015: 1). Another example would be a series of articles in the *The ANNALS of the American Academy of Political and Social Science* in 2015 exploring the politics of science based on underlying values. Elizabeth Suhay and James N. Druckman (2015: 8) describe the challenge in

the introduction: “While science seeks to establish facts and not values, it does speak to values. In determining what is perceived to be ‘fact,’ it both enables and limits – and therefore directs – human endeavour.”

Overall, the literature lists several risks for scientists involved in advocacy “the loss of credibility among professional peers, harsh public criticism, enhanced and perhaps invasive scrutiny of one’s professional and personal life, or loss of access to funding or resources” (Schmidt and Donner 2017: 345). However, these risks can evenuate from purely publishing a study when it gets picked up by interested parties, too. In a systematic review, Nelson and Vucetich (2009) identify a variety of arguments: On the one hand arguments against advocacy on the basis that “doing so compromises scientific credibility, conflicts with the essential nature of science [objectivity, neutrality, impartiality, certainty], and conflicts with the practical requirements of being a productive scientist” (Nelson and Vucetich 2009: 1099); on the other hand arguments in favour of advocacy “based on the fundamentally similar nature of science and advocacy, concern for the social harm that might arise from not advocating, and the dual nature of a scientist citizen” (Nelson and Vucetich 2009: 1099). Based on an argument analysis, only one reasoning remains valid for them: The argument that “scientists, by virtue of being citizens first and scientists second, have a responsibility to advocate to the best of their abilities and in a justified and transparent manner” (Nelson and Vucetich 2009: 1099). Especially, the presumed pure objectivity, neutrality and impartiality of science does not hold up in reality as “even to merely provide policy-relevant information unavoidably involves interpreting, filtering, and synthesizing facts” (cf. Nelson and Vucetich 2009: 1096; Oppenheimer 2011). Therefore, they consider science communication to be a normative activity.

Schmidt (2015) and Donner (2014) assume that there is – at least for politically contentious topics – no public engagement without advocacy: “[...] regardless of scientists’ actual positions on advocacy, the very presence of their voices in public on a controversial topic will lead to assumptions that they are advocating for other public policy goals” (Schmidt 2015: 72). This is an argument in line with Scheufele’s (2014) concept of science communication as political communication. Additionally, if scientists stay completely out of the policy process, then policy-makers and the public will turn to other – probably less informed – sources for advice (Oppenheimer 2011). Furthermore, it needs to be considered that the perception of messages is dependent on the audience’s existing concerns and beliefs (Lupia 2013: 14054). The political background is an important factor, especially since in several of the current larger science-based conflicts (like climate change), conservative-leaning people refute scientific findings and trust the established institutions less (cf. Gauchat 2012).

While the arguments in favour or against science advocacy are primarily normative in nature, empirical evidence on the actual effects is sparse. On the one hand, evidence of an experiment by Kotcher et al. (2017) suggest that “scientists who wish to engage in certain forms of advocacy have considerable latitude to do so without risking harm to their credibility, or the credibility of the scientific community” (Kotcher et al.

2017: 415). They measured reactions of members of the United States public to six fictitious statements by climate scientists “ranging from a purely informational statement to an endorsement of specific policies” (Kotcher et al. 2017: 415). They found that only one of the statements was hurting the scientist’s credibility, specifically the one advocating the building of more nuclear power plants and thus a specific policy. Older opinion polls support the view that scientific advocacy does not per se hurt scientific credibility: In a poll by the Pew Research Center (2009: 34) in the United States, 76 % of the public and 97 % of the scientists said that “it is appropriate for scientists to become actively involved in political debates on controversial issues such as stem cell research and nuclear power”.

On the other hand, however, a study also conducted in the United States by Bolsen and Druckman (2018) on the public perception of different messages on climate change found that scientific consensus was well received among people of different political backgrounds, but “politicizing science eliminates the positive impact of a consensus message” (Bolsen and Druckman 2018: 394).

### 5.3 What defines reasonable science advocacy?

So when science communication is also political communication for the most part and advocacy is almost unavoidable in public engagement (Shannon, Meidinger, and Clark 1996) – since the own beliefs and values cannot be neglected when communicating science – thinking about necessary conditions and approaches might be more productive:

First, it seems reasonable to think of policy advocacy and advice as a continuum instead of clearly distinguishable categories as suggested by Donner (2014), ranging from a more science-dominated to a more advocacy-dominated end. Towards the advocacy end of the continuum, scientific uncertainty and influence of normative judgements as well as associated risks tend to increase. Because “[i]n practice, there is no pure state of science, nor is there a pure state of advocacy” (Donner 2014: 2), it follows that “there [also] is no fundamentally correct position on the science-advocacy continuum” (Donner 2014: 5). Instead, the specific context determines how a researcher should position her- or himself and which consequences this might have.

This leads, secondly, to the question what constitutes good advocacy. For Nelson and Vucetich (2009: 1095) advocacy has to fulfil certain criteria to qualify as justified. The most important being transparency – including being transparent about one’s affiliations – being honest and avoiding unjustified claims.

Therefore, good communication is central. This communication has to be dialogical as in the Pragmatic-enlightened Model of Edenhofer and Kowarsch, because insights from the practice of science advocacy show that “[d]umping information from the ivory tower down clearly isn’t working” (Brown 2000; cf. Oppenheimer 2011) as scientific insights not automatically imply a certain policy.

If we follow Hannah Arendt's (1993: 28) argument that the true purpose of politics is freedom, then this implies that there are always several possible political pathways. Which one gets chosen should, at least in a democracy, be the result of a negotiation process among different interest groups. Thus one should not try to pass political judgements as following automatically from scientific expertise (Oppenheimer 2011). Even for challenges posed by scientific development itself, e.g. DNA research, good scientific advocacy ultimately acknowledges that "the answers to these questions are moral, philosophical, and political in nature" (Scheufele 2014: 13586).

It is important to note, that effective advocacy does not necessarily equate to good advocacy. There are many examples of successful – in terms of range and acceptance of the message – advocacy by scientists which is rather questionable. German psychiatrist Manfred Spitzer undoubtedly communicates very effectively and very actively in many media appearances, especially regarding his statements against the usage of digital media by children. However, he has been criticised for missing scientific support for his claims (Appel and Schreiner 2014). Another example would be "Dr. Oz", a physician and actual professor at Columbia University, who is hosting a very popular TV show in the United States on medical issues and personal health. But, he is often presenting unreliable "alternative" medicine and unsubstantial commonplace medical recommendations. A study by Korownyk et al. (2014) found, that only about half of the presented recommendations are supported by evidence.

As another example for misleading advocacy, Naomi Oreskes and Erik Conway describe in their book *Merchants of Doubt* (2010) how several scientists in the United States, as part of or in cooperation with conservative political advocacy groups, were advocating against environmental and health regulation in various fields, from downplaying the dangers of tobacco to the effects of atmospheric ozone depletion to climate change. Even though the campaigns were contrary to the then current state of scientific knowledge, the advocacy successfully built on promoting uncertainty and doubt among the public and policy-makers.

## 6 Conclusion

### 6.1 Observations on science communication and advocacy

The intersection between science and politics is crucially shaping the societies in which we live, and while the debates on the "right" mode of decision-making and the assignment of roles and responsibilities might be as old as modern democracy and modern science, they are nevertheless prevailing. Although some scholars' definition of advocacy sound quite straightforward, in reality advocacy is not so easily distinguishable from supposedly objective advice or assessment. When taking a closer look, one can distinguish between several levels:

First, one can look at the established theories about the role of science in the political process. Most of the older and simpler theories are linear models, in which science is either executing the orders of politicians (decisionist model) or dictating the way for politicians (technocratic model). Science communication, outside of the small circles of institutionalised advisory bodies, is virtually non-existent in these models. Following them, scientists would ideally play the roles of Science Arbiters or Issue Advocates. Newer and more nuanced theories on the contrary have a more circular understanding in which science, politics and the public are in a continuous communication process influencing each other. In these models, scientists can additionally assume the role of Honest Brokers, whose function it is to show politicians the different pathways they can follow in their policy.

Second, there has been a trend to open up the traditional mechanisms of scientific advice and advocacy towards more formalised public participation. Scientists there have the role of moderators, facilitating discussions of interested citizens. The goal of such public engagement is to find solutions which are more socially robust because of their societal embeddedness.

Third, the medialization of science as well as of politics opens up the interface between the two systems even further and beyond institutionalised and formalised ways of interaction. As a result, science communication becomes political.

Thus, fourth, public advocacy can be observed more often than before. However, this might not be necessarily bad when done right. This means, that advocacy should be transparent, honest and avoid unjustified claims. In short, one could say: Do it, but do it reasonably and responsibly. Bearing in mind that “science cannot tell us what to do” (Pielke 2007: 137), science in most cases cannot resolve political conflict because, as Pielke (2007) states, it is often about underlying value conflicts and – one might add – about different interests. Stephen Schneider has described this challenge already in 1988, when discussing the issue of climate change communication, as an “ethical double bind”:

First, admitting openly what our value system is; that is, what our world view amounts to. Second, we should invest effort in trying to promote it. But promoting concern over the negative connotations of the greenhouse effect in this media age usually means offering few caveats and uncertainties – at least, if you want media coverage. [...] Each of us will simply have to experiment to try to find phrases and metaphors that are both familiar and comprehensible to the public and politicians, but that do not do too much damage to the complex nature of evolving scientific knowledge (Schneider 1988: 113–114).

Lastly, it is important to keep in mind, that science advocacy – even when well-meant and conducted in good faith – always bears the risk of being wrong when new scientific evidence arises. While the case of climate change is an example, where advocacy only arduously is able to induce a widely enough shared public consciousness and sufficient political action, the case of the ozone hole (atmospheric ozone depletion) in the 1970s and 80s led to rather prompt action resulting in a worldwide ban of chlor-

ofluorocarbon chemical with the adoption of the Montreal Protocol in 1987. The difference in reception and policy adaptation between both cases is described by Ungar (2000), but the example is important for another reason: in the case of the ozone hole, everything went well and the problem was indeed solved. But in another example, the *Waldsterben* (forest dieback, especially through acid rain) primarily in Germany, roughly happening at the same time, things turned out differently. Scientists identified the problem of forest decline, assuming acid rain as one main cause and advocated for immediate policy action. In the time of a growing environmental movement, the issue became prominent in political debates, programmes like an extensive forest monitoring were implemented and environmental regulations tightened. However, now in hindsight, it turns out that the problem in large parts was rather a false alarm or at least exaggerated and not well understood (cf. Metzger 2015: 583–591). While falsification is an integral part of science and not problematic per se, being wrong in politics is a problem. In both cases, industry interest groups built on this argument to hinder regulation (cf. Oreskes and Conway 2010), the same can be observed for climate change. Therefore the communication of assumptions, uncertainties and risks (cf. Fischhoff 1995; Weiss 2002) needs to be given special attention – ignoring it does not help the message (Rabinovich and Morton 2012).

## 6.2 Need for further research

Most studies so far revolve primarily around environmental and ecological topics in general and climate science in particular – which tend to be politically contentious (Lackey 2007: 12). Therefore, a topical diversification of investigations would be a worthwhile endeavour. Especially new scientific areas or technologies which are not already highly polarised would be interesting fields of study.

One can also observe a lack of studies considering the effect of different political cultures and systems on scientific advising and advocacy and the associated communication in particular. This includes for example examining the role of scientific advice and advocacy in more authoritarian systems and the differences between more and less polarised systems.

Furthermore, one needs to keep an eye on the role of science journalism in covering and critically accompanying advocacy and public debates on science and science policy (Nisbet and Fahy 2015). While there has been extensive work on the issue over the years (cf. Boykoff and Boykoff 2007; Brüggemann and Engesser 2017; Holliman 2011), the ever changing media landscape and the increasing political and economic pressure on scientists as well as on journalists calls for ongoing investigations.

Besides research questions there are also practical implications: Universities and research institutions have to prepare students and junior researchers not only for scientific communication and public engagement but also for its political aspects and the associated risks. Basic knowledge of policy making, modern communication and

the sociology of science might be a useful of addition of curricula for STEM students. Pielke summarises the need for such knowledge when writing that “it is a responsibility of the expert to be informed about engagement before engaging. It does no good to explain how you wish the world worked or how it should work as an excuse for not understanding real-world political context” (Pielke 2015).

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Philipp Niemann, Laura Bittner, Christiane Hauser and Philipp Schrögel

## 24 Forms of science presentations in public settings

**Abstract:** Research and science are presented to a lay public in various forms nowadays. These presentations are understood as forms of lecture where the presenter not only uses the spoken language but also other communicative modes such as images, videos, sounds, or gestures and facial expressions. These forms of presentation can be differentiated in terms of their degree of multimodality, interactivity, performance, and event and entertainment orientation. The article applies this typology to three especially popular forms of external science communication: booth presentations, Science Slams and “presentation of research” videos. Results show that booth presentations can be regarded as highly multimodal, and in most cases, also very interactive. Performative components are rather negligible here, and entertainment is also not the focus. In Science Slams, by contrast, usually all four parts of the typology are quite pronounced, the strongest of which is the event and entertainment orientation. “Presentation of research” videos have a high degree of multimodality, and have considerable performative potential, too. As the degree of multimodality increases, so does the interaction of the presenter with elements within the video. However, interaction between presenter and viewer, or between viewer and video, play no relevant role. There is also no orientation towards an event or entertainment.

**Keywords:** external science communication – science presentation – typology – multimodality – edutainment – performance – interactivity – Science Slam – booth presentation – presentation in video

### 1 Introduction

For researchers during the last several centuries, oral presentations have been an important means of communication (Peters 2011: 26). If these are not directed primarily at peers in an academic discipline, but instead intended for a lay audience, one can speak of external science communication. Such external communication has always been part of science, if with varying intensity (Könneker and Lugger 2013). In recent years, however, communication activities have multiplied. In Germany, the “PUSH Memorandum” of 1999 (PUSH is an acronym for the Public Understanding of Science and Humanities), produced by major science organizations, can be regarded as the beginning for a systematic expansion of the public communication of science. It



encouraged scientists explicitly to inform and talk about their work, in a form understandable to laypersons (Oetker et al. 1999: 60).

This article focuses on a further development of the classic oral lecture in external science communication: the presentation. All multimodal forms of the lecture are considered as presentations, i. e. all forms in which not only the spoken language of lecturers but also other communicative modes such as image, video, audio, written text or gestures and facial expressions are used (see Bucher, Niemann, and Krieg 2010: 376). Analytically, one can distinguish between three main modes in these newer presentations: the spoken language of the presenter, the visual mode (image, text, or design) and the performative mode (e. g. pointing actions or facial expressions (Bucher and Niemann 2015: 76)). A standard example of the use of such forms in science communication today is undoubtedly the PowerPoint presentation.

Not only has the number of presentations changed, but also the variety of communication activities. Scientific presentations today can occur in events like the “Long Night of Science” or at science festivals, take place as entertaining competitions in Science Slams, or are orchestrated as elaborately staged shows (Bucchi and Trench 2014; Bultitude, McDonald, and Custead 2011; Dernbach, Kleinert, and Münden 2012).

The purpose of this chapter is to present a way of systematizing the multitude of presentation forms of external science communication and, moreover, to characterize particularly relevant forms in detail. For this purpose, a typology with four central classification characteristics is introduced below. The forms of presentation presented below, on the basis of these characteristics, are to be classified as particularly relevant insofar as they each represent a whole group of forms. The chapter refers to those forms of external scientific communication in which scientists themselves – and not journalists or public relations specialists – present their own research.

## 2 A typology of presentation forms in external science communication

A theoretically justified typology of presentations is possible in a variety of ways and depends always on the context of their function. Thus, regarding PowerPoint presentations, Knoblauch speaks of a “communicative genre”, meaning a communicative act in an institutional setting: “[T]hey are patterns of action that are typically expected and performed in certain situations” (Knoblauch 2013: 57). Henning Lobin, from a linguistic perspective and focusing on PowerPoint presentations in internal science communication, has suggested various classification criteria. They include text-external and text-internal criteria as well as criteria clearly related to individual modes (2009: 157–161; see also Chapter 12, this volume).

The focus here is presentation forms in external science communication, which go far beyond lectures supported by PowerPoint slides. A typology that wants to do

justice to such a range of forms, and yet simultaneously also means to be applicable in practice, needs to be at an analytic level below that of a “communicative genre” but above the linguistic “text level”. Its function is primarily to encompass the possible space for presentations, yet offer enough precision to identify, or differentiate, individual presentation forms from one another. As part of the “Science In Presentations” project, a systematic review of the science communication practices was able to identify more than 15 forms used in external science communication and identify their core characteristics (Schrögel et al. 2017). Based on these analyses, four classification criteria are proposed for the typology:

- the degree of *multimodality*
- the degree of *interactivity*
- the degree of *performance*
- the degree to which an *event and entertainment orientation* exists

The concept of *multimodality* differs depending on the theoretical perspective adopted, though the most useful in the current context is one which describes the historical change in media communication towards “novel hybrids of the various communication modes and channels” (Bucher 2012: 53). Presentations per se are an example of such a multimodal form of media communication. Yet the notion of a “communication mode” needs to be defined more precisely if one is to differentiate its various forms with respect to their degree of multimodality. Thus, in addition to text and image, one needs to also consider “design, typography, colors, graphics, pictograms or operations, signs, music, sound, etc.” (Bucher 2010: 42). We agree with the view that modes “may grow whenever a community of users puts work into their use and the material employed is sufficiently manipulable to show the traces needed to reveal that ‘choices’ between semiotically-charged alternatives have been made” (Bateman and Wildfeuer 2014: 182). The key question relative to the degree of multimodality in a presentation is: How many, or which, communication modes are used?

Just like the concept of multimodality, the notion of *interactivity* differs depending on the theoretical perspective and intended purpose (for an example which focuses on the new media, see Sutter 2010). In terms of the forms of presentation, it is helpful to distinguish between two main types of interactivity. One refers to the exchange or interaction between people, or groups of people, with the aid of a presentation as the means of communication, called “addressee-oriented [...] interactivity” (Bucher 2004: 136) or “interaction [...] through a medium” (Höflich 1997: 98). The other can be characterized as “supply-oriented [...] interactivity” (Bucher 2004: 136) or “interaction [...] with a medium” (Höflich 1997: 98). In essence, this is about how the recipients interact with the medium that is offered or its form. Without detailed observation of recipients or viewers and how they respond to a given presentation, it is not possible, in the case of the latter type, to determine the degree of interactivity. But one can make an assertion about which supply-side potential exists for an interaction between presenter and recipient (this is equivalent to the interactivity in online offers noted by Schumacher

2009: 63–64). This applies primarily to the presentation component “speakers”: How dialogue-oriented do they act during the presentation?

In the following, when using interactivity as a characteristic for the typology of presentation forms, its expression is seen in the answer to two questions:

1. To what extent does the presentation allow audience members to communicate with one another? (for example, by discussion in small groups as part of the presentation)
2. To what extent is the presentation designed so that the audience actually engages in an exchange of views with her? (for example, in a dialogue with the speaker, or audience members on stage with her, or the speaker going out into the audience to answer questions)

The term *performance* is widely used in theater research but has been included in various reflections about presentations of research (see, for example, Schnettler and Knoblauch 2007; Peters 2011). In the present context, it is necessary to specifically identify various dimensions of performance so that they can later be used to describe different presentation forms. Only those performative actions on the part of the speakers are relevant which are directly related to the content of the presentation of research.

One can distinguish, for example, between the material/corporeal/medial dimension as well as temporal and spatial dimensions of performance (Peters 2011: 39; similarly Schnettler and Knoblauch 2007). In determining the degree of performance in a presentation, the focus is the extent to which scientific content is staged, beyond the verbal, by the presenting researchers. Specifically:

1. What role do facial expressions and gestures play?
2. To what extent does the speaker use vocal dynamics, dialect or similar variations?
3. What role does movement or body language play?
4. Does costuming play a role? How are costumes linked to the presented content?
5. If props are used, what role do they play in conveying scientific knowledge?
6. What role do additional protagonists or presenters play in the presentation?

Regarding science communication, there are hardly any elaborated concepts or frameworks that describe the specific characteristics of *event* and *entertainment* in presentations. Activities in this field are covered by various terms, from “edutainment” (see, for example, Reinhardt 2005; Egenfeldt-Nielsen 2011) to “infotainment” (see, for example, Wittwen 1995) to “Scientainment” (see, for example, Dernbach 2012). Given this, one can suggest several empirically accessible parameters that could be applied to forms of presentation. These are catalogued below according to functional areas of entertainment (Popp 2005), and within the respective category, a differentiation is made between stimulus and situational features (Früh 2003):

1. Distractions and diversions: the stimulus features include using humor (see also Goldstein and McGhee 1972; Veatch 1998; Chapman and Foot 1996), an appealing aesthetic to the presentation, a more frivolous or light-hearted framing of the talk

(rather than a serious, problem-based approach) as well as stimulating emotions through the presentation. Situational features could include selecting an offbeat location that is interesting to the audience (both due to its nature as well as how it is decorated) and evoking a perception that it is an entertaining event to attend. In addition, a relevant situational feature is to organize the presentation to be concise or to combine brief individual components rather than to craft longer presentations.

2. **Conviviality and community:** The stimulus feature here is for the presenter to speak to the public as a group. Situational features include the atmosphere of the event (does the announcement, self-designation and design for presentations – for example, by having a host – stimulate a feeling of being part of a group or lead to exchanges between audience members?) and the communicative design of the presentation (does the location and order of events encourage or allow for communicative exchanges and/or a sense of community?).
3. **Personal relationship to the topic:** The relevant stimulus feature refers to customizing the presentation (does it contain group specific references to a target group which might allow listeners to establish a personal connection? Will the personal connection (potentially) later be queried?). A situational characteristic of this functional area is a spatial or thematic framing reference to the speaker (for example, she or he comes from the same town, or the occasion for the presentation is linked to a current or local topic).

### 3 Central forms of presentations

In the following, three forms will be presented which are used very frequently when researchers present their work to an interested (lay) public. They stand in for, or illustrate, the variety of forms described in the “Science In Presentations” project (for an overview, see Schrögel et al. 2017) and show both the range of forms as well as their typical characteristics.

The first of these examples is the booth presentation. These booths are used at various events to give visitors an opportunity to be directly in touch with researchers and scientists, and to learn something about their work. Depending on the purpose of the event, such booths address quite different target groups; they exemplify forms in which one-on-one conversations between audience and researchers are possible (sometimes also in the form of researchers with small groups of visitors). They are quite similar to guided tours by scientists through museums, laboratories and the like. By contrast, booth presentations take place much more frequently and are an integral part of events described in more detail below.

A further form that we look at is presentations by researchers in the context of Science Slams. Here we select a strongly entertainment-oriented form which, at least

in Germany, enjoys considerable, and steadily growing, popularity. It is a type of external science communication in which the primary focus is not imparting detailed scientific knowledge but rather to generate enthusiasm for science – notably by researchers themselves rather than by science journalists (who have been doing this for a long time in quite diverse media and forms). The overall trend of taking the communicating of research and scientific findings out of the universities and research institutes and putting it in unusual places is well illustrated by the rise of Science Slams (Eisenbarth and Weißkopf 2012). The focus is on the event, interaction with the audience is rather secondary. A similar orientation, though with differences in the details, can be found in forms such as science cafés, science notes, TEDx Talks or Pecha Kucha (Schrögel et al. 2017).

The third form, in contrast to the previous two offline forms, is provided by online presentations: Videos in which scientists present their own research – hosted by well-known platforms. For scientists, these are opportunities to present their work independent of time and space, and to reach an interested lay audience. However, though one can find numerous videos on scientific topics on portals such as YouTube or Vimeo (a search for the term “science” on April 10, 2018 generated 38,300,000 hits on YouTube), very few of them actually show scientists discussing their own research. Research institutions use science videos as part of image or public relations campaigns (see the University of Bonn’s YouTube playlist *Frag die Bonner Forscher* (‘Ask the Bonn researchers’))<sup>1</sup>, furthermore instructional offerings, like those made available by the National Institute for Science Communication in Karlsruhe or the Canadian company “ScienceFilm” on video productions, are integral parts of the further education of scientists. Due to inexpensive technical equipment as well as the uncomplicated possibility of dissemination through said portals, videos are a form of presentation which is open to all researchers and is therefore included here.

## 3.1 Booth presentations

### 3.1.1 What are booth presentations?

Researchers often present their own work, and the organization or institutional unit they work for, at booths set up at science festivals, annual open houses, “science nights”, and similar events. These are usually temporary separated spaces, created with the help of dividing walls or partitions, in which researchers (or other representatives of the unit) present their area of research. The institutional affiliation is usually

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<sup>1</sup> <https://www.youtube.com/playlist?list=PLz02QuHhvJgmSQF7Wt1S6NaDk9UmjA4c3> (accessed 10 April 2018).

made evident through logos or signs, so the interested visitor can tell at a glance which field or discipline a booth represents. Those doing the presentations are thus not the center of attention, as is often the case in other forms, but act as spokespersons of their organization (see also Horst 2013).

The presentations themselves might take the form of a brief lecture or be a demonstration of an experiment at a given (and communicated) time. More often, it is a spontaneous explanation or demonstration based on the expressed interest and questions of visitors. This dialogue-oriented setting allows individuals or small groups to be in direct contact with scientists or researchers, at eye level, and experience “hands-on” science – something which occurs rarely in many people’s everyday lives. As a rule, booths are designed without barriers, permitting visitors to participate in the presentation or demonstration in an immediate, close-up fashion (see Fig. 2). In addition to posters, displays and exhibits about a clearly defined topic, there is often a possibility to participate or make things, inviting the public to try things out and become themselves active.

At science festivals or the like, booth presentations are oriented especially to families with young children or adolescents, as well as to interested adults. One interesting observation, admittedly anecdotal, is that some adults – parents – seem to visit such booths “for the sake of their children” (and admit so, at least in passing, in interviews) and are themselves not particularly focused on their contents.

Booth presentations are frequently embedded in a larger event which contains different elements, and then represent the “technical” or “informative” part. At such events, there are often other activities which tend to be more playful or entertaining, including performances on a central stage or performances throughout the venue.

When the central focus of an event is booth presentations, surveys of visitors find most respondents saying that the most important reason for their visit is their interest in science (see Fig. 1). Nearly all those asked (93 %) also say it is important or very important to them to learn something. Entertainment plays a clearly subordinate role, with only half responding that this is “important” or “very important”.

The events in which booth presentations are embedded differ greatly in size, duration, and orientation. As a rule, they are free, and an easily accessible way to find out about quite varied scientific topics. Visitors can choose their own priorities, how long they want to visit each booth, presentation, or other part of the event, and how they want to use what is presented (Bultitude 2014). Options range from the completely autonomous and personalized “wandering through and reading/listening/watching” (much like visiting a museum) to a planned tour based on a published event program (e.g. “From lecture to experiment to performance”), and every conceivable hybrid form in between.

Our specific interest is focused on occasions when researchers present their own work at a booth. One example was provided by the booth presentation on “Micro Cold Forming – Processes, Characterization, Optimization”, which is part of the German Research Foundation’s SFB 747 multidisciplinary Collaborative Research

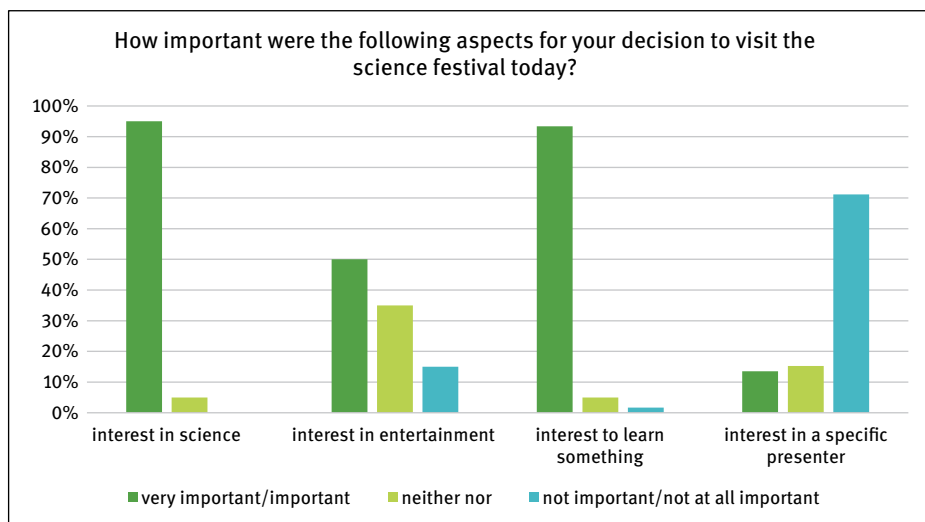


**Fig. 1:** Answers to the question “How important were the following aspects in your decision to come to the Science Festival/Research Mile today?” (Surveys conducted in Karlsruhe [EFFEKTE Festival, July 2017] and Bremen [Forschungsmeile, September 2017];  $59 \leq n \leq 60$ ).

Center housed at the University of Bremen.<sup>2</sup> This presentation took place as part of the Bremen “Research Mile” in September 2017.<sup>3</sup> Under the tent (see Fig. 2), visitors could see the micro-components, tools, and materials researchers use in their work, and information materials were also available. Visitors could find out about individual components of the research at a showcase, which had an integrated touchscreen specially developed for presentations. They could also talk with the researchers involved, making this a combination of exhibit and presentation. Additionally, interaction with researchers meant visitors could use “cold forming” techniques to create small figures and subsequently make films using their figures.

### 3.1.2 Placement in the typology

One can describe booth presentations more precisely with the help of the typology the authors have developed (Niemann, Schrögel, and Hauser 2017), though there is an enormous range in how this form of presentation is actually organized. In what follows, we refer specifically to the “cold forming” example just described as a typical booth presentation.

<sup>2</sup> [www.sfb747.uni-bremen.de/en/home/](http://www.sfb747.uni-bremen.de/en/home/) (accessed 10 April 2018).

<sup>3</sup> <http://www.mikromal.de/mikromal-fuer-alle/81-forschungsmeile-2017> (accessed 10 April 2018).



**Fig. 2:** Researcher using the touchscreen in interaction with a visitor. [Photo: Philipp Schrögel]

### **a Multimodality**

As a rule, booth presentations are highly multimodal, as they integrate not just the spoken word of the presenting researchers or scientists, but visual and often auditory elements as well, and that at differing levels. Posters with photos and diagrams, videos of actual events or using animation, and sound recordings or music may be employed as well. The arrangement of those within the space provided in which various (and often manifold) types of information are made available invites visitors to individually design their receptive experience. Experiments, whether demonstrated or carried out by visitors, are yet another mode used to convey scientific or research information. Virtual reality elements are increasingly being integrated in such booth presentations, for example to “bring architectural models to life”. Booth presentations are thus characterized by a high density and variety of modes.

### **b Interactivity**

The degree of interactivity which can be achieved in booth presentations is highly dependent on the type of presentation. If researchers discuss their work in brief presentations they have prepared beforehand, they often use what can be called a “script mode” (Niemann, Hauser, and Schrögel 2016: 4). Interactivity then only takes place when questions are asked at the end of (or during) the presentation. If, by contrast, researchers are in “repository mode” – meaning they structure their presentations



flexibly and individually in response to visitors' questions, interests, and thirst for knowledge, and make use of prepared printed material and/or what is displayed – then booth presentations can be highly interactive. Even if what is made available takes the form of joint experimentation or a guided discussion of the topic, lively dialogue can ensue in which laypersons are on a par with the researchers. Achieving this is often the stated goal of booth presentations, whether in general or at specific occasions such as annual open houses, science festivals, and the like. Spatial and personnel constraints dictate that booth presentations are oriented to, or designed for, individuals or small groups. While this strengthens the potential for interactivity, it also means the messages can only reach a limited number of those who are (potentially) interested.

### **c Performance**

Performance is a further criterion which can be used to describe and distinguish among presentations of research. Here it is meant in the sense of a conscious and targeted staging of the presentation of content, for example through costumes or props (see Niemann, Schrögel, and Hauser 2017). Booth presentations are aimed at creating a conversation as natural as possible, one that promotes an exchange between researchers and their audience, and that presents researchers as “people like you and me”. However, conscious staging and a strong performative note would be at odds with this goal and are not much used as a rule. Because the researchers as personalities are often not the center of focus at booth presentations (unlike at a Science Slam, an evening lecture, or comparable events) but rather the topics a research group addresses or the work done by an organizational unit to which the researcher belongs, there is often no performative implementation. Performative elements are instead often found in stage(d) presentations, or in the programs of the events booth presentations are embedded in (and in which visitors, presumably, do not expect “stage(d)” elements to be incorporated into booth presentations).

### **d Event and entertainment orientation**

The event and entertainment orientation of booth presentations can be regarded as taking place on two levels. One is that many booths have aspects to them which are primarily meant to entertain, such as things for children to tinker with, quizzes, games with prizes, and the like. What proportion, or what significance, such aspects play in booth presentations has yet to be studied. At the other level, this orientation comes about through embedding booth presentations in larger events (like science festivals) that are billed as entertaining to make them more attractive to potential visitors.

The perceived entertainment value of any one booth presentation varies considerably and depends a good deal on the communication of individual researchers. This can be seen in Fig. 3 reflecting visitors' assessment of the entertainment value of four different booth presentations.

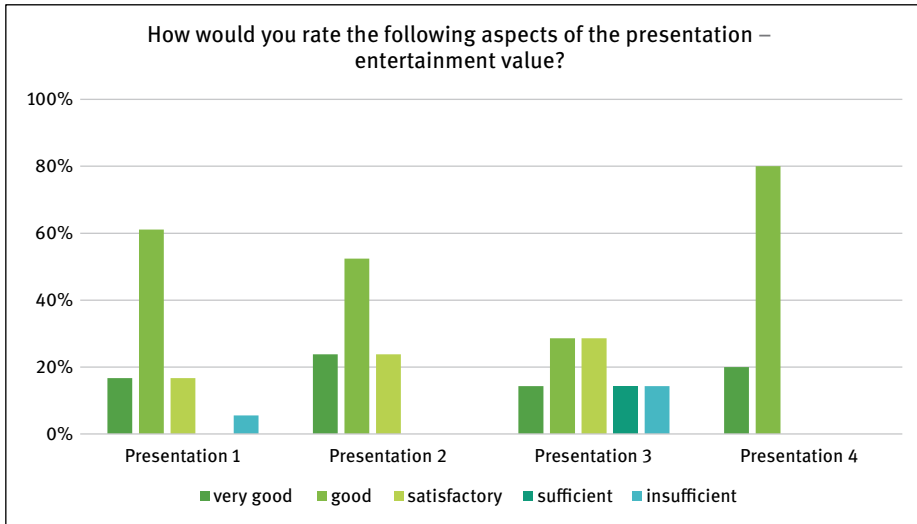


**Fig. 3:** Answers to the question of the entertainment value of four different booth presentations at EFFEKTE Karlsruhe (July 2017) and the Bremen Research Mile (September 2017),  $7 \leq n \leq 21$ .

### 3.1.3 Summary

Booth presentations are an option to present research that is highly multimodal and, in most cases, quite interactive. On the other hand, performative components are negligible, and entertainment is not the focus of the presentation. Observations at various events with booth presentations suggest that the communicative potential of this form is often not fully used, because spatial and personnel constraints mean many interested visitors have no (or cannot have) direct contact with the researchers. If all those presenting are deep in conversation with visitors already present at the booth, those who newly arrive are perforce left out. It can be difficult to integrate them into the dialogue because researchers often launch into an explanatory sequence to establish a context allowing for a conversation, discussion, or questions. At the same time, some visitors are observed to be in “sauntering mode”, strolling past various booths, picking up pencils or other advertising material on the way, but not engaging in any meaningful manner with the topics being presented or with the presenters. One can thus legitimately ask whether any transfer of knowledge to these visitors actually takes place – or indeed, what other motivations prompted them to attend the event. While this would be part of future research, another interesting question pointing beyond reception research, is what the added value of booths presentations is for participating organizations or researchers involved and what role, beyond conveying the state of current research, might aspects such as credibility or visibility play.

## 3.2 Science Slams

### 3.2.1 What is a Science Slam?

A Science Slam is a competition in which (mostly early career) researchers present their own work – but are given only ten minutes to do so. The presentations are meant for a general public and conducted in a relaxed, humorous manner. The audience rates the presentations and selects a winner (Erlemann 2011).

The Science Slam form evolved from the poetry slam, an event at which artists compete in performing their own poetic texts (Wildemann 2011). In Germany, the first slam that presented scientific topics was held in 2006 in Darmstadt. This was picked up and further developed by the Haus der Wissenschaft in Braunschweig, and subsequently spread to other cities (Eisenbarth and Weißkopf 2012). Today, about 60 continuously staged Science Slam events are established in Germany, run by universities, associations, or committed individuals. Additionally, many singular Science Slams also take place, embedded in conference programs, museum exhibitions, or science festivals. An annual, nationwide Science Slam championship has been held in Germany since 2010. Furthermore, individual institutions sponsor supra-regional Science Slams, and the format has been increasingly adapted internationally.

One characteristic of Science Slams is their framing as events. They are usually deliberately held outside university or research institution contexts. To distinguish them from typical evening lectures or public lecture series at universities, Science Slams often take place at youth or cultural centers and at clubs (Hill 2015). As a rule, they happen in the evenings, with a host taking an active role in announcing the next presenter and in encouraging the audience. The host also leads the final voting, with the slam winner determined through audience applause or by points awarded by small groups in the audience.

Apart from the framing of the event the design of the individual presentations by the scientists themselves is characteristic of Science Slams. The requirement is to present one's own research, for example a thesis, doctoral project, or research project in an understandable and entertaining way. The duration of the presentation is limited to ten minutes. At Science Slams, the entertainment value and humor are central components in addition to the scientific content, so slammers usually extensively elaborate their presentations. All aids are permitted, whether PowerPoint slides, videos, experiments, disguises, or props. The de facto standard is creatively and humorously designed PowerPoint slides, partly supplemented by other elements and aids and creative forms of presentation.

In principle, Science Slams can address any topic, and presentations during an evening frequently come from the most diverse corners of research. However, there does seem to be an over-abundance of natural science topics, even though social science and humanities topics are just as suited for Science Slam presentations (Grummt 2015). For example, four of the eight participants in the German national

Science Slam competition in 2016 were physicists, along with two physicians, a materials scientist, and a computer scientist (SlamBasis e.V. 2016). All were men. At the 2017 competition, in addition to six competitors from the natural sciences, there was also a philologist and a linguist. This time, three of the eight were women (Vogel 2017).

In recent years, there has also been an increase in thematically-focused Science Slams, including a “climate protection Science Slam”, a “mobility Science Slam”, and a “beer Science Slam”.

The public associates visiting a Science Slam with a high expectation of being entertained (Fig. 4). While a general interest in science exists, as does an interest in learning something, these are somewhat less important in terms of expectations.

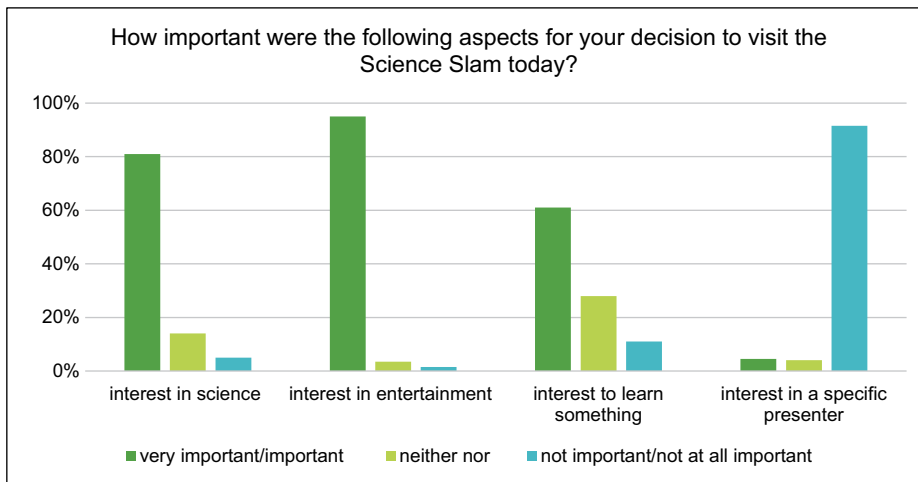


**Fig. 4:** Survey of visitor expectations (at the finals of the German Science Slam championship in 2016, a best-of-show the day before, and at a regular Science Slam event in Karlsruhe [444 ≤ n ≤ 458]).

### 3.2.2 Placement in the typology

To classify the Science Slam in the typology described above, on the one hand, overarching characteristics regarding the framing and the design of the overall event can be used. While these characteristics might not be present at all Science Slam events, they can be found at various events in different shapes.

On the other hand, the presentations, while central, are as heterogeneous as the presenters and reflect individual preferences, personalities, and available means or presentation aids. As a result, no generalizations apply even if one can observe repeated elements in many Science Slam presentations.



**Fig. 5:** An example of a Science Slam presentation which includes PowerPoint slides with text and illustration, as well as live music. [Photo: Nils Pickert]

The following classification of Science Slams as a form of science communication is based on comprehensive observations by the authors at several events as well as on the exemplary manifestations at the final events of the German Science Slam Championships in 2016 and 2017, complemented with empirical data on several Science Slam events.

### **a Multimodality**

As a general rule, a Science Slam allows any tool or presentation form to be used (Fig. 5). Some presenters use this open framework in creative pursuit of a show the public will find the most successful. Slammers may present PowerPoint slides with many images, built-in sounds, music, or videos. They also frequently use diagrams or posterboard illustrations, cardboard cutouts, or live music performances (both instrumental and vocal). As an example, in presenting his research on a medieval manuscript, Simon Hauser, a participant in the German championship final in 2017, not only used monastic chant as a musical element but also performed a rap song on the topic at the end of his presentation<sup>4</sup>. The open format means considerable potential for

<sup>4</sup> <https://www.youtube.com/watch?v=D-ER54SYJN0> (accessed 16 April 2018).



**Fig. 6:** Audience rating at a Science Slam. Representatives of smaller groups hold up cards to show their final vote. [Photo: Nils Pickert]

multimodality; compared with classic presentations of research findings, slammers use a wide variety of rather unusual modes in communicating.

### **b Interactivity**

The interactivity of a Science Slam as an overall event is characterized by the interaction between audience members. This takes place at a rather higher level than at a classic frontal lecture, where audience interaction would be perceived as disruptive. Because Science Slams involve evaluation of performance, there is more intensive interaction, especially if the form of assessment involves discussion in small groups (or with one's seat neighbors) prior to voting. The evaluation process itself makes up the high interactivity of the larger event, since – depending on the method used – this can be expressed through applause, writing a number on a card and holding it up (see Fig. 6), or voting by smartphone app. In addition, at many Science Slams, individuals from the audience are often involved in playing additional roles in helping shape the event, including as time-keepers who give optical or acoustic signals when the time limit is exceeded.

Often, the host of a Science Slam also involves the audience through activating elements in the course of the moderation (e. g. brief surveys of the audience or participatory activities). The interaction between the audience and the individual presenta-

tions strongly depends on the slammer. Sometimes, slammers also conduct participatory experiments or surveys. For example, in the German championship finals in 2017, Susanne Grube had an audience member come on stage to help illustrate the mating behavior of cicadas<sup>5</sup>. However, unlike in some evening academic lectures, there is no real discussion with the audience nor are questions from the audience common at Science Slams.

### **c Performance**

Due to the competition, which gives slammers an incentive to make their presentations as creative and entertaining as possible, the nature or degree of performance can take on considerable significance (as is the case for multimodality as well). Here, too, these types of presentations are in deliberate contrast to more academic presentations of research which strive for a neutral tone and which do not put the speakers in the foreground. Indeed, Science Slammers, in using gestures and intense facial expressions, often express their personal and emotional relationships to their research topics – for example their joy when they report on a successful experiment. Their use of slang, dialect, or colloquial expressions can also emphasize the slammer's personality.

As a rule, Science Slams take place on a stage. If this, for example, is at a club which has no lectern in the room, slammers may well move about more during their presentations, talking to the audience from different sides of the stage, or may hand around illustrative objects. Some slammers have even developed veritable choreographed performance styles and may use costumes so as to embody different roles or to depict historical personalities. Or a costume might be donned to literally embody the content of research, such as that conducted with micro-organisms. As an example, Michael Kloster, another participant in the German championship finals in 2017, clothed himself in a wrap so as to appear as a diatom, and spoke in part from its (fictitious and assumed) perspective<sup>6</sup>. Props may be ways to symbolically illustrate processes or structures (see Fig. 7). The degree of performance, and the exact form it takes, varies widely between different Science Slam presentations.

### **d Event and entertainment orientation**

Science Slams are meant to be entertaining events, and as a rule, humor is a key component in the individual presentations (Hill 2015). At their core these are efforts to make research results (or science) understandable, but to do so entertainingly. This typically manifests itself in humorous or creative visualizations on PowerPoint slides, in cartoons (partly self-created), and in references to popular culture (see Fig. 8). It is also seen in humorously visualized metaphors and puns, as most slammers

<sup>5</sup> [https://www.youtube.com/watch?v=Z\\_68Pu21oL4](https://www.youtube.com/watch?v=Z_68Pu21oL4) (accessed 16 April 2018).

<sup>6</sup> <https://www.youtube.com/watch?v=Wp8poJMCmww> (accessed 16 April 2018).





**Fig. 7:** A high degree of performance at the 2016 German Science Slam final. The slammer embodies and explains his research – the process of egg fertilization by sperm – by playing drums on a cart that is being pulled across the stage as he speaks. [Photo: Philipp Schrögel]



**Fig. 8:** A frequent method of making Science Slam presentations entertaining is the use of popular culture references, both oral and visual. Here, in a physicist's presentation, one sees a visual reference to the TV-sitcom *The Big Bang Theory*. [Photo: Nils Pickert]



use humorous elements in their speech. See, for example, the cartoon drawings of micro-organisms which Elisabeth Mettke, a participant in the 2017 German championship finals, used in her presentation about intestinal bacteria<sup>7</sup>.

One can also often observe efforts to make direct connections to audience experience by explaining a topic in terms of everyday situations. This can be in metaphoric (and humorous) form, as when the explanation of a microscopic process is explained using macroscopic everyday examples. Some slammers lean towards performing comedy skits, while others have drier, more subtle humor.

Many of the elements described above, which are counted among other areas of the typology (e.g. the use of various creative modes such as music, interaction with the audience through participatory activities, or even the use of costumes), are also used by the slammers to provide an entertaining presentation. A Science Slam is also entertaining in its overarching design as an event, reflected in how it is publicly announced and made attractive, and underscored by the often casual, if not positively laconic style hosts may adopt. Add to that the club environment, the availability of alcoholic drinks, live music, and audience participation, and one has many elements of a show event. Science Slam hosts also appeal to, or encourage, a sense of community among audience members by specifically addressing or querying them.

### 3.2.3 Summary

In summary, the form of a Science Slam is characterized primarily by a very high degree of event and entertainment orientation. Overall, however, the form also exhibits a high degree of multimodality, interactivity, and performance. This finding is also reflected in the expectations of the audience, as can be seen in survey data: spectators also associate a high degree of event and entertainment orientation with the form of the Science Slam (see Fig. 9).

There is wide variation in the exact nature of individual presentations at Science Slams, not only because the form itself is open (those new to it can freely try out presentation ideas) but also because there are no formal stipulations (or advance coaching of the presenters, as is sometimes the case in famelab or TED presentations). Their effect on knowledge transfer is also often noted in the literature on Science Slams as a form of external science communication, though this has not yet been considered in the studies of reception. Generally, and regardless of the form taken, different expectations relative to knowledge transfer will exist if one means a ten-minute or an hour-long presentation. One should note that an increase in knowledge is only one goal of science communication; introducing a topic may be a central goal as well.

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<sup>7</sup> See: <https://www.youtube.com/watch?v=9dm-WJ4FU58> (accessed 16 April 2018).

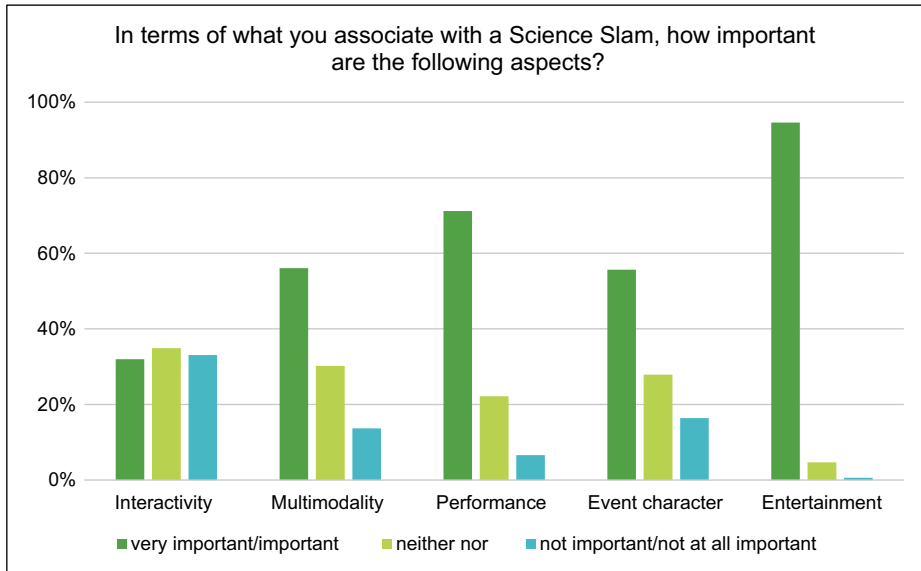


**Fig. 9:** Evaluation of the four aspects of the typology (event and entertainment orientation separated) by audience members at the finals of the German Science Slam championship in 2016, a best-of-show the day before, and at a regular Science Slam event in Karlsruhe ( $450 \leq n \leq 454$ ).

### 3.3 Science presentations in videos

#### 3.3.1 What are science presentations in videos?

Videos are a popular format for presenting research and scientific topics. In addition to widely broadcast TV programs, these come in many forms. A common one is the recorded university (or academic conference) lecture. But there are also numerous videos in which private individuals address scientific topics in many different ways. These can be overviews of current research which an individual has assembled, or a video of an experiment that illustrates a basic principle. The genres range from documentary to live experiments, and include animations, explanatory videos, and live drawings (or also videos, at times with animation, of whiteboards; see Muñoz Morcillo, Czurda, and Robertson-von Trotha 2016: 285–288; Muñoz Morcillo, Czurda, and Robertson-von Trotha 2015: 10). Such videos are made available on platforms like YouTube or Vimeo. A search for “science lecture” on YouTube on April 10, 2018 generated 1,100,000 hits and the private, commercial YouTube channel Veritasium has had at least 250 million hits (Körkel and Hoppenhaus 2016: 7). Popular, web-based science videos have been defined as: “a short video that focuses on the communication of scientific contents for a broad audience” (Muñoz Morcillo, Czurda, and Robertson-von

Trotha 2015: 1). For our purposes, “contents” refers not only to the findings presented, but explicitly also to discovery and development processes in science.

Interestingly, few videos appear to show researchers presenting their own research to the public. If one finds this form of presentation at all, then it is in the institutional context of universities, as on the YouTube channel of the Karlsruhe Institute of Technology under the heading “Research at the KIT”.<sup>8</sup> The Fraunhofer-Gesellschaft showcases its researchers and their findings on YouTube channels (or media libraries), offering a wide variety of interviews and brief, animated reports, on thematically differentiated playlists.<sup>9</sup> The Max-Planck-Gesellschaft presents its current research in animated form in its film series Max Planck Cinema.<sup>10</sup> These appear to be professionally produced, and put the research achievements of the institute as a whole in the foreground. Researchers themselves are usually only given brief airtime and are “quoted” in a manner similar to a text. In this context, one should keep in mind that institutional videos may well be part of PR strategy (Geipel 2017: 191).

Videos in which researchers or scientists present their own research can be distinguished from the numerous science channels available on YouTube. In 2017, around 34 million individual YouTube videos were devoted to the topic “science” (Geipel 2017: 189). Given the dynamics at work here – deleting or renaming old videos, uploading new ones – and the ambiguities of category assignment, an exact quantification of YouTube videos is not possible (Geipel 2017: 189). Many of these were produced by private individuals who neither conduct(ed) research on the topic presented, nor were they associated with an institution, nor did they have any other connection to a research system as such (Geipel 2018: 155). Examples of successful channels in Germany include *AsapSCIENCE*<sup>11</sup> (7.3 million subscribers) and *Kurzgesagt – In A Nutshell*<sup>12</sup> (5.5 million subscribers).

Compared to booth presentations or Science Slams, the digital character of video formats generally means the “presentation of research” is not live. As a result, a video of this kind is not bound to a particular location or time and is therefore also not received as such. Hence, the underlying presentation can be held several times, with the best (or an intercut) version distributed, which is of course not possible when research is presented live.

Stephan Breuer has studied the cultural differences between web videos in science communication and has concluded that German videos differ perceptibly from those produced in the English-speaking world in terms of structure, aesthetics, and content.

<sup>8</sup> <https://www.youtube.com/playlist?list=PLk9Jc1t-Cx0VgRdoq1E2ZbpbRVADIKOOe> (accessed 15 June 2018).

<sup>9</sup> <https://www.youtube.com/channel/UCLWYArko00jc5tJn0LxCXSg> (accessed 5 February 2018).

<sup>10</sup> <https://www.youtube.com/playlist?list=PL-19VItC9Gn2T3-ZjaZ4C9hycTaPod3Na> (accessed 5 February 2018).

<sup>11</sup> [https://www.youtube.com/channel/UCC552Sd-3nyi\\_tk2BudLUZA](https://www.youtube.com/channel/UCC552Sd-3nyi_tk2BudLUZA) (accessed 5 February 2018).

<sup>12</sup> <https://www.youtube.com/user/Kurzgesagt> (accessed 5 February 2018).

In the latter, the differences can be seen in the “strong focus on conveying knowledge”, the “authentic staging of the protagonists” (Breuer 2012: 105) and, as much as possible, not using journalistic formats (Breuer 2012: 106).

Both supply and use of science videos has risen sharply in recent years (Breuer 2012: 101; Geipel 2018: 189). Nevertheless, there has been little research trying to describe and characterize the videos themselves to date. One recent effort has identified the key or specific elements of web videos devoted to science using a typology which includes storytelling, intro and “outro” sequences, and aspects of the protagonists (Muñoz Morcillo, Czurda, and Robertson-von Trotha 2016; Muñoz Morcillo, Czurda, and Robertson-von Trotha 2015). However, unlike in our approach, this typology does not distinguish between presentations by researchers and those by laypersons. An approach that explicitly focuses on the presentation of scientists is provided by the typology of external forms of presentation by Niemann, Schrögel, and Hauser (2017). With the description of the terms multimodality, interactivity, performance, and event and entertainment orientation, distinct presentation aspects are differentiated and presented on a meso level.

### 3.3.2 Placement in the typology

In the description which follows, we focus primarily on those elements which seem to illustrate this form of presentation best. Due to the diversity of variant representational possibilities, including combinations, one can only speak of illustrative individual examples not easily generalized. What all such presentations have in common is that the presenter is the focus of the video and is seen in many (or at least some) frames.

#### a Multimodality

Science videos per se are multimodal forms of communication that combine the most varied modes in different ways: text and image, sounds, scenic language, voiceovers, animation, color schemes, and dramaturgy (Bucher 2011: 110). These varied modes allow for differing approaches to the topics at several content levels; they may also address the audience emotionally (Körkel and Hoppenhaus 2016: 19). However, in videos where scientists present their own research, modal diversity is less important. What is found in all such videos at the beginning, and in part again at the end, is a caption (usually in the lower third of the screen) with information about the presenter such as name, research area, and institution. If more than one researcher appears, each is introduced, at their first appearance, with a caption.

The auditory component usually consists only of the speaker’s voice, though individual sequences may be accompanied by off-screen narration, as in the visual and cartographic material shown in the video *Antiker Wirtschaftsboom – Landnutzung in*

*der römischen Eifel* ('Ancient economic boom – land use in the Roman Eifel').<sup>13</sup> Here one mostly sees the presenter in his office as he discusses his topic. To help visualize the topics, maps (see Fig. 10a) and pictures of the territory discussed are shown. Other videos may use whiteboard diagrams (see Fig. 10b), infographics, or drawings to illustrate various themes.

Slides of the kind used in classic PowerPoint presentations, by contrast, rarely appear. For complicated topics or those difficult to visualize directly, screens showing simulations, or images generated in the research conducted, may be shown. Thus, in the video *Diabetes: Neue Hoffnung für verbesserte Wundheilung* ('Diabetes: new hope for improved wound healing'),<sup>14</sup> the behavior of cellular mechanisms is illustrated with the help of a computer simulation (see Fig. 10c). Animation is also used sometimes, as in the video *Bioklebstoff aus Muscheln* ('Bio-adhesives from seashells')<sup>15</sup> (see Fig. 10d), but full animation of the kind often encountered in popular science video channels, is absent.

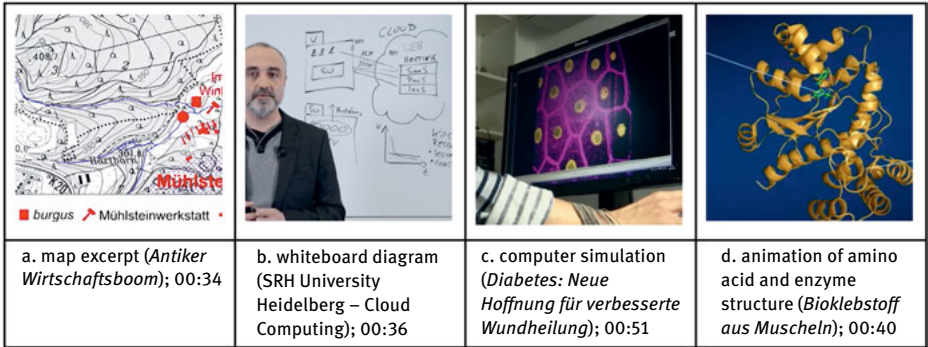


Fig. 10: Multimodality in science presentations in videos.

### b Interactivity

Two levels of interaction are potentially available in video presentations. One is the direct interaction of viewers with the video, for example through integrated hyperlinks. In the “presentation of research” videos we consider here, however, no such possibilities exist, either in the form of hyperlinks or in viewers being able to select topics.

The other potential level is a more passive form of interaction, one largely determined by the location and type of embedding of the video (on a homepage, a YouTube channel, etc.). In theory, the commentary function below a video makes communication and interaction between presenter and audience possible. However, if the video

<sup>13</sup> [https://www.youtube.com/watch?v=xMnUg\\_TfgLQ](https://www.youtube.com/watch?v=xMnUg_TfgLQ) (accessed 5 February 2018).

<sup>14</sup> <https://www.youtube.com/watch?v=B7OOFMeHjMA&list=PL66D59395E0C03AE8&index=38> (accessed 5 February 2018).

<sup>15</sup> <https://www.youtube.com/watch?v=1HUMaqjTpsY> (accessed 12 February 2018).

is part of an institution's communication channel, as is very often the case in this form of presentation, the researchers/presenters themselves may often not even know this possibility exists.

It is these two aspects in particular which set such "presentation of research" videos apart from privately produced videos on scientific topics. In private productions, there is significantly more interaction between presenters and viewers, with the videos themselves containing links to other videos (e. g. from the same private source) or to comparable topics.

There is more potential for the speakers' interaction with elements in the videos. At one level this involves how texts, formulae, and symbols are used (often on flat, "presentation" surfaces). An example can be seen in the video *Fluid Action: Die Natur als Vorbild für Humanoide Roboter* ('Fluid Action: nature as a model for humanoid robots') (Fig. 11a).<sup>16</sup> Another example is in *Biosignalverarbeitung für die humanoide Roboter-Interaktion* ('Bio-signal processing in humanoid robot Interactions'); in the course of the video, a comprehensive diagram is drawn (and created) on a whiteboard (Fig. 11b).<sup>17</sup> One also can see the presenters interacting with three-dimensional objects. This can be a quite pronounced use (as visual support for the verbal description), for example in the video *Rechenschieber – Aufbau und Funktionsweise* ('The slide rule: design and operation') (Fig. 11c)<sup>18</sup> or in *Biomechanik und Prothesen* ('Biomechanics and prostheses') (Fig. 11d).<sup>19</sup>

The degree of interaction here is closely linked to the topic and how research is done. If that research can readily be visualized using symbols, formulae, or with the help of objects, or if these objects are integral parts of the research process, then they are drawn upon as explanation, or for demonstration purposes, in the video presentations.

It is notable that videos with a low degree of multimodality also tend to have low levels of interaction within the video. When presenters themselves are the camera's focus, they often explain their topic without significantly interacting with PowerPoint slides, symbols, or objects. By contrast, the more multimodal such a video becomes, the more pronounced is the tendency to use didactic or pedagogical means or show interactions. These might involve using the hands to point or demonstrate a process (e. g. a running movement, as in the video *Energieeffizientes Laufen* ('Energy-efficient running')<sup>20</sup>), the operation of machines and computers, drawing sketches, or writing text.

<sup>16</sup> <https://www.youtube.com/watch?v=lx562FUYiEs&list=PLk9Jc1t-Cx0VgRdoq1E2ZbpbRVADIKOOe&index=25> (accessed 12 February 2018).

<sup>17</sup> <https://www.youtube.com/watch?v=Im5VXJiuBI4&list=PLk9Jc1t-Cx0VgRdoq1E2ZbpbRVADIKOOe&index=51> (accessed 12 February 2018).

<sup>18</sup> <https://www.youtube.com/watch?v=QW33fUp2JoA> (accessed 12 February 2018).

<sup>19</sup> <https://www.youtube.com/watch?v=V6Dl34oaNDM> (accessed 12 February 2018).

<sup>20</sup> <https://www.youtube.com/watch?v=emZyNm57VFw&list=PLk9Jc1t-Cx0VgRdoq1E2ZbpbRVADIKOOe&index=55> (accessed 12 February 2018).

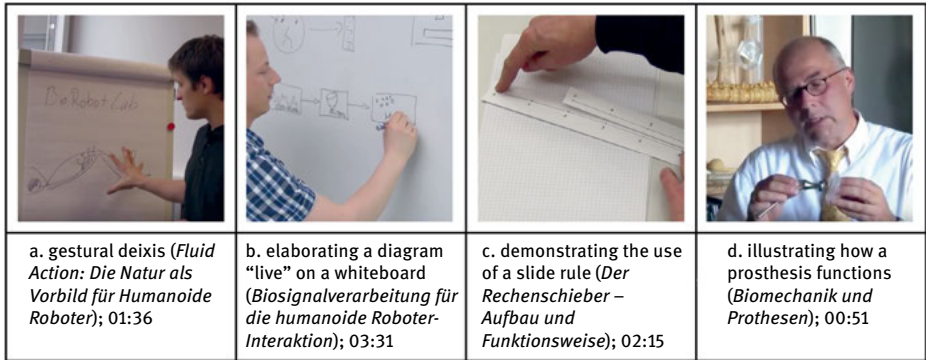


Fig. 11: Interactivity in science presentations in videos.

### c Performance

At the level of performance, videos have at least the same potential as offline presentations, if not more, as they are neither bound to a particular location, with its spatial and temporal limitations, nor limited in their selection of props. Rather, a video can visit different locales such as laboratories or machine shops, and have individual bits of the presentation shown there, and do so at varying times. This also means available equipment can be demonstrated in situ, as in the complete laboratory (with its non-portable devices) shown in the video *Objektorientierte Umweltmodellierung* (‘Object-oriented environmental modelling’).<sup>21</sup> In the video *Lebensammlung – Wissenschaftsgarten am Riedberg / Naturwissenschaften (1/9)* (‘Living collection – the Riedberg natural science research garden’), research in a greenhouse is shown, as it were, “live”.<sup>22</sup> The video *Das Centrum für Naturkunde (CeNak) stellt seine zoologische Sammlung vor* (‘The Center for Natural History (CeNak) presents its zoological collection’)<sup>23</sup> shows how insects are prepared, while *Programmieren durch Vormachen: Wie Roboter vom Menschen lernen* (‘Programming through demonstrating: how robots learn from humans’)<sup>24</sup> shows the testing and programming of a robot.

In addition to these various aspects, performative staging has particular significance in this form of presentation. As they are free of time, place, and even visual

<sup>21</sup> <https://www.youtube.com/watch?v=SWMQENSj2h8&list=PLk9Jc1t-Cx0VgRdoq1E2ZbpbRVADIKOe&index=54> (accessed 12 February 2018).

<sup>22</sup> [https://www.youtube.com/watch?v=CHhstRWkAx8&index=1&list=PLn5gYfEKIag\\_y6G-ivLcdsZbj\\_C25x6l7](https://www.youtube.com/watch?v=CHhstRWkAx8&index=1&list=PLn5gYfEKIag_y6G-ivLcdsZbj_C25x6l7) (accessed 12 February 2018).

<sup>23</sup> [https://www.youtube.com/watch?v=\\_02kH6Egkc8&index=1&list=PLpB9eUaLT4wIPfRUwmoSaXy3OpbVX7Qim](https://www.youtube.com/watch?v=_02kH6Egkc8&index=1&list=PLpB9eUaLT4wIPfRUwmoSaXy3OpbVX7Qim) (accessed 12 February 2018).

<sup>24</sup> <https://www.youtube.com/watch?v=0hf3beqi6dg&list=PLk9Jc1t-Cx0VgRdoq1E2ZbpbRVADIKOe&index=28> (accessed 12 February 2018).

sequence, videos are far more capable of showing comprehensive staging, such as being used to show – or rather recreate – historical events.

Thus, at the performative level, what is significant in videos generally (and specifically in “presentation of research” videos) is their freedom from spatial and temporal constraints, as well as their ability to combine backdrops in limitless ways. Explicit staging, by contrast, appears very rarely in these kinds of videos. What can be regarded as “normal”, therefore, is the interaction of presenters with various two- and three-dimensional means (elements) as part of their explanation. In videos with a lower degree of multimodality, and which essentially only show the presenter, performance is barely noticeable. In highly multimodal videos, by contrast, one sees an increased use of performative elements.

#### **d Event and entertainment orientation**

It is worth considering event and entertainment components separately in video presentations. The former is more readily evident in the case of competitive events such as

Fast Forward Science<sup>25</sup> or the Foresight Film Festival.<sup>26</sup> However, most of the reception of “presentation of research” videos very likely takes place in private, far from public events. The outreach (or potential knowledge transfer) can thereby be increased, but it also can mean a lack of context for the contents being broadcast, as is more possible at events.

The entertaining components in this form of presentation are only insignificantly limited by this, as they are well-anchored at the level of content and performance. Videos in which scientists present their own research, however, are marked by a predominantly objective, sober, and fairly emotionless presentation mode. It is all about research insights, processes, and requirements, presented clearly, understandably, and seriously, as in the video *Energieeffizientes Laufen*,<sup>27</sup> which shows the researcher remaining factual the entire time, presenting his research, various challenges, and developments, one after the other. The presentation remains clear and simple, even at the visual level; funny pictures and photos are almost entirely omitted. That does also apply to the video *Bioklebstoff aus Muscheln*,<sup>28</sup> in which one mostly sees the researchers in their laboratory. Inserted animated images of bacteria (01:05 minutes) show only a few, coarsely structured, bacteria against a monochrome background, the visual representation of broken bones is shown by using X-rays (01:37 minutes). These “presentation of research” videos can thus clearly be distinguished from videos with a strong entertainment orientation one can find on private science channels.

<sup>25</sup> <http://www.fastforwardscience.de> (accessed 12 February 2018).

<sup>26</sup> <http://www.fastforwardscience.de> (accessed 12 February 2018).

<sup>27</sup> <https://www.youtube.com/watch?v=emZyNm57VFw> (accessed 12 February 2018).

<sup>28</sup> <https://www.youtube.com/watch?v=1HUMaQjTpsY> (accessed 12 February 2018).



### 3.3.3 Summary

As an online form, these “presentation of research” videos stand out above all for their high degree of multimodality and their performative potential: they can show live research processes in a variety of settings. The higher the degree of multimodality, the more the presenter in the video interacts with various two- and three-dimensional didactic aids (elements). However, no significant interaction between presenter and viewer takes place, owing to the online format, and opportunities for such interaction remain unexploited. There is also little by way of an event evident; the focus is clearly on fact-based, simple presentations which are not intended as entertainment. Though some elements recur, and central elements can be identified, this is a form of presentation which offers an enormous variety of options as to content and manner of presentation. As of now, we have no systematic findings as to how relevant various forms or contents are received – for example, in comparing animation to whiteboard presentations – though these are part of the ongoing research of the “Science In Presentations” project.

## 4 Conclusion and future research

This chapter has focused on various forms in which research and science are presented to a lay public nowadays. These presentations are understood as forms of lecture where the presenter not only uses the spoken language but also other communicative modes such as images, videos, sounds, or gestures and facial expressions. We suggest differentiating these forms of presentation in terms of their degree of multimodality, interactivity, performance, and event and entertainment orientation. This proposed typology is then applied to three especially popular forms of external science communication utilized by researchers (rather than journalists or PR specialists) themselves for presenting their own work: booth presentations, Science Slams, and “presentation of research” videos. These are merely illustrative of a wide diversity of presentation forms and give some idea of the range and typical characteristics.

Our research suggests that booth presentations can be regarded as highly multimodal, and in the most cases, also very interactive. Performative components are rather negligible here, and entertainment is also not the focus. In Science Slams, by contrast, all four parts of the typology are quite pronounced, the strongest of which is the event and entertainment orientation. Their precise nature or degree can vary greatly from one Science Slam presenter to the next. “Presentation of research” videos have a high degree of multimodality, and have considerable performative potential, too, as they can show research processes “live” in various settings. As the degree of multimodality increases, so does the interaction of the presenter with elements within the video. However, interaction between presenter and viewer, or between viewer and

video, play no relevant role. There is also no orientation towards an event or entertainment: in “presentation of research” videos, the focus – unlike in many popular science channels on YouTube – is clearly on factual, simple presentations.

Regarding future developments and research on forms of presentations in external science communication, the authors see two basic tendencies: One is an increasing focus on dialogue, evident in other areas of society as well, such as in political participation processes. In the area of science communication, this is manifested in forms of presentation such as the “Interactive Scientific Poster” (Niemann, Hauser, and Schrögel 2016) or in the many forms of science communication which have sprung up in German restaurants and cafés (e. g. *Plötzlich Wissen*, *Wissenschaft on Demand*, *Wissensbuffet*, *Wissensdurst*).<sup>29</sup> The other, with respect to new technological developments in the realm of virtual reality – virtual research lab experiments (intended for schools, e. g. the Weltlabor VR-Experiment (‘World laboratory VR-experiment’) of the KIDS interactive GmbH firm<sup>30</sup>) or lecture halls which can be used with virtual reality goggles<sup>31</sup> – is a tendency toward individualizing presentation forms and their reception.

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<sup>29</sup> For an overview, see <https://www.wissenschaftskommunikation.de/format/pub-science-event/> (accessed 17 July 2019).

<sup>30</sup> <https://www.youtube.com/watch?v=H4JKK0lxfcI> (accessed 18 April 2018).

<sup>31</sup> e. g. <https://www.tricat.net> (accessed 18 April 2018).

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## **IV Historical perspectives on science communication**



Thomas Gloning

## 25 Historical perspectives on internal scientific communication

**Abstract:** In this chapter I give a sketch on major perspectives of a history of scientific or scholarly communication. It includes the question how functional and epistemic needs in the history of different disciplines have steered the evolution of communicative means, for example in respect of scientific genres, forms of visualization, multimodality, the use of media and vocabulary/terminology. In addition, I deal with languages of science and the changing relations between overarching languages of science and the vernaculars. Further perspectives are briefly mentioned in a concluding section.

**Keywords:** communication history – history of scientific communication – history of knowledge organization – history of text types/genres – languages of science

### 1 Introduction

The work and the communicative activities of a modern scientist working in the field of agricultural chemistry differs considerably from a 16th- and 17th-century scholar in astronomy like Johannes Kepler (1571–1630) or the compiler of the medieval *Herbal of Rufinus*. But it also differs in several respects from the work of a humanities scholar of his or her own time. Firstly, the respective states of their fields required different genres and forms of information representation. Secondly, they had different media and information technologies at their disposal (e. g. printing, electronic diffusion, bibliographical and information management technologies). Thirdly, they could or could not use research technologies that affected the forms of scientific communication, for example the telescope or photography. Finally, they used different writing and information conservation technologies (e. g. handwriting, printing, audiotaping, audio-visual conservation). Yet, they have many things in common. Firstly, their ultimate goal was to gain and to systematize trustworthy knowledge in their respective fields, even if they followed different scientific principles (medieval book science based on authority vs. empirical principles). Secondly, they had/have to rely on a shared pool of information in their fields (agricultural chemistry, astronomy, medical plant lore), which had to be accessible, findable and understandable. Thirdly, they also had to collaborate with other persons in their fields, for example in order to get relevant texts, to discuss positions and questions, to conduct controversies, or to make available their findings for a more or less broad scientific audience.

This example shows that historical communication among scholars/scientists can be examined from different points of view, for example in respect of its evolution over



time, in respect of its organization in specific disciplines or in different timeframes. Thereby, we have to deal with different parameters that affect scientific communication and we must assume that these parameters show interdependencies one has to account for. Among the main parameters are: the communicative needs of research in scientific disciplines and their dynamics in history, the text types/genres, forms of visualization and media that were available in different disciplines and timeframes, the availability and the changes in writing, publication and collaboration technologies, the choice of language(s), vocabulary and terminology. The relation between individual and social aspects of research and research communication is a further point.

The discussion of these parameters and their evolution can also be used to clarify the relationship between modern science and its historical predecessors. Speaking of science and scientific communication in a historical perspective, I refer mainly to the Western tradition from the Middle Ages onwards, occasionally including its Greek, Latin and Arabic roots. As far as I can see, a comprehensive history of internal scientific communication is not yet available. This chapter gives a panorama of main topics and communicative perspectives. I hope this agenda will stimulate discussion on how a comprehensive history of internal scientific communication could be written.

## 2 Communication needs and affordances in a historical perspective

The idea of modern science comprises a number of communicative principles like the principles of publishing scientific findings, the principle of scrutiny and criticism and the principle of reading or checking what information is available on a given subject before publishing new findings (see e. g. Weinrich 1995). These principles are not historically invariant. For example, the idea of publishing and public availability of scientific findings is dependent on historical notions of audiences and scientific participation. It also presupposes a specific infrastructure that includes libraries, interlibrary loan, bibliographies, databases, journals and the like. The second principle, the principle of criticism presupposes a specific understanding of science that is not consistent with the medieval and Early Modern idea that science is the reproduction of what “ancient” authorities said or wrote, which was tied to specific intellectual and textual practices. The third principle of “reading everything on a subject before publishing on that subject” has become particularly problematic in the days of “publish or perish” and of information overload. Already Leibniz spent a considerable amount of his time and energy on designing systems of organizing scientific information in the light of an “overflow” problem. In earlier periods the “reading everything”-principle was also problematic because of the restricted availability of scientific findings. Early Modern scientific correspondences often contain pas-

sages about the availability of publications and the possibility to share or to provide publications in a timely manner, which is mirrored in the modern-day exchange of pdf-files.

Hence, looking at scientific communication and its historical dynamics one can in the first place take a functional perspective and ask which kinds of functions and “needs” had to be met in specific periods of science and in specific disciplines. From a historical perspective, communication served basic functions like generating knowledge, publishing knowledge, collaborating with others. Even taking personal notes is a communicative practice that was embedded in research or teaching processes. From such global functions one gets to a widespread repertoire of more granular, specific textual and representational functions like the coordination of a description with a pictorial representation (e.g. Young and Gloning 2004: 192), to name only one specific procedure. While the communicative need to coordinate text with pictorial representation has been historically stable, its techniques have changed with the advent of new technologies that allowed, for example, the use of colour systems or digital hyperlinking.

The perspective of communicative needs in science at a specific time has to be complemented by the question of which “affordances” (Hutchby 2001) were available for communicative purposes. Basic communication resources do not strictly follow the communicative needs in the sciences according to the form-follows-function-pattern. While Benedictine monks of Montecassino in the early Middle Ages would have certainly benefited from digital text exchange, this kind of technology was not available at this time. Affordances (artefacts, technologies) have both an enabling and a constraining side (Hutchby 2001: 444; 448).

The three main affordances in the sciences, the humanities and its predecessors are (i) media, (ii) technologies of communication and (iii) technologies of knowledge production. To give a few examples for the kinds of media involved: A medieval medical scholar had to rely on the availability of manuscripts (Siraisi 1994). Seventeenth-century scholars like Leibniz made heavy use of letter writing for the purposes of scholarly communication. Books and journals (Habel 2007; Baldwin 2015) were the core media of publication for many centuries until today, while mailing lists (Bader 2018), social media like Twitter, Facebook, blogs, etc. and video platforms like YouTube are used more and more for scientific purposes (see Chapter 30, this volume; Fritz and Gloning 2012). Some of these media rely heavily on communication technology, for example in the use of mailing lists for scholarly purposes. In addition, there are specific communication technologies like the telephone, video-conferencing software or digital redaction and publication systems used by journals and academic publishers. Digitization not only changed scientific communication itself (Gloning 2018), but also the processes of knowledge production. Telescopes, microscopes, X-ray instruments, statistical software, corpus-tools and many other technologies changed the research methods and equally influenced the way of representing results of research.

It is therefore one of the tasks of the history of science communication to describe the interplay between communicative needs, learned practices and the affordances (media, technologies) that were available, both in a historic-synchronic (e.g. around 1600) and in a diachronical perspective.

### 3 Genres: written, spoken and multimedia genres in the history of scientific communication

The basic idea of the genre concept is that there are patterns or traditions that help people to solve communicative tasks. A communicative genre, a text type or an oral form of communication is organized in a typical way and is used to fulfill recurrent functions. Genre knowledge equally supports readers in text understanding. For example, reading a scientific paper raises certain expectations about structure, content and sequencing. In societies and communicative fields, groups of genres form coordinated systems that relate to tasks that have to be fulfilled recurrently. Thomas Luckmann (1986, 1997) proposed the notion of a “communicative economy” (“kommunikativer Haushalt”) to conceptualize how genres and communicative tasks are interwoven with each other and with their social contexts. Both genres and communicative economies are the results of historical evolution based on changing tasks, the availability of media and technologies and other factors.

Among historical genres we can distinguish written genres where the resource “text” fulfills the main functions. Herbals, philosophical treatises, written disputations or medical recipes belong to this group. The late 13th century *Herbal of Rufinus* (Thorndike 1946) is an example of a text-based herbal, that organizes knowledge about the medical properties of plants according to the sources available at this time. Nevertheless, even in manuscripts or prints that are not illustrated we often find multimodal devices that contribute to the organization of the text like colour, typography or spatial organization. The same holds true for primarily oral genres. Even a lecture, which is based on the spoken word in the first place, draws on other resources like direction of gaze, body movement, spatial orientation, not to speak of multimodal performances where a presentation (Bucher and Niemann 2012) or an experimental demonstration has to be orchestrated with spoken text, gesture, pointing practices or spatial movements (see Chapter 12, this volume). In the history of scholarly communication we have, on the one hand, early examples of complexly orchestrated multimodality (see e.g. Gloning 2015 on Thurneysser’s *Herbal*, 1578; still earlier examples can be found, for example, in mathematical or astronomical manuscripts of the Middle Ages) and, on the other hand, the overall trend of an increasing use of multimodality in certain disciplines, that is intimately connected to technologies of printing (e.g. colour), the availability of audio-visual resources and the confluence of technological affordances in digital devices. Colour, spatial arrange-

ment and typeface were already heavily used as resources in scientific manuscript cultures.

The repertoire of research-based genres and its components has developed historically in connection with a number of aspects or factors.

Firstly, in different disciplines specific genres and components of genres have evolved. The medico-botanical genre “herbal” with its core component “plant monography” goes back to antiquity (e.g. Theophrastus); in modern times biological and medical plant descriptions have differentiated, while Early Modern herbals still included both information types. An example from mathematics is the textual representation of a proof or a geometrical demonstration; mathematical genres rely heavily on forms of symbolic notation (see Chapter 17, this volume). With the establishment and professionalization of new disciplines, for example psychiatry in the 19th century, new genres and writing practices have evolved and stabilized over time (Schuster 2008, 2010).

In the second place, new or core media were the basis for the evolution of genres and their use. The most prominent example are the “new” scientific journals of the 17th and 18th centuries that brought about several new genres like the review (Habel 2007; for modern peer review see Baldwin 2018 and Chapter 14, this volume) or the experimental article (e.g. Bazerman 1988). Research contributions on the history and evolution of scientific journal articles include Gross, Harmon, and Reidy (2002), Moxham (2016), Banks (2017), Ylönen (2001), to name but a few. In our times the use of digital media has brought about new changes in the repertoire of genres and text types (Gloning and Fritz 2011; cf. Chapter 30, this volume).

There are genres that are intimately connected to intellectual and scientific movements. Scientific dictionaries of the enlightenment period are one example (cf. Yeo 2001). Encyclopedic genres and forms of knowledge aggregation have a long tradition in the history of the sciences (e.g. Vincent of Beauvais; Simon of Genoa; see Stammen and Weber 2004). It is one of the future tasks of the history of scientific communication to systematize the relation of specialized research results with their forms of aggregation in textbooks, handbooks, scientific dictionaries, encyclopedias, etc. in a historical perspective.

Furthermore, genres or genre-components can be closely connected to specific principles in the evolution of certain disciplines. A good example is the evolution of “methods discourse” in the history of experimental methodology within the life sciences and in the texts relating to this field. The textual component “discussion of aspects of experimental methodology” closely follows the historical development of the new methodology (Schickore 2017).

One can also look at genre aspects in respect of the “life cycle” of knowledge production. What researchers write down in notebooks might in many cases not follow the patterns of established genres, but the notes are in one way or another directed at the production of texts that do follow genre expectations. To jot down different aspects of a patient’s case can be used for the final version of a case study or the description

of a kind of illness. To take notes of one's own reading will in many cases end up in quotations or references of a publication. Notebooks or other material formats like sheets of paper are the place where work on the thematic disposition of publications is done. In a famous passage of his autobiography, Charles Darwin described the role of excerpts and thematic dispositions of different granularity for his own research and writing praxis (Darwin 1888: 99–100). Other examples include Niklas Luhmann's *Zettelkasten* ('Slip box'), the Jesuit praxis of building up systematically organized collectanea, the role of note taking in "laboratory life" (Latour and Woolgar 1986) or in Early Modern science (Yeo 2014; Mulsow 2012). Today, the praxis of excerpting, note taking and collecting references is supported by software systems.

Equally, the repertoire of teaching genres (e.g. lecture, disputation, seminaristic forms, student paper, textbook, types of exams) and its evolution, that shows similar connections to disciplines, their subjects and scientific principles, the media and technologies involved, can be related to the life cycle of scientific education. For the history of lectures, disputations and dissertations in medieval and Early Modern science teaching see Prinz (Chapter 26, this volume), for the role and history of student paper writing see Pohl (Chapter 9, this volume; cf. Pohl and Steinhoff 2010). Writing as an instrument has always been a basic pillar of scientific education, but only from the 19th century onwards has it been systematically implemented in teaching programmes, for example in the Prussian "seminar" or in the writing-to-learn approach with its different genres and activity types (for an overview see: <https://wac.colostate.edu/resources/wac/intro/wtl/>; accessed 5 May 2019).

From a communicative perspective, oral and written genres together with their multimodal and mediated versions are closely interwoven. In a historical perspective one can ask how and in which configurations different genres and specific texts were connected to each other. To give just one example: The Latin version of Avicenna's *Canon* was one of the most important books both in medical research and in medical teaching from the Middle Ages up to the Renaissance (Siraisi 1987). Referencing, quoting and commenting were the most important practices of interweaving the components in a complex and dynamic ecology of research and teaching.

From a linguist's point of view the description of genres/text types includes the analysis of function, activity structure, topic structure and topic development, linguistic means (syntactic patterns, vocabulary use), communicative principles like precision or comprehensibility, knowledge dynamics, the functional use of text/image-configurations and the analysis of different semiotic resources in their multimodal arrangement. Examples from my own work include Gloning (2007, 2008, 2010, 2011b, 2011c, 2012, 2015, 2016; see also Chapter 10, this volume), for examples of the description of text types in historical controversies see Fritz (2010, 2016: ch. 9 and 10; see also Chapter 15, this volume) and Fritz, Gloning, and Glüer (2018).

## 4 Visualization and multimodality in the history of scientific communication

It is safe to say that in the history of (internal) scientific communication in different disciplines written text has been the most important mode for the production and transmission of knowledge. It is, however, equally safe to say that forms of visualization fulfill specific functions in many scientific fields, past and present. The basic questions for a history of scientific visualization are, what kinds of images were used (e. g. drawings, diagrams, photos), which functions were they used for, and how and with which procedures were text and images and their respective functions coordinated. Apart from text and images, semiotic resources like colour, spatial arrangement, typography and others can be used in complex multimodal arrangements (Kress 2009). The use of multimodal arrangements in scientific manuscripts, books, journals and audio-visual media has a long tradition in the history of the sciences and the humanities, even if systematic theories of multimodality have been available only in the last few decades.

Forms of visualization, their scientific uses and certain aspects of multimodality in the history of the sciences and the humanities have been broadly studied in many perspectives. What follows is a sketch of the broad lines of research perspectives.

Firstly, one can ask for research on visualization and multimodality in respect of specific time frames (e. g. medieval, Early Modern or 19th century). A good example is a massive volume edited by Hans Holländer (2000) on the history of visualization (“Bildgeschichte”) in the natural sciences and different branches of technology from the 16th to the 19th centuries. It includes a wide range of contributions that relate to different disciplines (e. g. botany, astronomy, technologies), subjects (e. g. comets), practices (e. g. the demonstrational experiment), genres (e. g. the *theatrum machinarum*-literature), types of diagrams, and other aspects of visual representation in their institutional contexts. Many specialized articles also contribute to the history of the use of visualization and multimodal elements in certain time frames. For example, the articles of Barbara Obrist (1997 on medieval wind diagrams) or Faith Wallis (2015 on diagrams in medieval time theory) both contribute to the history of forms of diagrammatic representation in different branches of medieval science. Hankins (1990) reconstructs the invention and evolution of graphs (“nomograms”) from around 1770 onwards into the 19th century.

Secondly, we can group historically oriented research contributions on scientific visualization along different disciplines (e. g. chemistry, astronomy) and their predecessors these studies deal with. In a historical perspective, there is the problem that scientific disciplines are not “stable” entities. Modern chemistry, for example, is a child of the 18th century with roots in metallurgy, mineralogy, alchemy and other fields that have quite different traditions and in part different representation practices. Nevertheless, it can be fruitful to ask for the traditions of visualization and mul-

timodality in the history of scientific disciplines and their predecessors. An example of research along this line are investigations on the use and the functions of medical images in various centuries (e.g. Freyer 1998, 2000; Herrlinger and Putscher 1967, 1972; Keil 1990; Kusakawa 2012; Sudhoff 1914, 1918; Schlich 1997; Heßler 2005; Dünkel 2008; Van Dijck 2005; Roberts and Tomlinson 1992; van Otegem 2004). Some of the publications on disciplines are combined with time frames, e.g. *Visualizing medieval medicine and natural history, 1200–1550* (Givens, Reeds, and Touwaide 2006). Similar visualization research has been done in other fields like the history of astronomy (e.g. Haffner 1997; Müller 2008; Lefèvre, Renn, and Schoepflin 2003), chemistry and biology (e.g. Luisi and Thomas 1990), geology (e.g. Rudwick 1976) or mathematics (e.g. Bråting and Pejlar 2008; Edwards 2004). Apart from specialized studies, aspects of visualization are also mentioned by investigations into intellectual history or the history of scientific disciplines (e.g. Grant 1996 on medieval cosmology). With the advent of computer-generated forms of visualization in the second half of the 20th century the literature on scientific visualization, its practices and roles in different disciplines explodes, for example in the field of medical imaging. And forms of visualization enter fields of study where they were not previously used, for example literary history (Moretti 2007).

Thirdly, there is also an obvious connection between visualization, multimodality and genre. Theological and juridical commentaries from the Middle Ages and Early Modern centuries usually rely on a specific spatial arrangement, where the core text is in the middle of a page and the commentary runs around it, colour can be used in order to mark the relation between passages of the core text and its commentary section. As a further resource typography is used: The commentary is usually written or printed in a smaller typeface than the core text. In such texts, the functional configuration of a commentary guides the use of different resources in a multimodal arrangement. Other examples include herbals (e.g. Gloning 2015), animal books like those of Conrad Gesner or Ulysse Aldrovandi (both 16th century), the use of different types of illustration in encyclopedic works (e.g. Kockel 2004), the use of spatial arrangements of historical or astronomical information in tables (e.g. Brendecke 2004; Poulle 1994), the wide range of *theatrum machinarum*-literature (Hilz 2008) or the long history of machine descriptions (Lefèvre 2004).

Fourthly, different types of visualization are intimately connected to types of objects of scientific investigation. These include objects like plants (e.g. Nissen 1966), animals or the human body, structural or numerical information, and historical, chemical or physical processes, to name but a few. It is evident, that different kinds of objects require specific forms of visualization. The existence of some kinds of “objects” was only known through or was even constituted through forms and technologies of visualization, e.g. bacteria, remote stars, or the products of radiology, sonography, etc. (e.g. Lynch 1985; Kemp 2006). In other cases there were traditions of visualizing objects even if there was no empirical or technical basis for a representation (e.g. the rhinoceros or black holes). The representation technologies (e.g. drawing, painting,

woodcut printing, coloured woodcuts, microscopic photography, X-ray radiography, data visualization software) play a crucial role for the communicative and epistemic functions of forms of visualization.

Fifthly, an impressive body of research is devoted to the techniques of visualization and the role of visual or diagrammatical thinking in respect of specific scientists, e. g. Regiomontanus (Shank 2012), Georg von Peurbach (Pantin 2012), Vesal and Copernicus (Kemp 1996), Maestlin (Graßhoff 2012), Galilei (Bredekamp 2015), Descartes (Zittel 2004), Darwin (Bredekamp 2005; Voss 2010), Leonhart Fuchs (Kusukawa 1997), Martin Rudwick (Kusukawa 2016), John Herschel (Hankins 2006) to name but a few.

Lastly, one can ask for various types of visualization or diagrammatic representation and their epistemic potential for different functions (e. g. Hankins 1990; Tufte 1983, 1990, 2000; Pauwels 2006 and Chapter 11, this volume).

It is obvious that all these aspects and perspectives show various interdependencies, e. g. the use of X-ray technology and scientific “objects” that could not be represented before without destruction, or the persons that in most cases belong to a specific field (e. g. Vesal and anatomy), the different fields that typically require the use of specific text types, forms of visualization and multimodal arrangement and so forth. In most research it becomes evident that visualization is not something ornamental but a crucial element not only for the representation of knowledge, but also for its production. In her study of Georg von Peurbach’s *Theoricae planetarum*, Isabelle Pantin (2012: 3–4) writes: “Although a core of diagrams remained from the beginning to the end, new diagrams were regularly introduced by editors and commentators, thus revealing how much the *Theoricae* served as an active laboratory of astronomical thought.”

## 5 The languages of science in an historical perspective

The term “language of science” is ambiguous. It can refer to the specific use of language in science with its text types, its specific vocabulary, and other properties (Kretzenbacher and Weinrich 1995) or to individual languages like Latin. In this section, we ask, which languages like Latin, English, Greek, Arabic, German, French, etc. were used for scientific purposes in history and in which configurations.

In the European tradition, the vernaculars have a common tradition of “emancipation” from the use of Latin as an overarching lingua franca. This dynamic, however, followed specific patterns in different disciplines. As for German-speaking regions, Latin was the lingua franca in the sciences and humanities from the Middle Ages onwards, Latin dissertations were a common practice in certain disciplines up to the 19th century, for example in medicine and jurisprudence. However, there is also a



parallel vernacular tradition of learning in German, which gradually gained ground from the Middle Ages onwards over the centuries and in different disciplines (see Prinz and Schiewe 2018). This shift was at times tied to a more internal vs. external/popular orientation of scientists (for the history of external science communication see Chapter 27, this volume). In addition, German was the *lingua franca* for several disciplines during the 19th and early 20th centuries. Compared to its former position, the “englishization” of scientific communication was seen as a loss for German (Ammon 2010, 2015: part G).

As for other vernaculars, see, for example, Taavitsainen and Pahta (2004) for late medieval English and numerous editions of medieval and Early Modern vernacular scientific texts in English, French, Italian, Spanish, Portuguese, etc. Gordin (2012, 2015) are examples for research on language choice in a specific discipline (chemistry).

During the 20th century, English more or less became the dominant language of scientific communication in different countries (Ammon 2001). But there are differences in respect of disciplines like the philologies of specific languages. Scholars of French or German continue to publish in French or German, unless they have strategic reasons to do otherwise. The use of English as a *lingua franca* is discussed controversially in at least two dimensions. One aspect is the positive effect of global understanding in the scientific communities around the globe. The conflicting aspects include questions of identity, the values of multiliteracy and plurilinguistic organization, which are intimately connected to national or even regional standpoints and, from an epistemological perspective, to what has been said about the Humboldtian connection between languages and views of the world.

In order to illustrate this conflict, please allow for an anecdote in memory of Marcelo Dascal, the co-editor of this handbook. I was once on the same shuttle bus bringing us to Rauischholzhausen Castle near Gießen, where a conference on historical pragmatics was organized. The official conference languages were German and English. I first decided to give my talk in German. But when I saw that most of the contributors gave their talks in English, I mumbled in the shuttle bus: “Uhhh, dann muss ich meinen Vortrag wohl auch auf Englisch halten” (‘Uh, I guess I will have to give my talk in English as well’). Marcelo (German was one of the many languages he spoke, read and understood, an impressively multilingual person) obviously heard this and said in his deep voice: “Well, I might talk in Hebrew”. Later on, we continued joking on this subject and made plans about a conference in a small language, where most of the international participants would be “handicapped” in a similar way.

This anecdote illustrates three points: First, it shows a wonderful specimen of scientific multilingualism (Marcelo Dascal); second, it demonstrates that scientific multilingualism and the praise of an international *lingua franca* for scientific communication are not inconsistent; third, it shows that most scientists, even the multilingual ones, do not speak or read all important languages in which relevant publications are written. In respect of the third point, improvements in automatic translation like DeepL certainly will allow to at least get a rough idea of what foreign language

publications are about. But for the moment, reading Kant (German), Hildegard von Bingen (Latin with German interspersed), John Dee (English) or Montesquieu (French) will require mastery of the languages in question. Getting a rough idea of what a publication is or may be all about with a translation software and working on a text with a personal command of the language in question are two different things.

The relation between an overarching scientific language and the vernaculars has been a point of discussion and reflection for a long time. In the 16th century, Leonhart Fuchs commented on the difference and the division of labour between the Latin (1542) and the German version (1543) of his herbal. Leibniz, writing his texts mostly in Latin or in French, reflected on the role and the use of German as a scientific language. In our days, representatives or task forces of official bodies (e. g. the German “Wissenschaftsrat”) publish memoranda, for example in favour of scientific multilingualism (Mittelstraß, Trabant, and Fröhlicher 2016).

Scientific multilingualism had the consequence that translations were a vital part of the intellectual ecology in the history of scientific disciplines. One of the most important developments was the transmission of ancient Greek knowledge to the European Middle Ages via translations from Greek to Arabic and subsequently from Arabic to Latin. Constantinus Africanus and the translators of Toledo contributed to this process, specifically in medicine. In addition, there have been translations into the vernaculars, e. g. the 13th-century translations of scientific texts into Castilian at the court of Alfonso I “el sabio”. For an example of the interrelation of translation, transmission and transformation see Wisnovsky (2011) and Wallis and Wisnovsky (2016).

Apart from natural languages the idea of a constructed, ideal language for scientific purposes has been proposed, especially from the 17th to the 19th centuries. John Wilkins (1668), Gottfried Wilhelm Leibniz (*De arte combinatoria*, 1666; *Characteristica universalis*, 1677) and Gottlob Frege (*Begriffsschrift*, 1879) belong to different traditions of such an idea. They share the assumption that natural languages have drawbacks (e. g. vagueness, ambiguity) that precise scientific languages should not have. In addition, Leibniz and others planned to construct a *characteristica universalis* which should be a direct counterpart to thinking and thus stimulate the finding of new knowledge by operating with this language system, to allow for mutual understanding and to prevent unnecessary and fruitless controversies (Eco 1995; Maat and Cram 2000; see also Chapter 16, this volume).

## 6 Terminology and vocabulary use in a historical perspective

Words are the building blocks for human communication with spoken and written text. Therefore, they are a crucial part of the complex instrument with which scientific communication is performed by using texts, speech and multimodal arrangements. In

addition, some of the words used in scholarly communication are particularly closely related to aspects of knowledge and to theoretical ideas. To be more precise, it is in most cases not a word but a specific usage of a word which is connected to scientific ideas and notions. The German word “Widerstand” for example has several usages, one of them belongs to the realm of electrophysics, a different one to psychoanalysis, still another one to hydrodynamics. Hence, one must be careful not to ascribe to words what has indeed to be ascribed to specific usages of words.

One of the basic tasks in the historical analysis of scientific word use is to semantically describe the usages of words, to characterize their specific role for the discipline in question and to document the tradition of use by quotations from texts. This task has traditionally been worked on in specialized dictionaries that cover a disciplinary field and a specific time span. A modern example of such a historical dictionary is the *Diccionario español de textos médicos antiguos* (Herrera 1996) which describes the medieval medical vocabulary based on a large corpus of medical texts. Dictionaries of scientific vocabularies were also made in historical times, especially in medicine, the 18th and 19th centuries saw the production of copious medical dictionaries. Another example is Johnson’s alchemical *Lexicon Chymicum* (1652–53). Martin Ruland’s *Lexicon Alchemiae sive Dictionarium Alchemisticum* (1612) aimed at consolidating the alchemical and paracelsistic thought system via its language use. Another form of representation are monographic investigations. An example of this type is Jörg Barke’s *Die Sprache der Chymie* (1991) in which he combines the analysis of language use with the edition of four (al-)chemical texts and a glossary to specific word usages; Roelcke (1989) combines a dictionary and an investigation into a vocabulary segment of Kant.

Scientific usages are normally not isolated, they are part of a whole system of specific word usages, that are interrelated and mutually dependent in a complex way. For example, the expressions used in the antique and medieval theory of humours form an ordered system in which the components depend on each other. That means that one cannot describe an individual usage (e. g. of humoral “cold”, “hot”, “moist”, “dry”) without reference to other components, e. g. “temper” (cf. Gloning 2011a). Therefore, apart from describing the different usages of a scientific field, one has to describe the structure and the architecture of the whole vocabulary. Since dictionaries are usually ordered alphabetically, this task has to be fulfilled in a monographic component that is cross-referenced or hyperlinked with the dictionary component. A good example for such a combination of single word documentation and monographic investigation into vocabulary structure are Sieber (1996) and Knappe and Sieber (1998), who used the internal organization of the system of rhetoric to organize the vocabulary and to connect each vocabulary item with its “place(s) in the rhetorical system”.

The evolution of scientific vocabularies can be embedded in the establishment, the stabilization and professionalization of scientific disciplines. In such a case, vocabulary development, like the use of a repertoire of text types, contributes to the constitution of the discipline. An example of this type of evolution comes from the history of psychiatry. Britt-Marie Schuster (2010) has shown how the institutional

establishment and professionalization of psychiatry from the early 19th century onwards was closely intertwined with the development of a systematic repertoire of (new) text types and with the systematic work on a consistent vocabulary. Work on the further development of terminology is a constant task in all scientific disciplines. New ideas, new concepts, new theories, new kinds of objects, new methods usually come with innovation in the lexical field. Terminological innovation shows the evolutionary dynamics of invisible-hand processes, where individual innovation goes through stages of dissemination and discussion and finally becomes established or not. In these processes, specific word usages are often introduced together with commentaries, they are discussed, criticized and defended, and so forth. Not all innovative word usages become established. Meta-reflection on word usage can be found in reviews, in scientific texts themselves, in controversies, and in research discussions, among others.

Once scientific word usages are established, they can be used without further commentary and the readers will understand what is meant. However, there are two types of situations in which word usages have to be explicitly introduced. This is the case with innovation, as already mentioned above. And this is necessary in textbooks, for which one of the tasks consists of systematically introducing and explaining specific terminology items, their meaning and their role in the field in question. Hereby one can look at the hierarchical or network structure of terminologies, but one can also look at the dynamics of introducing items in a textual sequence. Roelcke (2013, 2014) introduces this sequential aspect of textual terminology work and includes historical examples. Because of the often holistic nature of terminologies, this task can be difficult. Introducing one term may require or presuppose the explanation of others. But one has to start somewhere. In a short article, Niklas Luhmann (1981) has commented on the problem that all or most basic concepts of systems theory are interdependent and that putting their network structure into a textual sequence is difficult.

From a historical perspective one can ask the following questions on terminology and on terminology management in scientific texts: (i) How were historical vocabularies and terminologies organized in different fields? How did they evolve over time? What did they contribute to the epistemic functions in the respective fields? An example would be Pörksen's (1986) investigation on the structure and development of psychoanalysis terminology. (ii) Which textual techniques and practices of terminology management were used in a historical period, in specific disciplines, in different text types and how did they develop over time? (iii) How can systematic terminologies evolve from individual word usages? (iv) How can specific word usages and terminologies become obsolete in the history of science?

## 7 Further perspectives

In this final section I want to briefly mention some further perspectives and questions that could and should be a part of a communication history of science.

### (i) Individual author profiles in scientific communication

Scientific communication is, on the one hand, regulated by patterns, genres and traditions. On the other hand, communication is individual. The question arises how patterns and traditions interact with “the individual” in different scientific biographies. Kepler and Freud (Pörksen 1986) are examples that definitively show individual traces in their respective works, for example in the use of literary techniques (on Freud see Pörksen 1995) or the use of humour (in Kepler 1610).

### (ii) Collaboration

Science is a collaborative endeavour. Yet the basic building blocks come from individual researchers or from small teams that work together. An important part of communication is collaboration. In a historical perspective one can ask questions like: (a) In respect of a given historical time and discipline: Which forms and media of collaboration were available? How were they used? An example of research on this kind of question is the vast body of investigations into learned letter writing during the 16th, 17th and 18th centuries (e. g. Dauser et al. 2008; Stuiber 2012; historical networks of letter writing are also studied with Digital Humanities methods). (b) What do we know about historical cases of collaboration and collaborative infrastructures? Kepler, for example, in his *Tertius interveniens* (1610) describes the intellectual “climate” at the court in Prague, where he is constantly under pressure in discussions with younger minds, which stimulates the development of his ideas. (c) What do we know about historical forms of co-authoring? From the study of historical controversies in religion, we know that Jesuit writers sometimes had a whole production and support team behind them. (d) A specific case of collaboration is interdisciplinarity. What do we know about historical cases of interdisciplinary collaboration and about historical thoughts on interdisciplinarity? For a case study on Dobzhansky, Schrödinger and Wilsen, see Ceccarelli (2001). (e) Finally: Which forms of organization of scientific collaboration evolved over time? Funded research projects, the personal commenting of the manuscript of a colleague, the Jesuit text production team are quite different instances.

### (iii) Meta-reflections about aspects of scientific communication in history

The history of the sciences, humanities, arts, etc. includes a vast array of reflections about its own communicative foundations. These forms include specialized disciplines like logic or dialectics, philosophical programmes like that of the Vienna Circle and forms of reflection about language use in scientific texts themselves, be that kinds of terminology reflections mentioned above, or be that reflections about new media

and their potentials and drawbacks, among other things. This segment of science communication deserves its own historical investigation.

(iv) Communication aspects of institutions and infrastructures

Historical science communication has been in part bound to specific institutions like monasteries, courts, universities, practitioners' groups in economic networks (e.g. in metallurgy), learned societies, up to the mailing lists and new media networks of our day. If one changes the perspective, the communicative profile can be used to contribute to the characterization of these institutions (e.g. Evans 1984 on the Prague court of Rudolph II). The core question, however, is to what extent and how historical institutions enabled or restricted individual or group research and its communicative components.

(v) Communication and the emergence of communities

The emergence of specific communities is intimately connected to types and media formats of communication. One prominent example is “the emergence of the community of scientific chemists in Germany in the course of the phlogiston controversy” in the second half of the 18th century (Hufbauer 1982: 1; cf. Chapter 15, this volume). A further example is the Royal Society of London as a centre of communicative exchange (Atkinson 1999; cf. Chapter 14, this volume).

(vi) The reception of research

While the production of scientific knowledge is an established topic in historical research, the questions concerning reception, (modes of) reading, choice of reading, individual time organization in reading, and so forth (cf. Engelsing 1976) have gained less interest, which might be due to the lack of sources for this kind of information in historical times.

(vii) Aspects of communicative variation in a evolutionary perspective

The wide range of topics and perspectives in the history of scientific communication comes with a built-in question for aspects of variation, for example along cultures, disciplines, time frames, styles of thinking (“Denkstile”; Fleck [1935] 1980), social criteria (e.g. Shapin 1994; Shapin and Schaffer 1985) and others.

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Michael Prinz

## 26 Academic teaching: the lecture and the disputation in the history of erudition and science

**Abstract:** Throughout the late medieval and the early modern period a number of academic genres have been closely associated with two influential and long-lasting teaching formats – the disputation and the privately or publicly taught lecture. This chapter deals with the question how such academic genres (e. g. lecture notes and dissertations) emerged and developed at institutions of higher learning. The text sheds light on the media of lecture announcement and the act of teaching in a historical lecture theatre. It also discusses the choices of language for academic teaching in the face of the language shift from Latin to the vernacular languages during the course of the 17th and 18th centuries.

**Keywords:** academic genres – academic teaching – disputation/dissertation – language choice – language shift – lecture – vernacularization

### 1 Academic teaching and its genres

The classification of genres (or *registers*, *text types* – sometimes with, sometimes without theoretical distinction) is a common way of assigning texts to a culturally recognizable category. In the present article the term *genre* is being used in a broad sense that allows for variation in medium (spoken, written, electronic) or level of generality (on sub- or super- or basic-level genres in a prototype approach, see Lee 2001: 48–52). The main emphasis in this paper is on German, but other languages are also addressed.

The analysis of *genres* has long been a pivotal question in investigating academic languages (Biber 2006: 10). However, text typological studies into academic genres (e. g. Gläser 1990; Göpferich 1995) rarely have a historical orientation or emphasis (cf. Hoffmann, Kalverkämper, and Wiegand 1998–1999, who at least include a few relevant contributions). Diachronic studies on certain written or spoken genres within the academic domain include ones on scholarly correspondence (Döring 2011; Cafilisch-Schnetzer 2018), medical reports (Taavitsainen 2011; Lindner 2018), the *album amicorum*, an early type of autograph book, that arose in academic circles during the 16th century (Linke 2010; Schnabel 2011), and many more. The emergence of scientific journals since the 1660s – *Journal des Sçavans* (Paris, 1665), *Philosophical Transactions of the Royal Society* (London, 1665), *Giornale de' Letterati* (Rome, 1668), *Acta eruditorum* (Leipzig, 1682) – facilitated several new genres (Habel 2011; Gotti 2011b),

the experimental essay, for instance, which was particularly well suited to the epistemic approach of natural philosophers during the 17th century (Moessner 2006; Gotti 2011a: ch. VI).

A number of academic genres (e.g. dissertation, academic program, lecture catalogue, lecture notes) are closely associated with two teaching formats (or “communicative genres” as described by Luckmann 1986) that proved to be the longest-lasting and most influential since medieval times: the lecture and the disputation. Both formats were prevalent not only in universities, but also in other institutions of higher education (knight academy, gymnasium academicum/illustre, Jesuit college, cf. Frijhoff 2016). Since lectures and disputations were “modeled on the sermon and the joust”, the teacher embodied “different aspects of academic charisma: the prophet and the warrior” (Clark 2006: 68, 76). Each format was a successful technique for showcasing academic knowledge – as an oral performance of virtuosity (Burke 2013) or an application for citizenship in what could be called an academic “theatre state” (Füssel 2006: 72, 155–156; in allusion to Geertz 1980). However, the culture of disputation – originally an oral culture first and foremost – continuously declined in importance during the 18th/19th centuries when in an increasingly research-oriented academic environment the seminar became the preferred format of instruction, the “wheel within the wheel, the real center of the life-giving, the stimulation, the creative forces of the modern university” (Seligman 1892: 63), that spawned new genres like the student paper (Clark 2006: 176–179; Pohl 2009). Notwithstanding the rise of the research seminar, the lecture, at least, continues to connect today’s academia with its medieval beginnings as an enduring element of scholarly communication. Despite the very recent integration of presentational tools into the lecture praxis, the transformation of media aids and the addition of e-learning technologies like LMS or MOOC (Lobin 2009; Krause 2019), the essential characteristics of the lecture have proven sufficiently stable to make it seem, still today, to be the “paradigmatic form of university teaching” (Stichweh 2013: 205).

A reconstruction of how academic teaching was conducted in the past is able to draw on texts like dissertations, lecture notes, or contemporary student reports but also on picture sources (on academic iconography, see Smolka 2007; Krug-Richter 2011). There are several databases of early modern dissertations available (dlib-diss.mpier.mpg.de, forschungen-engi.ch/projekte/projekte.htm; accessed 15 April 2019); an annotated corpus of historical German lecture notes (HiVoKo) has been put together at the University of Zurich ([www.wissenschaftssprache.org/pages/links/hivoko](http://www.wissenschaftssprache.org/pages/links/hivoko)). Additionally, an analysis of interactional “sediments” in architecture, i.e. traces of communicative needs in the past that have facilitated a certain architectural form, can also help to illustrate the multimodal constitution of the lecture theatre as a spatial resource and contribute thus to an “archaeology of interaction” (Hausendorf 2012: 65; cf. for example Clark 2006: 69–73).

## 2 The lecture

A lecture is essentially “an institutionalized extended holding of the floor in which one speaker imparts his views on a subject” (Goffman 1981: 165), often in a way that is aimed at providing a systematic overview of a certain topic. This procedure, in the form of the academic *lectio* (also *praelectio* in the early modern period), was institutionalized as a fixed teaching format upon the founding of universities from the High Middle Ages onwards (cf. in general Paulsen and Lehmann 1919: 37–39, 267–270; Hamsch 2009). In the 16th century the so-called public lectures (*lectiones publicae*) experienced competition from subsidiary *collegia privata*, which could also be offered by teachers who were not an ordinary professor. The *collegia* increasingly developed into a core component of academic teaching (Horn 1897: VIII u. 17–22; Ahsmann 2000: 240–244; Van Miert 2009: ch. 3). Unlike the free public lectures which professors were duty bound to give and which could draw a diverse audience including scholars, city fathers, merchants or even travelers (Van Miert 2009: 142–148), early modern private teaching was subject to fees and therefore socially selective. “Such private classes had to interest the student as a consumer, whose demands they in part created” (Clark 2006: 62). Private teaching established itself as an important source of income for all academic teachers in the context of this “economization of teaching” (Rasche 2008: 29). At the same time, the thematically and didactically flexible *collegia privata* became a gateway for innovation, and not least for academic teaching in the vernacular (see section 4). These classes were a beneficial addition to the often ossified traditional curriculum and increasingly came to outstrip the public lectures in the 18th century in terms of their popularity.

Throughout their existence, lectures have been associated with certain written academic genres like academic programs or lecture notes. However, most practices and media of lecturing, for instance the different types of lecture announcement, have only quite recently become a focus of research (cf. most recently Le Cam 2016; Prinz 2018): the lecture catalogue (*catalogus praelectionum*), for example, was the official list of courses for a particular semester or year of study and was regularly made public as a separate sheet of paper hung on the university noticeboard. The lecture catalogue served to impress the required curriculum upon students and professors (Rasche 2009), but was above all used by universities as an instrument of marketing and representation. The universities found themselves increasingly in a situation of competition which made it seem worthwhile to present itself to a more widespread public as an attractive study location by disseminating its own lecture catalogues. The lecturers themselves advertised their future teaching events by means of academic programs (*programmata*): “[T]heir contents were enticing and hyperbolic, given the professor’s aim of gaining the benevolence of the students by condescending to their reasoning abilities” (Pozzo 2012: IX). A specific invitation to attend a university lecture was often issued by means of simple handwritten notices (*schedae*) pinned to the university noticeboard which provided more details than the printed information sheet



or else updated it; it is only in certain special circumstances that these notices have survived to the present day (Rasche 2008: 29–37).

Over a long period of time lectures were used essentially to expound an exegesis of a previously determined text. At medieval universities, students attended the lectures equipped with a manuscript copy of the pertinent text from the canonical curriculum. The manuscripts might have been copied out by the students themselves or acquired as official copies through the medieval *pecia* system of renting manuscripts piece by piece (Weichselbaumer 2010). The teaching texts were often designed in a typical “lecture layout” for the purpose of double glossing (interlinear for language-related explanations, marginal for explanations of content). After the introduction of book printing, this practice was initially continued in students’ printed lecture texts as well (Leonhardt 2004; Leonhardt and Schindler 2007; Nelles 2007: 78). In the course of the 16th century, these were replaced with school editions containing a commentary, often interleaved with empty sheets (Leu 2008: 242). From the 17th century onward the canon of authoritative texts established in the statutes was increasingly replaced by modern compendia which provided a readily accessible introduction to a particular subject area (Huttner 2007: 163–164). Lecture praxis, however, remained text-bound, in some cases even into the 19th century – as a “textbook science” (*Wissenschaft des Lehrbuchs*, Stichweh 1984: 12).

Lecturing styles varied considerably: reports from audiences indicate that some professors delivered their lectures without any written prompts, while others read them word for word from a prepared text. Others again worked with pieces of paper containing key words or with notebooks containing brief formulations of the topic at hand, using these as a basis for the lecture which would then be delivered more or less freely (e. g. Fuchs et al. 2000: 319; Joost 2001: 44–45). Manuals on how to take notes in lectures likewise distinguish between a freely delivered lecture, a read lecture, and combined forms (Fischer 1826). Texts of lectures are, accordingly, handed down in different forms which only give a partial impression of what went on in terms of communication in the lecture theatre (Blair 2008; Clewis 2015: 14–15): the freely improvised sections are missing from the professors’ manuscripts. Such sections may have found their way into student lecture notes, though these contain a large number of errors on account of the cognitive strain experienced by the note taker. Lectures were sometimes published as well, either by the professors themselves, but on occasion also against their will as pirated editions based on lecture notes.

The most common form in which lectures have been transmitted through history, however, are student lecture notes, the composition of which was carried out in a multi-stage process (Nelles 2007; Eddy 2016). From the 18th century, for example, such manuscripts are extant either as a) original rough notes taken down by students in the lecture hall (a very rare form), b) a clean and expanded copy prepared from a set of original notes, or c) a copy made on the basis of one or several sets of lecture notes in circulation. Lecture notes (in particular those from lectures given by popular professors) were often copied and sold by professional transcribers. The Scottish medical

doctor Alexander Monro, for example, estimated in the 1790s that there were more than 400 copies of notes from his lectures in circulation (Eddy 2016: 114).

The question regarding the authenticity and value of such handwritten texts is not easy to answer for two reasons. First, such texts generally contain no more than 20–25 % of the likely number of words of a lecture (Brandt and Stark 1997: LXXXVII). One exception to this are the so-called “lectiones paraeneticæ” (exhortatory lectures) delivered by the Pietist theologian August Hermann Francke, which were written down by a writers’ collective (called *Schreibchor*, writing choir) and thus constitute an almost verbatim documentation of academic instruction in an early 18th-century lecture theatre (Boor 1968; Blair 2008: 59–62).

Second, lecture notes cannot simply be taken as a verbatim and authentic record of the professor’s spoken words, so that the following applies, for example, to a set of notes from a lecture by Kant: “A given set of lecture notes is indeed likely to be, in varying degrees, some mixture of Kant, the textbook author, and the original auditor’s interpretations of Kant (and, when applicable, later transcribers, copyists, or even editors)” (Clewis 2015: 13). Notwithstanding this, many academic texts of historical significance have been preserved and become well-known only in the form of lecture notes edited after their author’s death (e. g. Kant’s “Anthropology”, Hegel’s “Aesthetics”, De Saussure’s “Cours de Linguistique générale”). In addition, the broad circulation of such texts is a key factor for the dissemination of scientific knowledge. For these reasons a lively field of research on the *history of reading and note-taking* has developed over the last 15 years, examining the material culture of lecturing (e. g. Blair 2004, 2010; Daston 2004; Eddy 2016). From this point of view, student lecture notes are an important source for reconstructing the historical practices of reading and writing in academic note-taking communities.

Despite its longevity the lecture has repeatedly been at the sharp end of criticism. One frequently recurring point of critique between the 16th and the 19th century was a style of lecturing known as dictation *in calamum*, teaching with word-for-word note taking in mind (on this, see Huttner 2007: 164–167; Döring 2009: 681–682). Certain forms of note taking were also frequently regarded with skepticism by the lecturers or were even felt to be an “epidemic” which had wrought untold harm among the students (Schulz 1793: 236). The Early Enlightenment jurist and philosopher Christian Thomasius, for example, warned that students often produced faulty manuscripts due to the overload of listening to the lecturer and simultaneously taking notes, which might bear the risk of discrediting the teacher for things he never said (Thomasius 1691: 6–11). Since the 19th century, especially in light of the success of seminar learning and teaching, one also increasingly encounters general criticism of lecturing as a form of teaching, which is perceived as being repetitive and, on account of its monologic character, a “factory that produces subservient subjects” (Apel 1999: 32–33; Hamsch 2009: ch. V).

Possible reasons for the still ongoing “success story” of the lecture can be seen in the fact that it is a performative and increasingly multimodal teaching format, and

that it fulfils a core function of academic teaching: giving a structured and systematic overview of a scientific topic or field.

### 3 Disputation and dissertation

An oral event established by the medieval university that was to play a central role in scientific communication through subsequent centuries was the scholastic *quaestio disputata*. Based on theoretical foundations laid during Antiquity and perfected during the High Middle Ages with the advent of the *logica nova* (Marti 1994: ch. B-II), its purpose was to conduct argumentation around contested issues. Having originally emerged as an offshoot from high medieval lecturing practice, scholastic disputation developed during the 13th century to become an autonomous teaching format alongside the *lectio*, albeit one that took many forms. It came to be an integral part of university courses across all faculties (Bazán 1985; Weijers 2010). Despite attracting criticism from humanists, the disputation was able to maintain its dominant position over a long period of time – as “an educational method, a research method and an instrument for testing knowledge and skills” (Weijers 2005: 24).

From the 16th century onwards, printed dissertations were increasingly used as invitations to and as a foundation for oral disputations. This involved the printed theses (arguments) being defended by a respondent (*respondens*) against the arguments of opponents (*opponentes*) in a complex process of logical and rhetorical communication overseen by a presider (*praeses*) (Marti 1994). This institutionalized dissent, which proceeded either in strict accordance with the syllogistic method or was allowed to follow a freer, erotematic model, was to a large extent a staged affair embedded within an academic culture of politeness, and was designed to prevent any escalation of conflict (Mulrow 2007: ch. 7; Marti 2010: 65–66). The academic prerogative of interpretation lay with the presider, who would support the respondent where necessary and would thus contribute towards the theses ultimately being substantiated in the disputation (Gindhart and Kundert 2010: 17).

Any number of circumstances gave occasion for such a disputation. These included the need for practice (*disputatio exercitii causa*) – to improve one’s ability to express oneself and conduct arguments in Latin and to practise the maxims of a respectful and truthful discussion of disagreements (for the early modern ideal of controversy, see Gloning 2018: 113–114). This was of practical use to theologians and jurists especially (Marti 1994). Since academic disputing posed a challenge to the students who participated in it, *collegia disputatoria* were offered in the context of private classes (Ahsmann 2000: ch. V; Schlegelmilch 2016). In addition to this, the 17th and 18th centuries saw the publication of disputation handbooks which addressed theoretical and practical issues and served as manuals for how to conduct a disputation (Felipe 2010). Disputations were also held to provide proof of a person’s academic

achievements and to mark their graduation (*pro gradu*); they were also held on the occasion of leaving a university or similar institution (*valedictionis causa*) and as part of the procedure of applying for a university post (*pro loco/cathedra*). Depending on the type of disputation (public, semi-public, private), the audience consisted of fellow students, family members, preachers, professionals in the respective field, and others (Van Miert 2009: 157–158).

The dissertations were generally written by the presider or the respondent, frequently by both together (see Schubart-Fikentscher 1970 and Rasche 2007: 189–201 on the difficult issue of authorship). Alongside the actual dissertation text, they usually also contain paratexts (e. g. a title page, dedication, list of contents, corollaries, congratulatory remarks), which shed light on the circumstances of the disputation and those involved in it as well as reflecting the extent to which the latter were a part of the *respublica litteraria* and the stratified society. The texts were simultaneously proof of a successful academic socialization and evidence of inclusion in society's clientele systems (Rasche 2007: 162–163). Beyond the *theses*, recorded in written form, the *actus* of disputation itself can be reconstructed, at least in its basic features, as a multimodal cultural praxis (oral, visual, performative) from contemporary personal accounts, pictures and scholarly satires (Füssel 2016). The actual communicative content of an early modern disputation, however, is lost to us because generally no notes were taken during the course of the debate. A few exceptions to this are occasional students' notes that have survived (Schlegelmilch 2016) and interleaved copies of dissertations in which either the presider or the opponent has noted down his position or opinion (Mulsow 2007: 195–200).

The disputation was occasionally criticized for being a ritualized and ossified obligatory exercise (Ahlwardt 1733: 18), a hair-splitting “public farce” (Clark 2006: 88) – a critique which ultimately led to a fundamental shift in practice in the 18th century: the decline of the traditional system of disputation (Rasche 2007: 178–180) and the growing literalization of what had originally been, first and foremost, an oral teaching format. What was now required of aspiring scholars was a piece of writing that was to be researched and produced independently in accordance with scientific principles (Chang 2004; Marti 2010, 2018). As part of the same development, the presider was no longer the (co-)author of the dissertation, and the originally diverse formats for a dissertation were reduced to the self-authored inaugural dissertation and habilitation as the means of acquiring the academic title of doctor or the authority to teach at a university. Following on from this, in the 19th century Latin was dropped as the exclusive language of the dissertation and disputation (see section 4).

During the early modern period tens of thousands of Latin dissertations were printed in German-speaking countries alone. These constitute a significant source for the history of knowledge relating to this era on account of the broad range of topics covered (on the value of this source, cf. Gindhart and Kundert 2010; Marti 2011: 301–307). While some contemporary figures from the 18th century were of the opinion

that these dissertations were barely fit to “light tobacco” (as stated by Apin 1719: 26, albeit with an attitude of regret), this genre – long neglected by researchers – is now appreciated as an important source (on the history of research, see Komorowski 1995; Marti, Sdzuj, and Seidel 2017: 15–27): it sheds light on the history of higher education, provides evidence of early modern argumentation praxis, is an expression of a scholarly culture of representation, and exhibits a “polyvalent apparatus of production of scholarly knowledge” (Gindhart, Marti, and Seidel 2016).

## 4 Choices of language for academic teaching

Although the “vernacularization of science” was a long and gradual process that started in the medieval period (Pahta and Taavitsainen 2010: 550–558), the European university was a predominantly Latin one for a long time. Students were even expected to use the Latin language when engaging in spontaneous communication with one another – so-called *vulgarizare*, *teutonizare* was punished with a financial penalty (Henkel 1988: 94–102). For a long time, the dominant status of Latin at universities was not affected directly even by key academic discourses: the late medieval controversy between the realist *via antiqua* and the nominalist *via moderna*, for example, may have led to a disruption of some faculties but it had no impact on their language of instruction. Intensive lexicographical efforts on the part of German humanists likewise did not bring about any improvement in the status of German as an academic language, and even the Reformation had no direct influence on the language used at universities (Schiewe 1996: 74, 162–163). It was only relatively late – generally during the course of the 17th and 18th centuries – that a noticeable shift from Latin to the vernacular languages occurred at Europe’s universities (Schiewe 1996: 124–131; Burke 2004: ch. 3; Gunnarsson 2011: 6–7). This is often seen as a corollary of early modern nation-building (Ammon 2015: 519). Schiewe (1996), however, sought to show that the academic language shift was embedded in a process of comprehensive transformation in the history of science and scholarship: the enlightened absolutist state had, he argued, made the independent universities into state institutions. Studying at a territorial university had become a precondition for gaining access to the civil service, while university professors had themselves become civil servants. The regional state ruler had introduced the requirement that the universities must be geared towards the needs of the state and that they had a duty to ensure their activities were useful to society. This, Schiewe argued, constituted a shift away from an older “thought style” (*Denkstil*, Ludwik Fleck) oriented principally toward the handing down of a canon of knowledge supported by acknowledged authorities. Over recent years, however, there has been increasing skepticism about the representation of the early modern university as a traditional and anti-progress teaching institution (cf. for example Döring 2009: 554–559; Marti 2018: 285–286). It is also important to consider that the language

shift occasionally faced opposition from the sovereign (Huttner 2007: 170–171; Alvermann 2018: 38–39).

Although the use of early modern vernacular languages varied considerably from university to university and also from one individual to another, certain trends can nonetheless be identified regarding language choice (Schiewe 1996: 277–280):

- Protestant universities generally pre-empted Catholic ones in using the vernacular.
- The arts and philosophy faculties tended to be less reluctant than other faculties to use it, for example in experimental lectures on physics or for certain subjects such as history, rhetoric and poetry (Weimar 2003: 32; Huttner 2007: 170–174; Alvermann 2018: 17).
- Vernacular languages were more often used in both non-institutional contexts and ones involving more practical matters.
- The choice of language depended heavily on the target audience: vernacular texts were often intended for the benefit of a wider public and not just for learned members of the *respublica litteraria*.

There is also considerable variation when it comes to the choice of Latin as opposed to the vernacular for different teaching formats and genres. At German-speaking universities, for example, the transition to using German in lectures (especially in *collegia privata*) occurred much earlier than for disputations. There is isolated evidence dating from as early as the early 16th century to indicate that lectures were occasionally held in German (Weimar 2003: 11–38), with evidence of the practice becoming more plentiful from around 1700. The written genres associated with lectures and disputations were also increasingly caught up in the language shift: more and more teaching compendia and academic programs were published in German. And from the 1720s onwards the first universities began to publish, in addition to the existing Latin lecture catalogue, a version in German for a non-university public (Prinz 2018: 295). At the close of the 18th century German had largely become established as the language in which lectures were delivered, even though Latin made a shortlived comeback in isolated instances in the 19th century, usually due to pressure exerted from outside the university (Alvermann 2018: 38–42).

It is crucial to keep in mind, though, that many early modern scholars taught in more than one language and even gave mixed-language lectures. Whereas Luther's Latin lectures contain few German expressions – albeit the exclamation “o stulti, o sawtheologen” (*oh fools, oh pig theologians*, WA 56, 274.14) in the autograph of his 1515/16 lecture on the epistle to the Romans did become more widely known about (e.g. Pesch 2007: 1) – there are early witnesses to the multilingual nature of lectures, including the contemporary editor of lecture notes based on a mixed-language lecture by Paracelsus, who comments that the mixing up of Latin and German in teaching was common at many universities in Germany during the 16th century (cf. Sudhoff 1894: 418). Thus extant lecture notes demonstrate that multilingual practices such as

codeswitching or nonce borrowing were certainly common in teaching settings of the early modern period (cf. Pörksen 1994).

This is also true to a limited extent for dissertations, where the traditional language of academe, Latin, was still dominant initially. Latin remains the matrix language in these texts despite a growing trend toward multilingual practices in early modern dissertations (e. g. Kriisa 2018: section 4.3.4). The close association of this text type with the Latin language was even put to use in a caricature of purists' refusal to use loanwords in academic language, one in which the terminology of disputation was (almost comically) rendered in German (Thomasius 1691: 17–19). Even if the issue of vernacular disputations was occasionally subject to disputation (conducted in Latin, naturally), the transition to the modern languages occurred late on, and in the case of German not until well into the 19th century (Alvermann 2018; Marti 2018).

Overall, the shift in academic language away from the universal authority of Latin as the language of scholarship led to a phase in which various vernacular languages coexisted in the world of higher learning and created a “scientific Babel” that would eventually give way to a state of “scientific Anglophonia” in the 20th century (Gordin 2015; Ammon 2015: ch. G).

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Monika Hanauska

## 27 Historical aspects of external science communication

**Abstract:** For the last three decades, the science of external science communication has become a flourishing field of research. However, one can observe rather an orientation towards contemporary forms and developments of this field and a neglect of its historical roots. The following article will try to shed a light on historical aspects of external science communication by focusing on the historical conditions of its evolution. It will also highlight the actors who communicated scientific knowledge to various publics and the purposes they followed as well as the addressees of this external science communication. The focus will lie on the 19th century as the time of the rise of natural and technical sciences as well as on the 20th century as the century of mass media – two conditions, which had an essential impact on the further development of external science communication. For this, an additional aspect of this article will be the formats that emerged during the last centuries and which also reflect technical and medial developments. Communicating science to publics outside the academic field also meant that places and locations that were more accessible for various publics were established. The following article will give a short overview of those locations. Finally, the article will propose desiderata for future research in this field.

**Keywords:** history of science communication – popularization – vulgarization – historical science journalism – professionalization of science communication

### 1 Introduction

Though the science of science communication was established as a field of research in recent decades by incorporating approaches from diverse humanistic and socio-scientific disciplines, there is still a deficiency of a systematic examination of its historical genesis (Massarani, Moreira, and Lewenstein 2017). It does not lack studies concerning single aspects like the development of the modern system of sciences and the emergence of scientific communities which circumscribe increasingly from non-academic communities in the way they communicate (Kintzinger and Steckel 2015; Hoffmann, Kalverkämper, and Wiegand 1998, 1999) as well as popularizing scientific knowledge for non-expert publics (Bauer 2012; Reichvarg and Jacques 1991). Some of the works on science popularization focus on certain periods like the Age of Enlightenment (Lynn 2006; Gipper 2002; Golinski 1992) or the 19th century with the rise of natural and technical sciences (Boden and Müller 2009; Fyfe and Lightman 2007; Schwarz 1999; Daum 1998). There is also research about the evolution of science communication in different countries (Gascoigne and Metcalf 2017; Watanabe 2017; Fleming and Star 2017). Other

works reflect the development of media and formats of science communication like popular books (Diederichs 2010; Turney 2008; Luey 1999) or science and documentary films (Bernhardt 2010; Scott 2010). Finally, there are studies on recent developments like the professionalization of science communication during the second half of the 20th century (Bauer 2017; Weitze and Heckl 2016; Schäfer 2014) and the emergence of science journalism (Daum 2008; Goede 2010; Kohring 1996). However, there are only few attempts to bring these aspects together as did Knight (2006) for example. The following chapter will try to point out some lines for future ventures. Due to important developments in the field of science as well as in the field of media during the 19th and 20th centuries that reinforced tendencies of professionalization in both these areas the focus will be on these periods. However, there will be glances to earlier centuries to contextualize those developments.

The definition of external science communication for earlier periods constitutes a special problem, because it would be a naïve and non-historical view to distinguish between scientific communities and their traditions of communication and non-scientific communities as we do today (and even today it is not a trivial matter). This distinction would involuntarily imply a strict separation of internal science communities as esoteric circles and external non-academic and therefore exoteric publics in the sense of Ludwik Fleck (1980: 138–139). It may be doubted, if this is the historical perception of the formation of scientific communities and non-academic publics.

Still, there are single disciplines like mathematics or theology, which look back on a long tradition of building esoteric communities of experts (Shapin 2016: 45). However, the general formation of specialized scientific communities within the domains of scientific disciplines is a phenomenon that dates from the 16th to the 19th century as a part of the genesis of the modern system of sciences in an institutionalized and professionalized field (Schwarz 1999: 48–60). During this process as well as for earlier periods it is very difficult to draw a strict line between experts in the sense of actors inside an academic environment and laypersons in the sense of actors outside this environment which would be the main criterion of the distinction of external science and internal scientific communication (Bauer 2017: 20; Schindling 1999: 63–69; Cooter and Pumfrey 1994: 241). Nonetheless, there are forms of communication dedicated for a learned and esoteric public, which can be seen as internal scientific communication and such forms of communication which address a broader public that may consist of learned and laypersons as well as laypersons only (Daum 1998: 25–27). These latter forms of communication will be at the centre of this article. In many historical works they are considered as *popularization* (e.g. Schwarz 1999; Daum 1998) or *vulgarization* (Gipper 2002; Reichvarg and Jacques 1991) of science. However, these terms tend to imply a hierarchical view on science communication as the diffusion of knowledge to an ignorant public (Daum 2008: 36–37; Hilgartner 2016; Cooter and Pumfrey 1994: 248) that does not regard the many interdependences between communicators and their respective publics. In the following chapter, those terms are used with precaution and in a wider sense that also considers effects of

interaction between science communicators and their audiences. To avoid misunderstandings, I rather use the term (*external*) *science communication*.

## 2 Historical conditions and developments

The emergence and establishment of external science communication is based upon various factors, which are highly interwoven with each other. In the following, I will highlight core aspects of scientific developments, of socio-cultural and political factors as well as of economic aspects, which had an important impact on the historical development of external science communication.

From the perspective of science history, the formation of the modern academic system with its differentiation into several disciplines ranging from humanities to natural and technical sciences is closely connected with a differentiation of internal scientific communication with peers and external science communication with broader and diverse publics (Bucchi and Trench 2016: 1; Shapin 2016: 45). This general development is rooted in the 17th and 18th centuries when in the wake of the Scientific Revolution new scientific approaches based on empirical and observational studies introduced a new paradigm of science (Gipper 2002: 41–42; Hall 1998). This affected especially natural science studies like physics, biology, chemistry or astronomy, which became increasingly independent from theologically based dogmatic theorems and for this reason were able to develop as discrete disciplines (Hall 1998: 176–208). This process led to the evolution of scientific communities, which developed their own scientific discourses as well as languages for their special purposes. In a long-term process these communities negotiated the question of membership by several forms of boundary work (Shapin 2016: 50; Gieryn 1983) that resulted in the differentiation of scientific experts and laypersons (Weingart 2011: 45). However, as Shapin (2016: 52) pointed out, this delimitation of expert communities and lay publics also led to the emergence of external science communication, because exoteric audiences were no longer able to participate in internal scientific communication of these specialized esoteric circles:

The differentiation and specialization of science meant that scientific knowledge no longer enjoyed a matter-of-course place in general culture. Yet that same differentiation created an opportunity for the explicit ‘popularization’ of science, and, thus, for literary forms designed to convey otherwise inaccessible or impenetrable scientific knowledge to sectors of the public. (Shapin 2016: 52)

From a socio-cultural and socio-political point of view, the emergence of external science communication is due to the rise of the upper middle class during the Age of Enlightenment and especially in the first half of the 19th century. Political developments like the protests against the restoration policy of the Vienna System marked



the upper middle class's claims to political participation (Hill 2015: 130). From the Age of Metternich (German *Vormärz*) and the German revolution of 1848 onwards, the upper middle class expressed its desire for participation in societal affairs in a greater interest in scientific and technological research (Daum 1998: 1–4). This interest was manifested, not least, in the huge numbers of visitors who attended the public lectures, delivered by Alexander von Humboldt in 1827/28 at the University of Berlin and the adjacent Academy of Song (*Singakademie*), about the physical composition of the Earth. These lectures, dubbed the “Cosmos Lectures”, constituted a first peak in the popularization of scientific knowledge in the 19th century (Thomas, Fiechter, and Hug 2016: 287–288).

From an economic perspective people in the 19th century understood scientific and technological research during the period of nascent industrialization as a driver of the economic upturn as well as a part of the public discourse in which this section of society sought to participate (Daum 1998: 4). This rather enthusiastic attitude towards science changed during World War I, which introduced a new perception of science as part of the machinery of warfare (Weingart 2011: 51; Reichvarg and Jacques 1991: 244).

Nonetheless, due to mechanization processes the production of popular science publications such as journals or science books became cheaper and enabled a wider public to access scientific knowledge. During the course of the 19th century, new publics like labourers were addressed by diverse forms of science communication (see also section 3).

Due to these developments, the 19th century has been called the century of popularization of (natural) sciences. The increasing importance of mass media technologies led to new formats and ways of mediation of scientific contents to a mass public in the 20th century, which also implied a growing medialization of science communication (Weingart 2011: 50–54). These developments had impacts on an increasingly professionalized and self-reflective external science communication, which started to evaluate their strategies of communication and continually developed new concepts of science communication (Weitze and Heckl 2016: 20–21).

Especially in the second half of the 20th century, during the Cold War, professional science communication gained a new importance because of an increased interest in scientific research concerning nuclear issues or astronautics but also in order to meet the concerns in society about the dangers of scientific and technical progress (Schäfer 2014: 8; Bauer 2012: 45–46).

### 3 Actors, audiences, and purposes of external science communication

The field of actors of external science communication transformed over the course of the last three centuries as well as the constitution of the audiences that were addressed. Together with those shifts the aims pursued with external science communication also changed.

#### 3.1 Science communicators

Until the beginning of the 19th century, scientists regarded it as their task to communicate scientific contents and knowledge to non-expert addressees. They led this kind of communication via journals and books, but there were also forms of interactional exchanges via face-to-face-communication or letters (Shapin 2016: 52).

During the 19th century, the scientific field underwent a phase of professionalization with the establishment of new academies, research institutions and universities which guaranteed scientists a living by focusing on their scientific work. With the beginning of World War I, this process of professionalization seemed to be accomplished (Bauer 2012: 43; 2017: 21 f.). Due to this development, scientists confined their communicative activities more and more to internal communication with peers and left the field of external communication to actors outside the institutionalized scientific field (Schäfer 2014: 5–7):

Popularization, as it (= science communication, M.H.) was called, was an integral part of the lives of leading scientists and scientific institutions. But specialization and professionalization in science in the late nineteenth century progressively distanced scientists from public spaces. (Bucchi and Trench 2016: 1)

This process of professionalization also led to a situation where not all of those interested and active in science were able to find a position at a scientific institution and had to find other means of supporting themselves. Thus, a group of individuals gradually emerged who were academically educated but who did not enter or who quit the academic system to dedicate fully to the popularization of scientific knowledge to a lay public. They included, for example, Emil Adolf Roßmäßler (1806–1867) and Alfred Edmund Brehm (1829–1884), whose work contributed to the growing professionalization of external scientific communication and the establishment of science journalism (Daum 1998: 378–383).

The roots of science journalism can be dated back to the 18th century when science journals met a constantly growing public. From the middle of the 19th century onwards, the distribution of science journalistic publications augmented steadily. In the beginning, scientists and persons with an academic education constituted the

main actors in this field, but as mentioned above in the wake of the increasing professionalization of sciences scientists increasingly withdrew from this external communication (Daum 2008: 156–162). From the 1890s onwards and in accordance with the growing importance of media, science journalism became increasingly professional (Weingart 2011: 54).

Nonetheless, it is only in the second half of the 20th century that external scientific communication came to acquire a decidedly professional image. This went hand in hand with both a diversification of the contexts in which it was deployed and a process of theorization and meta-reflection about the forms and methods of scientific communication. It also became a field of academic research and teaching (Bauer 2017: 23; Daum 2008: 168–172). In the course of the 20th century new actors of science communication emerged: most scientific institutions realized the importance of practising public relations about their research and established professional departments which functioned as transmitting elements between scientists on the one side and journalists and the public on the other side (Koenen and Meißner 2018: 47–53; Bauer 2012: 49). From the second half of the 20th century onwards a new consciousness of scientists as public communicators of science awoke, supported by initiatives like PUS (*Public Understanding of Science*, 1985) in Britain or PUSH (*Public Understanding of the Sciences and Humanities*, 2000) in Germany. Although there were controversial discussions about the way science was transmitted to the publics, it rendered scientists and their work more visible in society (Weitze and Heckl 2016: 11–20).

### 3.2 Audiences and purposes of external science communication

Regarding the recipients of science communication is important to differentiate between several kinds of audiences and publics who consumed science communication – those who were addressed by the communicators in first place and those who unintentionally took notice of it. Furthermore, social changes had consequences for the composition of these publics (Burke 2014: 102). These considerations imply the use of the plural form “audiences” and “publics” instead of the singular forms.

During the early period of the establishment of the new scientific paradigm from the 16th to the 18th century, science communication mainly addressed courtly audiences as well as princes and sovereigns who sustained research. The aim of this kind of science communication consisted on the one hand in finding patronage and financial support. On the other hand, it served to increase the credibility of scientists who often had a lower social status and who had to gain social acknowledgement (Weingart 2011: 46–49). Another function of external science communication was linked with the new experimental approaches of natural sciences: the demonstration of experiments in front of a courtly (and therefore credible) audience served to testify the results and findings (Gipper 2002: 18; Stafford 1998: 248). This principle of eye witnessing lost its importance in the course of the 19th century due to precise measuring

techniques which excluded the public from the experimental rooms in order not to disturb the process of measuring (Weingart 2011: 49–50).

From the beginning of the 19th century, members of the upper middle class took an increasing interest in natural sciences and technologies by consuming popularizing publications and lectures but also in engaging in clubs and associations dedicated to the study of natural sciences and technology (Hein 2003: 158–164; Daum 1998: 86–112). Over time, external science communication also addressed broader parts of the middle class, as can be seen in the subtitle of a 19th-century popular science journal in Germany, *Die Natur* (1852–1902), which defined as its readers “alle Stände” (“all ranks”). Since the middle of the 19th century, external science communication also took into account the working class, although it had a strong didactic impetus in the sense of a diffusionist concept of science communication (Hein 2003: 149–153; Hinton 1979), which implies the idea of transforming specified knowledge to a lower and therefore more accessible level of complexity (Cooter and Pumfrey 1994: 248). The emergence of mass media since the 19th century and its growing importance in the 20th century broadened the scope of science communication again. Technological and medial progression enabled science communicators – especially science journalists – to address large and heterogeneous publics (Schäfer 2014: 7; Daum 2008: 168).

The functions science communicators tied to their activities ranged from legitimizing the establishment of natural and technical sciences in front of a new political relevant public and promoting acceptance of technological progress to finding financial support for new research as well as generating public interest in scientific work as a part of social life. In addition to this, didactic aspects also played an important role as several forms of public education manifest which derived from science communication, like the establishment of public libraries, museums or adult education centres (German: *Volkshochschule*) (Kretschmann 2003; Langewiesche 2003).

## 4 Places and institutions of external science communication

As science communication does not only consist of textual transmission but also of a variety of multimodal, exhibitional and performative forms (see section 5), over the centuries a variety of places and institutions of external science communication have developed. These can be found both inside and outside academic settings as the following overview will show.

Rendering scientific objects or phenomena vivid and “tangible” seems to be an important aspect in communicating scientific knowledge to non-expert publics. Due to this, since the 17th century a variety of venues have been established where not only scientific objects are stored and archived but where knowledge and science are also conveyed – botanical and zoological gardens, public observatories, cabinets of

curiosity and scientific collections, to name just a few. The special thing about these places of knowledge consists in the intertwining of an auditory, visual and haptic experience of scientific objects. Their task, in other words, consists of making science 'grasp-able'. From the end of the 18th century these institutions – which also served as places of entertainment for the court and the nobility, though they also functioned as locations of research – were increasingly made accessible for the middle-class public as well (Reichvarg and Jacques 1991: 196–198; Kretschmann 2003: 176). Cabinets of curiosity and scientific collections laid the groundwork for natural history museums, which began to emerge in the 19th century. However, they first had to develop strategies for communicating the knowledge associated with the objects gathered within them in a productive way.

From the mid-19th century onwards, technical and scientific innovations were presented in grand style and for an international audience at the world expos. Since the first world exhibition in London in 1851, these events have served to display national successes in the fields of applied technosciences. They also promoted broad public interest in these areas and conveyed knowledge in a vivid manner, by linking auditory, visual and performative media (Müller 2018: 17; Knight 2006: 68; Reichvarg and Jacques 1991: 205–207). The world exhibitions of the 19th century also became established as a forum for transnational scientific debate, a role they maintained up until the outbreak of World War I in 1914 (Trischler 2015: 90–93).

Towards the end of the 19th century, scientific theatres were established and made use of the availability of stage techniques to present scientific knowledge in a way that made the greatest possible impression. They were accessible to the largest number of people possible while simultaneously doing justice to the task of educating students as well as the public (Reichvarg and Jacques 1991: 237–240; Wilke 2018: 38).

As mentioned above dividing scientific communication into specific internal and external types is possible only to an extent from an historical perspective, as the individuals, organizations and publications involved during the early days in the 17th century and up until the first half of the 19th century are in some cases the same ones, so it is difficult to view them separately. This is why it is hard to determine clear forms of external science communication in this early phase. The most likely candidates for such forms are isolated events that emerged from the circles of learned societies during the 17th and 18th centuries. This includes, for example, gatherings such as *Kaffeekränzchen* (the tradition of an afternoon social get-together over coffee and cake) at which scholars and interested individuals would convene at a person's home to discuss scientific topics as well as more general issues. The French salon culture of the 17th century, which gained popularity in Germany during the 18th century, can be regarded as part of this context. It is one in which women too had the opportunity to participate in scientific discourse (Döring 2009: 667–670). As princes and sovereigns often financially sustained scholars and scientists, their courts equally became places of scientific communication and the courtiers an interested audience (Schindling 1999: 63–69; Burke 2000: 55).

From the end of the 18th century several organizations emerged, whose purpose was to disseminate scientific knowledge to the public. In Britain, the Royal Institution, which was founded in 1799, pursued this aim in addition to a general facilitation of natural and technological sciences as did the Conservatoire national des arts et métiers in France, which was founded in 1794 (Burke 2014: 104). In Germany, from the beginning of the 19th century a great range of natural history associations emerged, which played a significant role in popularizing science. They developed numerous instruments and formats of science communication, including popular science talks, nature excursions, making scientific literature accessible in their own libraries, as well as the publication of popular science books and magazines (Hein 2003: 154–159). Among the predecessors of these associations are learned societies, which had developed in the 17th and 18th centuries as non-university institutions devoted to the exchange of scientific knowledge and consisted predominantly of academics. These societies also played a part in conveying matters of science to the broader public in the form of public lectures and popular science publications (Henkel 2010: 219–220). In contrast to this, most of the individuals involved in the natural history associations of the 19th century were initially amateur scientists who were keen to pursue their own scientific interests and who maintained contact with experts (Daum 1998: 86–112). In 1888 as an equivalent of the Royal Institution, the Urania was founded in Berlin – an institution dedicated to give broader publics access to scientific knowledge and to enable them to participate in scientific culture and discourse. It offered a wide range of different events and activities like the above mentioned scientific theatre, public lectures, public experiments and public astronomical observation. With reduced prices for labourers, it guaranteed access to all groups of society (Müller 2018: 11; Wilke 2018: 33–43). In the 20th century and due to new concepts of science communication, the range of locations and institutions has been enlarged. It encompasses static and mobile locations like science centres or science ships (e.g. in Germany *MS Wissenschaft*) as well as virtual locations on the Internet that offer a platform for exchange about science or for getting involved with science (like forums of citizen science).

## 5 Genres and formats of external science communication

The history of external science communication shows a huge range of different genres, media and communicative formats, which underwent specific transformations during time with respect to the needs and affordances of the communicators as well as of the target audiences. There are written formats like journals, encyclopaedias, guidebooks and non-fiction books or oral and performative formats like talks, experiments or scientific shows.

## 5.1 Written genres

Popular science publications were an important means of mediating matters of science. The natural history associations played an important role here too, as they became the publishers of popular science magazines and books (Hein 2002: 158).

Since the 18th century, the journal has come to be the key medium of scientific exchange both within and outside science. This development can be seen to begin in the learned journals that appeared in the mid-17th century in France, England and Italy and were directed primarily – though not exclusively – at the educated members of a *respublica literaria*. These publications soon became the most important medium of communication of scientific knowledge (Habel 2011: 354–356). The main feature that characterizes the popular science journals of the 19th century, such as *Gaea* (1865–1909) and *Der Naturforscher* (1868–1888), is that they explicitly addressed the problems of mediating scientific information to a broad lay public. They also sought to establish direct communication with their readership by, for example, setting up question boxes, printing readers' letters and publishing calls to work on specific tasks for which a prize was offered. Those popular science journals covered the entire spectrum of natural science disciplines as well as neighbouring academic fields (Daum 1998: 337–341).

From the turn of the 20th century onward, the older popular science journals came to be increasingly supplanted by magazine-like publications such as *Kosmos* (1904–1999) and *Unsere Welt* (1909–1941), which more emphatically met the demands of modern mass publishing: the format became easier to hold in one's hands, readily understandable graphic representations were included and illustrations and photographs used. The selection of topics was more obviously review-like, attending both to lay scientific interests as well as to various ideological positions (Daum 1998: 371–372). Comparable developments exist in France and in Britain with journals like *La Nature* (1873–1972) or *La Science et la Vie* (since 1813), *Nature* (since 1869), *Knowledge* (1881–1918) or *National Geographic* (since 1888) (Reichvarg and Jacques 1991: 176; Burke 2014: 116–120).

In addition, science reporting and natural history contributions also found a place in non-scientific media such as daily newspapers or entertainment magazines for the family, such as the *Journal des Débats* (1789–1944) in France, the *Quarterly Review* (1809–1967) in Britain or the *Gartenlaube* (1853–1937) in Germany, thus witnessing to an interest in scientific developments and knowledge in society (Schwarz 1999: 80).

Another form of dissemination for popular science knowledge are non-fiction books whose precursors in the 18th century included popular educational writings such as pedagogical and moral texts, geographical descriptions and practical teaching texts. In the 19th century the spectrum expanded to include technical and economic self-help books, encyclopaedias (*Realenzyklopädien*) and conversation dictionaries as well as natural history representations such as Alexander von Humboldt's *Ansichten der Natur* (1808), Ebenezer Brewer's *Guide to the Scientific Knowledge of Things Familiar* (1847), Emil Adolf Roßmäßler's *Die Geschichte der Erde* (1858), Alfred Edmund

Brehm's *Illustriertes Thierleben* (1864–1869) or Camille Flammarion's *Astronomie Populaire* (1879) (Burke 2014: 120–123; Diederichs 2010: 36–38; Daum 1998: 266–267). It is possible to identify, even early on in the conception of this kind of popular science literature, a concern to direct it at readers who are either not educated or who have little prior specialist knowledge. In addition to this, popular science books also seek to present the material in an entertaining way that is nonetheless appropriate to the subject matter (Diederichs 2010: 34–35). This was due to the ever more marked functional distinction between scientific and popular representations during the second half of the 19th century (Daum 1998: 328). The spread of non-fiction books to less privileged sections of society occurred by way of people's libraries and workers' associations. In addition, the authors of this literature helped to draw attention to and disseminate their publications by giving public talks (Diederichs 2010: 44–45).

## 5.2 Performative-multimodal genres and formats

In the course of establishing natural sciences as observational and experimental disciplines, practices like public experiments in front of a courtly and later on in front of a bourgeois audience occurred from the 17th century. As they were presented in a spectacular manner including “special effects” like flashes, detonations or electrical phenomena, they had also entertaining aspects additional to their knowledge disseminating functions and for this proved to be a major crowd puller (Burke 2014: 108).

Talks and public lectures were among the most important forms of external scientific communication in the 19th century. A famous and still practised genre is the Christmas Lecture. Initiated by Michael Faraday in 1825 at the Royal Institution, it presents scientific subjects in an entertaining manner to a larger – and in first place “Juvenile” Auditory (James 2007: xvi–xvii). In Germany, popular science talks organized by the natural history associations were accessible not just to their members but also to a broader interested public. Having said that, this “public” consisted until well into the 19th century of members of the male population (Hein 2003: 159). Initially conceived as an opportunity for the various members of an association to expound their knowledge about topics of general interest, however, these talks gradually turned into lectures held by acknowledged experts in a given subject matter. These experts had been recruited initially from the ranks of the associations themselves; later, they came increasingly from academic institutions like universities or research facilities. This gave rise to a differentiated system of public talks or lectures that even today is largely organized by civil associations (Hein 2003: 157–158).

Progress in technology and media has, since the close of the 19th century and more so in the 20th and 21st century, enabled the development of new multimodal formats and media of science communication. Alongside talks incorporating projected images, cinematography and later television became increasingly significant in this regard. The media format of the popular science film in Germany emerged during



and after the World War I (Reichert 2007: 125–134). From 1918 onwards for example, the German film society Ufa produced numerous educational films in a wide variety of scientific fields, an activity which came to an end during the 1940s but was picked up again after World War II (Müller 2018: 11). In the 20th and 21st century technological progress continues to sustain multimodal presentations of scientific knowledge to an internal scientific public as well as to an external audience. Formats like Science Slams, Science Cafés or FameLabs use the range of technological possibilities to present their scientific contents in a multimodal and appealing way (Niemann, Schrögel, and Hauser 2017; see also Chapters 19 and 24, this volume).

## 6 Conclusion and prospects on further research

This chapter had to choose from a variety of aspects of its subject, which also meant leaving out other viewpoints and factors that have impacts on the formation of modern science communication. Therefore, the following considerations will resume some of the omitted points, which might be part of a more exhaustive history of external science communication that is still to be written. There is a number of works that focus on popularization of science, although these presuppose a concept following a deficit model of science communication (see also Chapters 5 and 19, this volume). This focus could be expanded by studies, which try to follow the trail of exchange between experts and non-experts. Considering a concept of science communication that is more than the diffusion of scientific knowledge to a public that is eager to learn there could be studies that focus on the reciprocal effects of science communication as a vehicle of discourse about science, for example in the field of entomology. Linked to this question one could ask which persons (with which social status) were involved in such a discourse and how did they engage in it. Which were the scientific, political and social effects of such a discourse about science? And how did it (if it did) help to develop the fields of science? In addition to this, a more detailed view on methods the communicators used as well as reflections about their concepts of communication could enlighten our knowledge about early theories of science popularization or communication.

A history of science communication could also comprise studies on the evolution and status of science communication in cultures beyond the western world to widen the view to other developments and practices of communicating scientific knowledge to broader publics. This is connected with the awareness that cultural peculiarities (like the perception of science in society) might have an important impact on the conception of how it is communicated to non-expert publics.

Finally, a history of external science communication could also reflect early forms of mediating scientific knowledge to broader publics from antiquity to early modern times. This would allude to the use of vernacular language in contexts of pre-modern

science (e.g. theology, artes liberales, medicine) as well as in contexts of technical communication (e.g. artes mechanicae like agriculture or mining). It would also refer to the question of an evolving differentiation of scientific communities from such circles, which consist either of experts and laypersons or of laypersons only (see also Chapters 25 and 26, this volume).

These aspects constitute only a few considerations, which deserve further examination if we talk about the history of external science communication.

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## **V Science communication: present and future**



Martina Franzen

## 28 Reconfigurations of science communication research in the digital age

**Abstract:** This article is dedicated to the sociological problem of what digital change means for science communication. Without giving definitive answers, at least relevant questions should be generated to explore the extent and depth of digitalisation as a sociotechnical process. One of the central effects of the digital shift is the emergence of large amounts of data. This fact still has to be taken into account in research on the digital transformation of science communication, which is still primarily concerned with the habits of use and presentation logics of journalistic versus social media. If the term science communication is broadened and also includes scholarly communication, the continuous generation of data becomes all the more obvious. Numerous scientific communication activities are constantly producing user-generated data whose empirical potential is far from exhausted. These data may provide insights into science communication processes that were previously not readily available to researchers. The application and further development of methods handling large amounts of data offer new possibilities for science communication research together with the opportunity to counter purely data-driven approaches by new competitors with a critical reflection.

**Keywords:** datafication – social theory – science communication research – scholarly communication – citizen science – altmetrics – automation – social bots – data science – social media – Twitter

### 1 Introduction: a social theory view of science communication

We are currently experiencing a shift from the printing press to digital communication, which affects all areas of society. One of the first noticeable effects is that the previous business models for the distribution of digital products such as newspapers, music or scientific publications are no longer working. With the (unauthorised) sharing of products, the publishing industries have experienced a sharp drop in sales in recent decades, as the case of the music industry has impressively demonstrated. The emergence of competition from online providers sometimes even meant bankruptcy, as media companies had to learn when traditional newspaper titles were discontinued. This circumstance is interpreted as a crisis of journalism (e. g. Peters et al. 2014) or the death of science journalism (Brumfiel 2009). Science publishers, for their part, are responding to the desire for open access, i. e. free availability and online access



to scientific information, by switching from a user-pays to an author-pays model. But the question of the scope and depth of digital change goes beyond the way business models are developed. Rather, the most challenging aspect is to what extent digitalisation affects the way information is produced, disseminated, received and evaluated (cf. Franzen 2018b).

Science communication offers a particularly exciting case of investigating the digital transformation. As social practice, science communication reflects changing science-society relations over time, as science historian Bensaude-Vincent (2001) has reconstructed in detail. To the extent that science becomes differentiated and withdraws more and more from the individual everyday reality, mediators are needed to inform society about new scientific and technological developments. Such a role of imparting knowledge to the general public has been assumed by journalism. According to the historic analysis of Bensaude-Vincent, the gap between science and the public, as it is known today, only emerges when the journalistic mass media differentiated into a system in the 20th century and assumed the function of popularizing knowledge by its own selection and presentation rules (Bensaude-Vincent 2001). Public engagement with science and technology, politically fostered since the 1980s to address legitimacy problems, aims to bridge this gap with numerous outreaching activities (Franzen, Rödder, and Weingart 2012). This trend is accompanied by the differentiation of public relations at a time when research institutions are increasingly vying for attention in the competition for scarce funding (Marcinkowski et al. 2014). Thus, science communication consists of at least three professional roles to bring science back to society: scientists, journalists and press-relations professionals.

Since science communication is both a field of practice and a field of research, this constellation of actors is generally the starting point for the theoretical modelling of science communication. But as sociologist Massimiano Bucchi emphasises, digitalisation undermines the previous mediator roles (Bucchi 2013). With the change from science communication 1.0 to science communication 2.0, previous boundaries are blurring. Digital communication infrastructures make it possible for scientists or research institutions to communicate directly to recipients, without having to rely on traditional mediators. In this context Bucchi speaks of a recent “crisis of mediators”. In addition to the way science is communicated, digital changes also affect the way scientific knowledge is produced. Digital infrastructures allow new kinds of collaboration that no longer appeal to professional scientists alone, but potentially to everyone. The keyword here is citizen science. Bruce Lewenstein (2016: 1) interprets citizen science as “one of the most dramatic developments in science communication in the last generation”. Citizen science is concerned with efforts to bridge the institutional gap between science and the public. It aims at various objectives such as achieving sustainable development (Irwin 1995), increasing scientific literacy (Bonney 1996; Bonney et al. 2009) or producing epistemically and socially robust knowledge (Finke 2014). In empirical terms, the majority of citizen science projects, however, concerns crowdsourcing of routine research tasks (Franzoni and Sauermann 2014). Volunteers

are involved by gamification to collect or classify data and thus, to compensate scientific manpower to handle the large amount of scientific data (Franzen 2019b). Today, however, not only science is confronted with an almost infinite amount of data; digital data accumulates everywhere and awaits interpretation.

It is the continuous and automatic production of data that is regarded as one of the decisive effects of digitalisation. Data is even being traded as the new currency of the digital age (Mayer-Schönberger and Cukier 2013; Geiselberger and Moorstedt 2013). Couldry and Hepp (2017) ascribe disruptive potential to big data and define datafication from an evolutionary perspective, as the core of what they call a new wave of mediatisation (after mechanisation and electronification and/or digitalisation). They emphasise that “media are not *only* means of technologically based communication any more. Being digital, at the same time and in addition they became means of producing data that can be delinked from the specific acts of communication and can be used for very different purposes” (Hepp, Breiter, and Hasebrink 2018: 5, original emphasis). According to various authors from the social sciences, we are moving towards a “data society” (Süssenguth 2015; Houben and Prietl 2018) whose contours, however, are still relatively indeterminate. If we want to take a closer look at the digital transformation of science communication, we need to clarify what datafication actually means.

In this chapter, this will be explored in several steps. First, the question of the digital transformation of science communication is sociologically recontextualised (section 2). In a further step what the datafication of science communication empirically involves is explained (section 3). Section 4 provides insights into methods and methodologies of data-driven science communication research. Finally, future research perspectives for science communication research are formulated that take into account the change of science itself through digitalisation (section 5).

## 2 Transformation of science communication in the digital age

Science communication is a transdisciplinary field that has gained in importance over the last three decades, both in practice and in research (Bucchi and Trench 2016). In view of the existing training paths science communication has become professionalised. Some authors even speak today of science communication as an “industry”, “in which many different stakeholders battle for attention and the power of definition, because there is money in the game, there are jobs to be captured, and there are professional identities at stake” (Weingart and Guenther 2016: 1–2). Due to the political importance of science communication in times of grand challenges such as climate change or global health, science communication research has become an important advisor to educating and involving the public. A main research focus lies on descrip-

tive analyses of science coverage in various media, above all in press products and with growing interest on social media. Given the abundance of topic-centred studies on climate change, biomedical technologies or risk communication in different media, places and countries, it is easy to lose sight of the big picture. This concerns the question how science communication shifts in the digital age in particular.

Science communication research often stems from journalism studies. From this perspective, a key research question concerning digital change is, if “the communication of science via the ‘new media’ online [is] a genuine transformation or old wine in new bottles?” (Peters et al. 2014). In view of the rapid socio-technical development and the different speeds in different countries, it is relatively difficult to arrive at general statements about the scope and depth of the digital transformation of science and journalism (for an overview on empirical findings, see Schäfer 2017). Furthermore, there is a relative short half-life of survey results on online usage patterns. This is not least due to the rise of ever new functions and platforms in the social media sector (see Chapter 30, this volume). But also traditional media are becoming increasingly differentiated, adding new online content, particularly multimedia elements (Peters et al. 2014).

What most studies on digital change in science communication ignore, however, are the digital transformations of academic science and the scientific publishing system. This may be due to the semantic distinction between science communication (external) and scholarly communication (internal) in the English-speaking world. But as science communication scholars have stressed already in the 1980s, the transition between internal and external communication is rather fluid (Bucchi 1996; Hilgartner 1990; Lewenstein 1995; Shinn and Whitley 1986). In a nutshell it says: “Popularisation is a matter of degree” (Hilgartner 1990: 528). This statement applies even more strongly to social media such as Twitter or Facebook.

Not only to separate internal from external science communication in digital environments, but to distinguish between science and non-science has become difficult. Categorical differentiations between science and non-science on the basis of communicative purposes in some respects no longer make sense when communication channels can be used by everyone, whether as a scientist, journalist or citizen scientist for different communication purposes. On Twitter for example, personal handles take the place of institutional affiliation. Anyone can set up a Twitter account, even anonymously. Not to forget the share of social bots on Twitter. Between 9 % and 15 % of active Twitter accounts are bots, as a recent study by Varol et al. (2017) shows. Such a “robot tweeting” (Darling et al. 2013) does not necessarily have to be a concern for science communication, it can even be useful if bots disseminate news and publications. Twitter bots as either topic or platform feeds function insofar as automatic dissemination tools (Lokot and Diakopoulos 2016; Haustein et al. 2016). Robot tweets about new scholarly publications thus form a functional equivalent to the science press release to trigger public communication. With social bots, however, the distribution of news is not preceded by any qualitative human judgement or guided by what

is called news values. The emergence of social bots is only one fascinating example of how the computer has become the “hub of communication” in the last thirty years (Hotho 2017: 269).

When we talk about the digital transformation of science for which various terms such as science 2.0, cyber science or open science are used, it can mean very little or very much at the same time (Brossard 2013; Brossard and Scheufele 2013; Franzen 2018b; Vowe 2016). Scholarly communication in the digital age is most often associated with open access publications and is reduced to this aspect by many authors. But the digital transformation of science, which is significantly promoted by the EU commission under the dictum of *open science* (European Commission 2016), is perhaps even more advanced than in the media sector and above all, it is classified as “radical” and “irreversible” transition by those driving this process forward (European Commission 2014). But not only a functional change of the academic journal is envisaged (Kriegeskorte 2012). We can also witness an opening up of peer review by publishing reviews, reviewer’s identities or editorial decisions for public view (see for an overview Ross-Hellauer 2017; and see also Chapters 14 and 30, this volume). Among the structural changes in scholarly communication is the publication of the underlying data.

EU research funding already requires the publication of data (open data) that accompany or are detached from the corresponding publications. (Internal) science communication is no longer just about the reception and referencing of texts, but increasingly also about the secondary exploitation and recombination of data, even if data in academic disciplines have very different meanings (Levin et al. 2016) and the willingness to share data also varies between research cultures (Haeussler 2011; Tenopir et al. 2011). Data analysis is increasingly supported by computers that are to be trained to act autonomously with the help of metadata. The so-called FAIR principles were developed exactly for this purpose (Wilkinson et al. 2016). FAIR stands for Findability, Accessibility, Interoperability and Reusability. “Distinct from peer initiatives that focus on the human scholar, the FAIR Principles put specific emphasis on enhancing the ability of machines to automatically find and use the data, in addition to supporting its reuse by individuals” (Wilkinson et al. 2016: 1).

With the advent of big data, machine learning is flourishing. Therefore, we are currently not only observing a progressive automation of routine activities in research (Hotho 2017; Franzen 2019a), but also an analogous development in journalism up to automated content production of certain formats (Neuberger and Nuernbergk 2015; Loosen 2018). So, if we want to give an appropriate answer to the above question whether the transformation of science communication is only “old wine in new bottles”, then we must take into account these evolutionary changes in communication. According to the science communication literature, however, an evolutionary perspective is rarely applied to this question. In addition to numerous empirical studies on the differentiation of the media landscape and media usage behaviour, socio-theoretical approaches are rarely used to interpret the observed changes theo-

retically, even if this seems desirable for science communication research in general (Görke and Rhomberg 2017).

With regard to the genuine question of social change, on the other hand, a certain analytical scheme is common in science communication research and is characteristic of journalism research as a whole. It is about interpreting social change either as de-differentiation or as a progressive functional differentiation of journalism (and science respectively). Even if such approaches follow a paradigm of differentiation theory or especially systems theory that distinguishes social systems such as journalism, politics or science (Luhmann 1984), the aspect of dissolving boundaries – de-differentiation – is theoretically not captured or may even be impossible to capture from a systems theory point of view (Loosen 2007). A de-differentiation would be difficult to grasp empirically once the focus is on the self logic of journalism. If we operationalise the question of radical change in science communication through digitalisation just as Peters et al. (2014) did – as de-differentiation or progressive differentiation – the answer can only be negative. Their diagnosis of science communication 2.0 reads as follows: “Self-presentation of science cannot replace the signalling/surveillance function [of journalism]” (Peters et al. 2014: 752). This statement cannot be denied but can also be made beyond empirical observation. The crux lies in the lack of a connection between theory and empirical phenomena in the concept of de-differentiation.

From the point of view of sociological theory of society, the question of socio-technical change must be posed somewhat differently: Doesn't the evolutionary achievement of the Internet as a new dissemination medium of communication mean a similar structural change as once the printing press, which was the catalyst for the emergence of a functionally differentiated society? This question drives many researchers from different disciplines. For sociology, more precisely for sociological systems theory, this represents a certain challenge, since its descriptive apparatus is based on functional differentiation, which by definition distinguishes science from politics, law or journalism by its mode of communication. In order to grasp the implications of digitalisation, we probably have to think beyond the categories of a functionally differentiated society. Current discussions in sociology, initiated above all by Dirk Baecker, are running in this direction of the possibility of a “next society” (Baecker 2007; Dickel and Franzen 2015). Following Luhmann, Baecker formulates the thesis that the social spread of computers might be the catalyst for a new societal structure in which functional differentiation is superimposed by a network structure (Baecker 2018). Elena Esposito takes the same line for an update of systems theory, to discuss whether communication is still suitable as a basic concept of social theory when machines and algorithms become communication partners of humans (Esposito 2017). This question can also be turned around: Do we have to “abandon modern society's idea that only human beings qualify for communication and to extend this peculiar activity to computers?” (Baecker 2011: 17). Without taking up this debate on sociological theory of society in more detail, let alone providing answers as to whether digitalisation has inherent disruptive potential, these references provided by various authors should

serve as heuristics to formulate the corresponding questions to the digital transformation of science communication. As already discussed above, datafication appears to be one of the most obvious and perhaps most important effect of a switch to digital communication that allows for participation, even of machines. Let us therefore take a closer look at what datafication means for science communication.

### 3 Science communication becomes datafied

What datafication of social action actually means becomes particularly clear from the following quotation, borrowed from bibliometrics:

Today, for every single use of an electronic resource, the system can record *which* resource was used, *who* used it, *where* that person was, *when* it was used, *what* type of request was issued, *what* type of record it was, and from *where* the article was used (Kurtz and Bollen 2010: 4, emphasis added MF).

This explanation of the automatic recording reminds us of the classic W-questions of journalism. It moreover shows us that the answers are already in the data. User-generated data is part of online content marketing. Services such as Google Analytics automatically provide the provider with usage statistics and real-time analyses. Specific tracking tools exist not only for media companies (Neuberger and Nuernbergk 2015; Muhle and Wehner 2017; Fürst 2018), but also for scientific journals. Journal editors are offered, for example, the AI tool Bibliometric Intelligence (Meta) to predict the citation probabilities of a manuscript and thus to inform or control editorial decision processes (Franzen 2019a). Based on large-scale usage data, it is possible to determine more precisely which types of research or news articles attract the most attention according to click rates. On this basis, trending topics can be identified to develop marketing strategies for scientific journals and media outlets alike (e.g. to address certain user groups).

However, it would be wrong to claim that usage data are an invention of the digital age and were not available or could not have been collected before the development of the WWW. The decisive point, however, is that these data are now simply generated automatically and no longer have to be collected selectively. In this context, it is worth taking a look back at the extent to which data has been collected in scientific communication in the pre-digital age or in the Web 1.0. An illustrative case for this is provided by the history of the Institute for Scientific Information (ISI), founded in the 1960s, which set itself the task of establishing a comprehensive scientific citation database. ISI founder and information scientist Eugene Garfield recognised the potential of scientific citation networks to derive reading recommendations for scientists in view of the growing flood of scientific literature. This idea was already presented in 1955 in the journal *Science*, where Garfield was already speculating about a citation-based

indicator, the journal impact factor, which later developed a certain momentum of its own (Garfield 1955). A team at ISI began to create this scientific citation database manually, which is now known as Web of Science. In the year 1992, Garfield sold the Institute of Scientific Information to the Thomson corporation. With its commercial owner the Web of Science still provides the basis for the provision of citation-based indicators, not only for scientific but also for economic purposes – similar to Google Analytics. The current owner is called Clarivate Analytics. Today the Web of Science is updated automatically – even if manual cleanups are required, because the error rate should not be underestimated. There have been no such collections of usage data for journalistic media prior to the Internet, as there is no equivalent citation culture. A precursor for today's user tracking tools in media outlets might be the Readerscan, which, however, is provided with a limited range and therefore not meaningful for an entire readership with its individual reading habits.

Today's automatic recording of all online usage behaviour opens up a new field of content marketing for journalistic media. In addition, it is also assumed that click rates will have an impact on journalistic news production (Fürst 2018). These usage statistics are also becoming increasingly important for science and science communication, as they are used as an evaluation of scientific outputs. What is now called Altmetrics (Priem et al. 2010; Priem 2013) is intended to contribute to a democratisation of science evaluation and greater fairness in performance measurement (Gross 2012; see also Mareike König's chapter in this volume on the impact of altmetrics on scholarly communication). Instead of one-dimensional citation-based indicators such as the journal impact factor or the person-centred h-index, altmetrics takes the entire spectrum of how publications are handled into account (viewed, saved, discussed, recommended or cited) together with the coverage in social media (Franzen 2015).

If we take the example of Altmetric.com as the most prominent service provider in this segment, the range of defined sources for the automatic measuring of online attention ranges from social networks such as Facebook, microblogging services such as Twitter, video platforms such as YouTube, as well as to international and national media outlets. Large international publishers such as Elsevier, Wiley, or Springer, as well as the top journals *Science* and *Nature* have already integrated this evaluation tool into their portfolio. For each new paper or chapter (see Bookmetrix), the Altmetric Score is displayed online in the form of a badge, the so-called Altmetric donut, whose respective colouring provides information about the type of resonance and whose centre is a numerical value. As soon as the online attention of scientific outputs is measured for rating and ranking purposes, we can expect repercussions on science. A science that is oriented to news values in order to attract the necessary public attention runs the risk of losing sight of its core business and thus its legitimacy, as the medialization concept suggests (Weingart 1998; Rödder, Franzen and Weingart 2012; Marcinkowski and Kohring 2014). If altmetrics changes from a "narcissistic technology" to a "control technology" (Wouters and Costas 2012), as the latest considera-

tions regarding the integration of altmetrics into the research evaluation suggest, then gaming the system becomes an undesirable consequence (Franzen 2018a). Altmetrics challenges scientists to use social media to disseminate research results, but less to inform the public and more in strategic self-interest (see also Chapter 30, this volume).

Other examples suggesting that science and PR are increasingly intermingled are the academic social network sites ResearchGate and Academia.edu (see also Chapters 22 and 30, this volume). These platforms are meant to support scientific exchange by offering academics a central platform to upload papers, recommend and discuss findings or pose research questions. The use of academic social network sites among scientists is widespread (Van Noorden 2014). ResearchGate also relies on altmetrics on the basis of the collected publication data and usage statistics – with the relevant difference that a person-centred evaluation is also created for each author profile. With the person-centred score, ResearchGate pursues the far-reaching claim to provide information about the reputation of an author. The algorithm behind this score is not transparent.

For the study of scholarly communication, particularly the online forums offer some interesting scientific starting points, for example on role behaviour, power asymmetries or from a linguistic point of view, how “scientificity” materialises. In a sense, the ResearchGate Q&A Forum is a form of communication that normally takes place in face-to-face interactions, such as in teaching. But even in written form, questions of this kind “What is the optimal number of case studies in qualitative research?” were actually only ever addressed to personalised addressees. Now that questions and answers are posed online, they potentially reach everyone. The interaction intensity also flows into the individual ResearchGate score, including the quality of the respective answers, which in turn can collect recommendations and remain retrievable. In this respect, digital infrastructures make scientific interactions publicly visible as a form of scientific communication that alternates between informal and formal communication.

If we want to investigate scholarly communication, we no longer have to limit our material to research products or media products but can get insights on “science in the making” by studying for example the academic social network sites. As the discussion above on Altmetrics shows, in addition to traditional media outlets (newspapers, journals, radio), other sources (e. g. YouTube, Mendeley, Facebook) are becoming increasingly relevant to academia and should therefore also be considered more strongly in science communication research.

Another valuable source to study science communication efforts are the interactions of scientists and nonscientists (see also Chapter 30, this volume). Some of these kinds of interactions now take place in so-called citizen science platforms like *zooniverse.com*. An intriguing example of citizen science is *galaxy zoo*, which was launched in 2007. *Galaxy zoo* invites everybody to participate in classifying images of one million galaxies from the publicly available Sloan Digital Sky Survey data. The task is to classify each galaxy on the basis of randomly provided pictures according



to predetermined morphology choices (spiral, elliptical, other) in an online environment. The public response to the initial call for participation was unexpectedly high: 100,000 people participated in the first 50 days and contributed 25 million classifications of data (Raddick et al. 2010). By the open call for participation the project leaders were overwhelmed with questions from the participants (Straub 2016). In order to deal with the high resonance, they created an online forum to facilitate discussion. This event of virtual interaction can be regarded as one of the conditions of success for the scientific discoveries that emerged from the project. “The forum took on a life of its own as the volunteers talked with each other, answered questions, and were able to create opportunity for both community and deeper scientific contribution” (Straub 2016: 3). Based on the qualitative analysis of one forum’s thread Straub (2016) reconstructed the iterative process of discovering a new galaxy, called the Green Peas. While the initial spark for this discovery was the thread “Give peas a chance”, whose title was initially meant as a joke in reference to John Lennon’s song “Give Peace a Chance”, this was also the anchor point for further research into the causes of a previously unknown pea-sized, green-lit galaxy. The discussion in the online forum about a non-classifiable picture of a galaxy, in which at first only laypeople, later also astrophysicists participated, thus resulted in new knowledge about a previously unknown galaxy, the green peas. The reconstruction of a co-produced astrophysical discovery is only one example of how (citizen) science in the making can be empirically investigated. Citizen science projects are, however, a still underestimated source for science communication research, for example to investigate interaction processes between scientists and non-scientists.

This list of science communication activities should be enough to make the point that the digital developments in the field of science and science communication are so rapid that science communication research can hardly keep up with capturing all relevant outlets in which science communication takes place today (for an overview König and Nentwich 2014; Hotho 2017; Lobin 2017). Journalistic media are only part of a much broader picture, but they remain the most popular research subject in science communication research (Schäfer, Kristiansen, and Bonfadelli 2015). Similarly, the question of digital change in science communication research is often shortened to online media and their degree of utilisation (Peters et al. 2014; Schäfer, Kristiansen, and Bonfadelli 2015; Su et al. 2015).

However, the communicative structure of social media also blurs the categories that shape the models of science communication research. Did the press media perhaps still offer the opportunity to specifically separate between the spheres of science, politics, business – such an attribution is no longer plausible on the basis of social media such as Twitter. This is not solely due to the existence of social bots in science communication (Haustein et al. 2016; Lokot and Diakopoulos 2016). Above all it is unclear what the function of social media is for science communication and to which sphere it can be attributed, such as internal or external communication, scientific PR, journalism or even politics. One way to avoid the theoretical difficulties of

analytical categorisation is an inductive, data-centered approach (see also Chapters 4, 22, and 30, this volume).

## 4 Methods and methodologies of data-driven science communication research

What we are currently observing not only in the case of science communication research, but generally in science is the increase in data-driven approaches similar to business analytics. Unlike traditional methods of science communication research such as media content analysis following code book instructions, data-driven approaches refer to big data methodologies to identify structural patterns in the data via statistical correlations. These include text mining technologies such as latent dirichlet allocation (LDA) to apply topic modelling for automated content analysis of journalistic data (or any other text and image data) (DiMaggio, Nag, and Blei 2013; Puschmann and Scheffler 2016). Some authors in the field of science communication also started to use sentiment analysis to explore the tone of media reporting in more detail (e.g. Su et al. 2016). Whereas the analysis of textual data such as press articles previously depended on manual coding and was correspondingly limited in number, automated text analysis procedures now open up completely new possibilities for journalism research in terms of scale (Jacobi, van Atteveldt, and Welbers 2016; Günther and Quandt 2016). Despite the euphoria about large data and methods, it should not be forgotten that their epistemic value is also limited and by no means can replace theory (González-Bailón 2013). In the course of the big data hype, however, we can observe exactly such a development in the field of science studies to let “data speak for themselves” (Anderson 2008).

We are talking here about a newly developing field of research under the label “science of science” (SciSci). The aim of SciSci is to investigate mechanisms of doing science by using large data sets. In a brand new programmatic article in the journal *Science* (Fortunato et al. 2018) SciSci is introduced as a transdisciplinary research field that follows the tradition of Scientometrics, i.e. measuring science by its own methods. This approach goes back to the historian Derek de Solla Price, who first developed the idea of measuring science on the basis of its own data, publication and citation patterns. His book *Little Science, Big Science* (Price 1963) paved the way for the flourishing of bibliometric technologies and the development of publication-based indicators, culminating in the aforementioned journal impact factor and later on, the Altmetrics score.

What is remarkable about this case is that the SciSci protagonists no longer come from bibliometrics, science studies or science communication research and their academic traditions, but mainly from the computer sciences. It might be an example of how social sciences seem to lose their distinctive expertise of innovative methodolog-

ical resources (Savage and Burrows 2007). As the following quotation shows, SciSci is a positivist approach in which theories of different colour are fed in for the purpose of modelling:

SciSci integrates findings and theories from multiple disciplines and uses a wide range of data and methods. From scientometrics, it takes the idea of measuring science from large-scale data sources; from the sociology of science, it adopts theoretical concepts and social processes; and from innovation studies, it explores and identifies pathways through which science contributes to invention and economic change (Fortunato et al. 2018: 1).

SciSci's ambitious goal is to provide "a deeper understanding of the precursors of impactful science" in order "to develop systems and policies that improve each scientist's ability to succeed and enhance the prospects of science as a whole" (Jasny 2018: 1006).

If this project of SciSci is taken seriously, the political demand for these kinds of studies is high when it comes to distributing research funds and making funding decisions. Unlike bibliometrics, SciSci promises predictions about impactful science. Unlike classical science studies, SciSci deals with large data sets instead of individual case studies. Unlike the gross of science communication research, SciSci focuses on scholarly communication instead of public communication of science. Nevertheless, the methods and approaches used can very easily be transferred from scholarly publication data to other data sets such as newspaper archives to carry out similar pattern recognition for science communication research. Currently, scientific communication research seems to make only selective use of these methodological innovations (e. g. Su et al. 2016). On the basis of the many small-scale studies on social media, however, it is hardly possible to get an overall picture (Neuberger 2014: 341). The majority of science communication studies are still based on traditional methods of empirical social research such as sample surveys, content analyses or qualitative interviews to investigate social media, primarily blogs (Neuberger 2014: 340–342).

In contrast, however, we currently see a dynamic movement in journalism – data journalism, that is engaging in collaborative, investigative journalism through large amounts of data. For example, around 400 journalists from over 100 media organisations in around 80 countries participated in the data leak of beneficiaries of offshore companies in the so-called Panama Papers project. A current example of data journalism in science journalism comes from Germany, which in the summer of 2018 was dedicated to the phenomenon of predatory journals. This was a cooperative project between various public media, in which large amounts of data were evaluated in order to determine the extent of predatory publishing. What is remarkable about this case is that journalism quantifies a problem of (German) science that scientists do not regard as such or perceive only as a marginal phenomenon of scholarly communication, as the accompanied debate suggests (Pössel 2018). Rather, a fierce controversy arose over the hashtag #fakescience created by its authors, which aroused false associations on scientific credibility when it came to profiteering in scientific publishing.

These examples should suffice to note that digital communication infrastructures can create both new forms of cooperation *and* competition in science communication research. Overall, the opportunities and topics of research on science and science communication have increased with digitalisation and are far from exhausted. But digital data is not exclusively available for academic research. Thus, it is time for social science communication research to address the new methodological possibilities and to add its own scientific value before it runs the risk of being overwhelmed by purely data-centred approaches to computer science in the realm of SciSci, to data journalism or even to commercial businesses.

## 5 Future research perspectives for science communication research

Since science communication reflects the changing relationships between science and society, the most fascinating sociological question is what societal consequences emanate from the change from the print to the digital age. Instead of a technic-deterministic point of view, it is worth understanding digitalisation as a socio-technical process. It is unlikely that everything that is technologically imagined will actually be socially implemented. Instead, socio-technical developments show that the availability of technology leads to social uses that cannot even be predicted (Hutchby 2001). With regard to digitalisation, many empirical studies have emphasised that we are still at the beginning of development (Bader, Fritz, and Gloning 2012).

So far, only vague contours of what constitutes digital change for society are emerging, even if numerous case studies are already available (see the contributions in Süssenguth 2015; Houben and Prietl 2018). However, there is a certain tendency that demarcation lines drawn so far seem to become fragile. For science communication research, this concerns for example the former dichotomies between science and the public or between journalism and public relations. Attributions within the current models of science communication that equate internal science communication with truth-finding and external science communication with science mediation or popularisation (Kohring 2005) are no longer convincing and probably never were (e.g. Hilgartner 1990). Instead, we have to deal with blurring boundaries and adapt our models of science communication research (Bucchi 2013).

*On the one hand*, this concerns the role of science journalism in the digital age (Trench 2007; Fahy and Nisbet 2011), which is currently being negotiated under the heading of “the crisis of mediators” (Bucchi 2013) (see also Chapters 20 and 21, this volume). Direct-to-consumer materials from research institutions, for example interviews with scientists and direct approaches to the public by scientists via science blogs or Twitter, bypass traditional mediating roles (Bucchi 2013; Neuberger 2014). The phenomenon of fake news illustrates the need for quality-tested, journalistic sci-

entific reporting for an enlightened media public. However, to the extent that media outlets make their editorial decisions dependent on click rates, they run the risk of losing sight of their core journalistic business (Fürst 2018). However, the dependence on metrics of attention affects science as well. Scientists are increasingly using social media not necessarily to disseminate knowledge, but to promote their publications to get cited (Liang et al. 2014). Related concerns about a loss of quality in science communication are one of the drivers of research on digital change (cf. Weingart et al. 2017). What is lacking, however, is the formation of theories of science communication in the digital age. Journalism research has already embarked on this by working on the concept of computational journalism (Anderson 2013).

*On the other hand*, science communication research needs to open up towards new actors entering the scene of science communication. Among them is the citizen science movement. Citizens' participation in science is encouraged through policy programmes, particularly within the EU Horizon 2020 framework (European Commission 2016). Thus, classical topics of science communication research are once again on the agenda as to how best to promote scientific literacy (Bauer, Allum, and Miller 2007). With digital media, however, new attribution addresses for communication are also emerging. In the case of Twitter, it was discussed above to what extent not only human actors but also machines are involved in communication, for example when it comes to pointing out new scientific publications via social bots. So far there have only been isolated results on the role of social bots in science communication (for instance Haustein et al. 2016). Closely linked to computer-mediated communication is the question of how algorithms influence the perception of science news. While critical algorithmic studies are a growing field of research in the social sciences (Gillespie 2014), science communication research is still largely unaffected by these debates, although it will be worth integrating those perspectives in empirical studies. Numerous studies published in journalism research respond to the question of fragmented publics through algorithmic cultures (e. g. Anderson 2011). First results show that the postulated filter bubbles (Pariser 2011) do not exist in this way (Flaxman, Goel and Rao 2016) or are far less an Internet-related development than proclaimed (Muhle and Wehner 2017).

Especially in view of the large amounts of data to which science communication research can refer, it is worth exploring the potential of large-scale methods for science communication research in order to arrive at statements that can be generalised, even in cross-disciplinary settings. Automated text analysis methods offer completely new possibilities, especially for longitudinal analyses of media reporting. In a recent programmatic article on the future of communication and media studies in Germany, Andreas Hepp (2016) argued in favour of moving away from the traditional fixation on public communication. In order to do justice to the data-driven age, the subject area must be extended from the public media to mediated communication. Any form of digital communication implies the continuous production of data (Hepp 2016: 233). Within these digital processes, sociality is not only represented by comput-

erised data, but rather co-produced (Hepp 2016: 230). Digital media should therefore no longer be regarded as a means of communication only, but as an “*additional means of algorithmised reality construction*” (Hepp 2016: 230, original emphasis). This is what he calls “deep mediatisation”. A much closer examination of what mediatisation actually implies seems promising in particular for science communication research. However, this also requires a special methodological reflection, preferably a multi-method design and a theoretical framework that allows the empirical observations to be interpreted accordingly.

As discussed above, the field of science communication research (as well as other data-intensive research areas) in principle carries the risk of being overrun by data sciences; SciSci is one example of such approaches (Fortunato et al. 2018). Analogous to the division of labour proposed for the life sciences for big data science and small data science (Ratti 2016), the SciSci protagonists (Fortunato et al. 2018) seem to strive for a specific division of labour that locates the social sciences in the deepened insight on the basis of case studies to understand the diversity of specialist cultures, while the selection of problems on the basis of large data analyses is the responsibility of SciSci with the goal of efficient research funding and innovation development. Without directly appreciating or rejecting such a form of division of labour, the first thing that is needed is sensitivity to the emerging developments in the datafication of academic research and science policy in order to respond appropriately to such attempts. Just as scientific publishers are increasingly relying on Big Data Analytics to predict research trends and derive new journals from them, science policy is also interested in data on science in order to inform funding decisions. In addition to the production of knowledge about the way scientific knowledge spreads and how science is reported in the changing media landscape, a critical attitude is indispensable in science communication research to reflect its techniques and its own role and those of other actors.

If we consider science communication as a showcase of social change, we find several indications that digital change brings shifts in how knowledge is produced, disseminated, received and evaluated today. One of the most obvious changes currently emerging from digitalisation is, as this contribution suggests, not only the way in which knowledge is produced in data-driven times in the field of science communication research but especially by whom. If I interpret the emerging trends correctly, the biggest competitor for science communication (research) in the future will be the machine. Thus, it is time to devote much more attention to the possibilities of digital science communication, in order to turn the machine into a cooperation partner.

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Peter Reuter and Andreas Brandtner

## 29 The library in a changing world of scientific communication

**Abstract:** The digital transformation has fundamentally changed the work and self-understanding of academic libraries over the course of the past two decades. Early on, library science experts attempted to address what impacts comprehensive digitalisation in research and academic instruction would have on libraries and to anticipate further new developments. There is a general consensus that the key challenges arise from the fact that academic research is now a digital process from the outset and throughout all phases of work. As a result, academic libraries now face new tasks, which include ensuring the accessibility of research data and implementing reliable solutions for storing and long-term archiving of digital data. Today's libraries not only acquire and make available large volumes of digital information; use of library space has also increased enormously in recent years. Besides providing virtual books, information, and data, libraries can actively support situated learning by creating new kinds of spaces and buildings and thus contribute significantly to the ongoing development of academic cultures of learning and instruction. The traditionally close link between libraries' role as reservoirs of knowledge and as spaces for instruction and learning continues to define their function within the post-Gutenberg galaxy, even as they develop new forms of serving academic communities.

**Keywords:** academic library – digital library – digital transformation – scholarly communication – situated learning

### 1 Introduction: transformations in library use

Recently, the University of Zurich announced plans to merge the university's more than forty autonomous, specialised libraries within various faculties, institutes, and departments – currently occupying more than eighty sites – and create a centralised university library that will house a large part of all print media in a new building (Steinfeld 2018). Surprisingly, the plans foresee storing books and journals in closed stacks accessible to staff only and retrieved for users on request, a widespread practice in large European libraries until well into the twentieth century. By the 1960s, at the latest, with new universities being established in Germany and elsewhere in Europe, this concept was frequently perceived as outdated. Libraries were reorganised on the basis of open-stack access with book shelves and work spaces arranged in close proximity to one another and book holdings presented according to systematic classification. So why is the University of Zurich, an institution with a progressive reputation, returning to what many would consider to be an “outdated” model?

The concept for the University of Zurich's new central library would seem to be motivated by the desire to create as much study and reading space within the library as possible. There are good reasons for pursuing this goal. Not only in Zurich but around the globe, there has been a significant increase in on-site use of academic libraries in recent years, accompanied by a sustained and frequently articulated need for additional modern and appropriately equipped areas where users can read and work. Many libraries have reacted by creating more study carrels and other work sites and have done so, due to a lack of space, at the expense of open-stacks for books. Considering the widespread decline in the use of printed books, this would seem to be a sensible, albeit involuntary trade-off in the use of limited physical library space. At the University of Zurich, however, those responsible for the new plans appear to be convinced that this is not merely a short-term solution for an acute space problem but rather constitutes a groundbreaking scheme that sets the stage for advantageous future developments for the library and its users.

At least at first glance, the significant increase in on-site use of libraries that has emerged despite the fact that ubiquitous access is generally available for the large amounts of digital information acquired by academic libraries appears to be a paradox. User surveys (for example Hornig and Walker 2018: 28–34) reveal an urgent need for library services that can be accessed from mobile devices as well as for study and reading spaces for a variety of on-site use situations, including individual carrels for quiet, concentrated work and group rooms or other spaces for communicative and collaborative activities. Empirical studies demonstrate that there has been a significant rise in the average amount of time spent in academic libraries by individual users per day and week (Vogel and Woisch 2013). One consequence of this trend is that more recent concepts for library buildings place a much higher priority on the quality of the environment that library buildings and their furnishings and fixtures provide for users than was previously the case. Moreover, these concepts highlight the social function and role of libraries.

There can be no doubt that the shift away from the dominant, traditional concept of library reading rooms, with an architecture designed to discipline users and a repressive social culture frequently fostered by library staff, can be welcomed as progress in library design. And it is certainly also true that some of the key factors that have contributed to these transformations in library use have developed outside the library, for example new forms of university teaching that have spread with the introduction of the Bologna Process to harmonise higher education in Europe and more fixed curricula and forms of learning or a more general change in dealing with authorities in the education system and their manifestations. The question remains whether these changes in libraries and the paradoxical relationship between availability and diversity of information, on the one hand, and the physical presence of users, on the other, are more than simply the result of a broader development in society – a development that libraries as well as other educational and cultural institutions participate in only on a secondary level.

## 2 Libraries and the ongoing digitisation of research

The work and self-understanding of academic libraries has already changed fundamentally as a result of the ongoing digital revolution. And in the wake of the semantisation of the web the digital revolution has now entered a new phase, with far-reaching and to date incalculable impacts. Early on, academic libraries attempted to anticipate the consequences for their work of comprehensive digitalisation within research and to generate appropriate new areas of activity. In the relatively broad, lively, and by no means homogeneous debates that have taken place within library science in recent years, a number of key topics and perspectives have taken centre stage internationally. The main challenge for academic libraries is perceived as resulting from the fact that academic research is now a digital process, from the outset and throughout all phases of work and that this entails new forms of presentation, communication, distribution, and publication.

In recent publications and recommendations, the *Deutsche Forschungsgemeinschaft* (German Research Foundation, DFG) asserts that academic work is a genuinely digital process and that, in academia, the transition from analogue to digital information systems has for the most part been completed (Deutsche Forschungsgemeinschaft 2018: 12). For the DFG “[ist] die Ausgangslage dadurch gekennzeichnet, dass sowohl die Informationsversorgung (Zugriff, Suche, Rezeption, Weitergabe, Austausch) als auch die Forschungsarbeit (Analyse, Weiterverarbeitung, Daten, Software, Methoden, Publikationen) in vielen Fächern (nur noch) digital erfolgen. Diese tiefgreifenden Veränderungen des wissenschaftlichen Arbeitens betreffen den gesamten Forschungszyklus” (‘the starting point is characterised by the fact that in many disciplines, both provision of information (access, search, reception, transmission, exchange) and research work (analysis, processing, data, software, methods, publications) now occurs (mostly or exclusively) in a digital mode. These far-reaching changes in academic work effect the complete cycle of research’) (Deutsche Forschungsgemeinschaft 2018: 12). As a core element of information infrastructure, academic libraries are thus “nicht nur vor die Herausforderung einer erheblichen Ausweitung und Veränderung ihrer Aufgabenfelder gestellt, sondern ebenso vor erhebliche Anpassungs- und Aushandlungsprozesse im Zusammenspiel miteinander” (‘not only facing the challenge of a considerable expansion and transformation of their areas of work but also face substantial interrelated processes of adaptation and negotiation’) (Deutsche Forschungsgemeinschaft 2018: 13). Among the tasks and areas of activity that, according to the DFG, have emerged for information infrastructure institutions and that should in future be supported with new funding programmes are the development of new methods for cataloguing and digitalising information, procedures for dealing with research data, and realising the transformation to open access (Deutsche Forschungsgemeinschaft 2018: 19–42). This most recent DFG position reflects recommendations from other German and international research funding organisations and consultation bodies (Adams Becker et al. 2017: 18–19, 34–35) and



also takes up ideas formulated in its own recommendations and position papers in recent years (Deutsche Forschungsgemeinschaft 2012).

### 3 New tasks for libraries

By adopting the paradigm of the data life cycle, the primary focus of libraries' work has shifted from attention to the results of scholarship – in the form of publications – to the entire process of conducting research. New tasks for libraries have emerged while other, traditional fields of activity continue to decline. The following brief outline of significant lines of development highlights the extent of these changes.

(1) There is a clear consensus in library science in recent years that the dwindling significance of print media, on the one hand, and the rapid development of digital products, on the other hand, have now rendered the traditional notion of collections – which formerly defined libraries as institutions in the proper sense – questionable if not completely superfluous. With the increase of licence-based electronic media and genuinely digital publications, collecting media for the future, traditionally a core function of libraries, is now obsolete, at least for classic mainstream libraries like university and college libraries, and at best remains important for peripheral activities such as the maintenance of special collections (Anderson 2011). A study published in the United States in 2011 concluded that the collection size of academic libraries and with it the use of local media was less and less significant. The authors concluded that, where this had not already occurred, “just-in-case” collections should be replaced by “just-in-time” acquisitions that respond to the needs of university library clients; they see electronic media as especially well-suited to meeting these needs (Education Advisory Board 2011).

(2) Acquisition of analogue information media is traditionally one of the essential basic functions of libraries, along with the processes of analysing and classifying (cataloguing), providing access (use), and storing (archiving) such media. With the digital transformation, there is an ongoing shift in the provision of information by libraries from physical to electronic media, including databases, e-books and e-journals but also genuine web content (e.g. blogs). Whereas the acquisition of individual printed books and periodicals was the result of a personal selection process by a librarian with an academic qualification (subject librarian), providing digital information is for the most part a de-individualised process. Most libraries join others to form so-called consortia, which together procure access for several years to e-media from publishers or aggregators. Since some publishers have a monopoly on the academic information market, libraries are often confronted with horrendous prices and price increases when acquiring licences. Moreover, the content of the packages offered is for the most part determined by the suppliers, so libraries have little or no influence. The digital data remain on the publishers' servers; the libraries' role is to ensure that users have

access in the medium and long term to the stored data by means of appropriate licence contracts (access vs. ownership).

A further factor that has led to a separation of media acquisition and the intellectual activities of libraries and librarians is PDA (patron-driven acquisition). Here, decisions to buy media are delegated to library users, who initiate purchases after finding media metadata in a discovery system by calling up the complete text.

The reformulation of libraries' role in creating and maintaining collections has also resulted from a further aspect of digital culture, namely, the creation of publication platforms and repositories in the course of the open access debate. This discussion about opportunities for cost-free and public access to academic information on the Internet has intensified since the beginning of the twenty-first century (Budapest Open Access Initiative 2002; Berliner Erklärung 2003; OA2020 2015). Libraries play an especially active role in these debates and support the transformation of academic publishing in various areas. By providing repositories, they promote green open access, meaning depositing texts published by journals or publishing houses on servers maintained by institutions or by disciplinary repositories. Moreover, libraries promote the golden open access, that is, initial publication of academic work in open access journals, monographs, or collected volumes. To do so, they establish open access publication funds to pay the article processing charges (APCs) that publishers often require authors (or their employers) to pay, rather than subscription charges, to finance open access publications. Libraries also provide organisational and technical support in creating open access journals and negotiating offsetting and transformation contracts that are intended to facilitate the stepwise transition from subscription fees to author fees. Since established publishers have meanwhile appropriated open access as a business model, hopes have been dashed within the librarian community that implementation of open access would lead to reduced expenses in procuring academic journals. Instead, the expectation today is that the transition from subscription to open access will be cost-neutral but will enhance the transparency and visibility of results from academic research. Libraries aim to contribute to this goal by linking research results to research information systems or social networks and also see their use of bibliometric processes as a means of supporting the research pursued by universities and other academic institutions.

Within the context of all these activities, academic libraries are shifting their focus from the classic outside-in perspective, in which information media are brought into the library and access to them is provided inside the library, to an inside-out function, in which data and information generated within the university or research institution are made available and fed into networks outside the library (Dempsey 2013).

(3) At the same time, the systematic digitalisation of unique or otherwise especially valuable manuscripts and printed materials, as well as contemporary digitalisation methods have led to modifications of the traditional concept of collections in academic libraries. The structural, syntactical, and semantic meta-information incorporated in digital text editions that have been transformed into XML (Extensible

Markup Language) formats such as TEI (Text Encoding Initiative) create opportunities for automated processing. This includes opportunities, for example, for alternative ways of ordering the information provided, which can also be further modified by users (e. g. via social bookmarking and social tagging). Moreover, digital editions allow for links to numerous other materials, both textual and non-textual. This means that the text is replaced by a “kontinuierlich fortschreibbares Ökosystem digitaler Objekte” (‘ecosystem of digital objects that can be continuously extended’), in which “der Text selbst nur noch ein Element, und nicht einmal das wichtigste ist” (‘the text itself is merely one element, and not even the most important one’) (Ceynowa 2014a: 54). In the wake of this shift, traditional textual forms of storing knowledge are replaced by a “sich kontinuierlich neu knüpfende[s] Netz flüchtiger, medial entgrenzter Inhalte” (‘constantly renewed network of ephemeral content that is not subject to borders set by media’) (Ceynowa 2014a: 56) as is already evident in the simultaneous presence of textual, audio, and visual documents in various stages of being created and commented on that is now becoming commonplace.

Beyond these various possibilities for collaborative editions and commentary processes of texts and the creation of new types of communication and publication – which comprise textual, audio, and visual aspects and can hardly be subsumed under classic concepts of works and authors – the most significant consequences of this shift are the associated opportunities for manipulating and utilising digitised media, for example, big-data processes for text mining. This results in new types of objects for collection by academic libraries and thus in a new area of work in close cooperation with researchers, namely, the creation and sustainable maintenance of access to texts and data corpora from and for research. German copyright law stipulates that archiving such corpora is a task reserved exclusively for academic libraries and archives (Gesetz zur Angleichung des Urheberrechts UrhWissG § 60d).

(4) On the level of objects, appropriate contemporary modes of collecting and cataloguing therefore begin with the administration (storage and cataloguing) of research data. The relevance of such data for policies on academic research has increased considerably in recent years. “Where data justify it, scientists should make them available in an appropriate data repository” (The Royal Society 2012: 10). Research data can be described with standardised metadata, using methods similar to those applied to traditional media, but which incorporate additional technical aspects. Since research data in most instances are linked to or build the basis for publications, these new tasks are obviously closely related to the classic functions of academic libraries. Research data as well as electronic publications are also hosted and indexed in repositories, so they can be located via search engines. In comparison to traditional publications, however, research data has special features that require very specific knowledge, for example with respect to document versioning or rights management. Frequent calls for the free availability of research data as part of an open science concept – in other words the extension of the open access idea to areas beyond publishing – conflict with rather strict limits set, for example, by contract or commissioned research or

patent law. Aside from these issues, ensuring the sustainable availability of such data – in some cases perhaps only for specific groups of users – is a task that should be assigned to institutions that provide the necessary infrastructure for academia, including academic libraries, as trustworthy institutions that play an important role in meeting such needs.

(5) Since digital media are no longer characterised by the “starre Verbindung von der Materialität des Mediums und deren Erscheinung als konkrete Publikation” (‘rigid connection between the materiality of a medium and its appearance as a specific publication’) (Stäcker 2010: 727), classic bibliographic terms such as edition, print run, or copy must be replaced by descriptions that are appropriate for volatile digital media. Classic bibliographic descriptions and procedures like those norms laid down in the ISBD (International Standard Bibliographic Description) are inadequate for dealing with the diverse media topology of digital objects. More recent bibliographic models like FRBR (Functional Requirements for Bibliographic Records) borrow concepts from semantic ontologies and attempt to substitute the rigid terminology of classic bibliographic description with dynamic data models, which are intended in particular to reflect the diverse variety of presentation forms in the digital world. One example is RDA (Resource Description and Access), a new set of cataloguing rules that has been introduced worldwide with the aim of internationalising and standardising library cataloguing systems but unfortunately has a variety of inconsistencies that result from its hybrid use for print and digital media.

(6) With the introduction of newer, dynamic data models, the boundaries between formal bibliographic descriptions and subject cataloguing have been blurred, with consequences for both classic catalogues and cataloguing procedures in libraries. The enormous pool of retrospectively digitised media now available from other libraries or institutions via the Internet has meant that classic catalogue concepts, including electronic catalogues like OPAC (Online Public Access Catalogue), are being replaced by search-engine-based discovery systems with functions that resemble Google. These systems not only find books and periodicals held by the institution in question, they identify all available literature and simultaneously offer all licenced full-text resources, generally amounting to more than one hundred million media and thus a much larger body of media than that discovered with earlier catalogues. Since discovery systems offer new forms of subject cataloguing, e. g. full-text searches, classic library subject cataloguing and especially verbal cataloguing, has experienced a considerable decline in significance. The Deutsche Nationalbibliothek (German National Library) in 2017 began successively introducing automatic cataloguing to replace manual subject cataloguing of (individual) print media by library staff based on the subject headings of the Integrated Authority File (German: *Gemeinsame Normdatei*), in order to provide a single catalogue for printed and digital media that is suited for use with modern retrieval systems. The German National Library also plans to incorporate machine-learning processes to ensure that cataloguing procedures will be subject to “cyclic”, ongoing development and adaptation (Deutsche Nationalbibliothek 2015). In

numerous libraries worldwide, verbal and classificatory subject cataloguing by more traditional means involving human intellectual intervention were abandoned some time ago.

(7) Due to the “immateriality” of digital objects, certain material traits of printed texts cannot be reproduced. Nonetheless, substitutive procedures now exist, even for the three-dimensional characteristics that purportedly can only be associated with printed books. These include the gesture-based, touch-free manipulation of three-dimensional digital books on displays (Ceynowa 2014b). Interestingly, discussions about the extent to which print media can be substituted by digital media (Spoerhase 2016) has led to far-reaching reciprocal effects and interactions that are relevant to academic research on the well-known and purportedly obsolete artefacts of the Gutenberg galaxy. Besides the problem of ensuring the sustainable accessibility of digital data – a problem with dimensions that are more or less apparent but by no means resolved in terms of logistics or technology – sustainable access to printed data has been the object of heightened debate in recent years. These discussions have resulted in implementation of concepts for cooperative or centralised storage for “last copies” in numerous countries (Sommer 2017). This is also the case for the long-term digital availability of formats with low to medium risks of format obsolescence (JPEG, TIFF, PDF), most of which are the result of the digitising of printed material and multimedia objects (audio data, photos, videos) and for which tried and tested long-range archival concepts that go beyond mere bitstream archiving are already in place. For objects with a higher risk of obsolescence, for example research data, numerous international projects as well as commercial services already exist. Nonetheless, long-range archiving of digital data is presumably one of the greatest challenges that libraries face when it comes to securing diachronic accessibility as part of a systematic plan for preserving all forms of media.

(8) Besides the need to establish virtual sites for digital data, libraries are currently also experiencing special and heightened demands as physical sites. The most significant modernisation of the type of building referred to as a library, which was described by Leopoldo Della Santa in 1816 in his text *Della costruzione e del regolamento di una pubblica universale biblioteca*, set the standard internationally for nearly one and a half centuries. Della Santa outlined the ideal floorplan for a library encompassing the three functional units of storage, use, and administration. It was not until the second half of the twentieth century that this paradigm began to change, as libraries shifted their focus in the late phase of printed books toward user needs. In this period, the formerly strict division of these three areas was abandoned in order to bring users together with books – which, ideally, were to be arranged systematically – and with the librarians charged with assisting users. This ideal did not survive the digital transformation. Not only did printed texts lose their status as the most important form of information, so that the significance of direct access to a large body of books classified in a time-consuming process also became negligible; it also seemed as if there was little demand for the kind of personal support services provided (e. g.

as bibliographic information) by librarians that had become established under the conditions of the world of print media. With the onset of the digital transformation, the quality of library spaces began to change, as the specific needs of users linked to virtual networks became the prime determinant of library design. In response to these developments, libraries implemented plans for specific room segments and building types to meet the various primary use scenarios. In this process, new rooms were and are being developed and segmented as learning centres, creative labs, or maker spaces or as flexible spaces that offer the latest in information technology equipment.

(9) Just as the spatial constellation of libraries was clearly defined for much of the history of libraries, so too was library organisation. Since the work of librarians became professionalised in the course of the nineteenth century and until well into the late twentieth century, most traditional libraries were managed as line-and-staff organisations. The self-understanding of libraries as administrative entities (with in part the responsibilities of a public administration) and standardised work routines meant that clearly defined hierarchies were deemed necessary and the organisational implementation of bureaucratic forms of authority seemed to be a plausible consequence (Weber 1921–22). With the introduction of new public management schemes and criteria of efficiency, effectiveness, and client service in the civil service sector, modern management skills and a new organisational self-understanding were introduced into libraries. Authoritarian-patriarchal leadership concepts and the associated disciplined subordination of library staff was gradually substituted in favour of organisational cultures that emphasised the delegating tasks, participatory strategies, goal-oriented schemes, and project and team work. Following a period of rather unsuccessful experiments with matrix organisation concepts, libraries have recently begun testing approaches rooted in systems theory and in doing so are relying on self-organisation, network structures, and agile work modes. Monolithic line-staff organisation forms have proven inappropriate in responding productively to the highly dynamic environments in today's libraries, which are subject to rapid and at times disruptive change. This is all the more true within the framework of providing information resources for universities and research institutions, since organisational flexibility of libraries and the individual flexibility of their staff are essential factors in determining successful communication and interaction with researchers.

(10) Parallel to discussions focusing on the contemporary and future institutional role of libraries, there has been a no less lively debate about the demands that library professionals in academic libraries will face in the years ahead. The growing significance of support for research activities underlines the need for improving the academic qualifications of library staff that must draw on professional skills in direct contacts with researchers. The favoured model is now the “embedded librarian” (Dewey 2005; Bonte 2014), who has extensive and well-grounded capacities in the realm of information technology, who can competently discuss issues of metadata formats and concepts for long-range archiving of digital data with IT specialists, actively participate in creating virtual research environments, and develop useful contemporary e-learning

concepts for acquiring and enhancing informational and media literacy. This includes a broad range of systematic courses grounded in appropriate didactic concepts that aim to enhance informational and media skills – that is, the informed and critical use of electronic information, data sources, and media. In the English-speaking world, the term “data librarian” is frequently used to refer to professional library staff members who are expected to fulfil some of these tasks; this term is now also increasingly used in Germany. The classic job profile of the subject librarian whose core responsibilities are selecting, cataloguing, and procuring relevant literature for specific disciplines is now often perceived as outdated.

## 4 Perspectives and approaches

In his ground-breaking study on the demise of written culture and the rise of digital culture, Henning Lobin asserts that the structure of libraries along subject fields can no longer be regarded as the “Leitbild für das Wissen” (‘conceptual model for knowledge’) (Lobin 2014: 252) as long as their self-understanding is rooted in the order, maintenance, and presentation of textual and sequential forms of knowledge that are and have been chiefly associated with printed books as units of knowledge. With his call for a digital library of the future, Lobin is in agreement with relevant recommendations for the development of research infrastructures that have been formulated in recent years (Gemeinsame Wissenschaftskonferenz 2011; Wissenschaftsrat 2012). These recommendations call for intensified and closer cooperation between academic libraries and research and a new self-understanding of libraries as elements of a digital research landscape that is unequivocally client-oriented. Numerous libraries that work closely with research institutions, such as those that are part of universities and institutions of higher learning, have incorporated these demands into their product and service portfolio. Since many of these products and services cannot be provided without a dense, collaborative network on a regional, national, and international level, many participants in professional discussion have expressed the need for a reform of informational infrastructures. They suggest that such a reform should not be limited to local and regional solutions but instead be strictly based on functional divisions of labour that include all institutions (libraries, archives, museums, data processing centres, etc.) that should be involved in creating a national digital research infrastructure. However, in a country like Germany, in which the jurisdiction for education, culture, and research is subject to federalist government structures, propagating the establishment of a national information and research data infrastructure unavoidably involves significant governance issues.

These diverse, complementary, and self-reinforcing processes do not (yet) result in a clear model for the future of academic libraries. In a lecture held in 2013, Ulrich Johannes Schneider referred to the “Urszene der modernen Bibliothek” (‘primal

scene of the modern library’): readers run to the library; they need specific books very quickly. And in fact, just such a description was written by a student of Trinity College in Dublin in 1827 (McKitterick 1986: 612). What will be the “primal scene” of the digital library? In search of an answer to this question, we can currently identify a few factors that are of critical importance for the success of libraries in the digital era:

1. *The development of cultures of academic publishing and media distribution.* A possible success of the open access movement, the replacement of the subscription model for academic periodicals, the ongoing development of low-threshold publication platforms, and the systematic expansion of data collections for research (research data, corpora from data and text mining, etc.), all of these factors could mean that libraries not only continue to fulfil their collecting function in a modified form but in fact extend their activities.

2. *The development of university instruction and of the reading skills of “digital natives”.* The end of the print culture will not be the end of the culture of reading: “Das digitale Lesen und Schreiben ist hybrid, multimedial und sozial, und damit unterscheidet es sich grundlegend vom Lesen und Schreiben, wie es bis dahin in der Schriftkultur gewesen ist” (‘Digital reading and writing is hybrid, multimedial, and social and thus differs fundamentally from reading and writing as it has been a part of print culture to date’) (Lobin 2014: 17). The traditionally close link between sites for storing knowledge and sites for instruction that has been a constitutive element of libraries can be maintained under other framework conditions, since libraries are “specialised in maintaining, providing, and compiling all types of information as the raw material of knowledge” (Lobin 2014: 236–237). Beyond the virtual provision of data, information, and books, new types of spaces and buildings (creative labs, maker spaces, etc.) could actively support situated learning. “A hub is a place where people and information come together. This Strategic Direction will further develop research libraries as a hub for digital skills and services in both physical and virtual research environments” (LIBER 2017: 12).

3. *The systematic digitisation of analogue collections.* By systematically digitising collections and using pragmatic but effective forms of cataloguing (full-text recognition, geo- and time-referencing, thematic navigation, etc.), new kinds of collections emerge that are attractive for academia as well as the broader public. Such developments offer opportunities for democratising knowledge beyond the realm of marketing strategies pursued by dominant commercial service providers like Google and have the potential to rekindle ideas proposed in the early phase of the Internet (Darnton 2017).

4. *Cooperative plans for preserving knowledge as an essential cultural task.* Discussions about digital forgetting reveal that designing and implementing plans for digital preservation based on transparent rules is an important social and political issue. As respected, trustworthy, and sustainable institutions for preserving societies’ textual knowledge memory, libraries are also well-equipped for assuming an important role in the digital world.



Various perspectives and approaches that are relevant to all four aspects outlined here currently compete with one another and indicate that the current state of development is marked by uncertainty as well as hasty activity or lethargy, as the case may be. But in today's digital age, that holds true for many areas of public life, not only for academic libraries.

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## 30 Scholarly communication in social media

**Abstract:** Social media enables scientists to cooperate and collaborate from various places around the world – considerably enriching their worlds intellectually. Utilising social media, researchers engage personally in processes of creation both as participants and critics, gaining access to different publics and audiences in- and outside academia. Furthermore, social media facilitates opportunities to improve traditional patterns and techniques of scholarly communication and publication. However, promises of democratisation, participation, and transparency have not yet been fulfilled, despite a flourishing practice in scholarly use of social media. It is, so it seems, a highly controversial subject, touching the fundamentals of our research culture: The ways in which research is done, organised, and published, in which knowledge is created and evaluated, and how research results are communicated with peers and larger audiences. This article addresses these interrelated questions by asking how the use of social media effects forms and principles of scholarly communication and publication in- and outside academia.

**Keywords:** scholarly communication – social media – scientific blogs – Twitter – alt-metrics – citizen science

Computers and the Internet have fundamentally changed the way in which researchers communicate and collaborate. Beginning in the early 1990s, scholars were able to simultaneously work on text, images, audio, video, and code while living in different places and time zones. While email, newsgroups and online chats allowed a many-to-many communication in the virtual space, the most important recent developments in online scholarly communication came along with social media: With microblogging, blogs, wikis, and Social Network Sites (SNS) such as Facebook, Academia.edu, ResearchGate and others. Thereafter, barriers for online publishing and communication have been reduced significantly. Production processes that needed professional knowledge, equipment and capital can now be executed by ordinary individuals with a computer and Internet access, in theory allowing every individual to join the conversation. Multimedia can easily be integrated without increasing costs. Communication became mobile and ubiquitous with the advent of mobile devices and cloud storage, and the quantity and speed of publications and communication increased exponentially. Subsequently, the scholarly communication ecosystem became broader, quicker, interactive and dialogical, highly dynamic, multimodal and growingly interconnected. With alternative perspectives becoming visible and social media encouraging creativity, science seems more vivid, more open, and more transparent. Many researchers saw a disruptive potential in social media, awaiting democratisation, participation, decentralisation and transparency of communication processes inside academia.

But despite high potentials and some fundamental changes, the revolution in the communicative dimensions of scientific activities some hoped for did not take place: Reputation and career opportunities, especially in the humanities, remain linked to traditional communication and publication channels. Furthermore, old structures and hierarchies seem to re-emerge in social media, filter-algorithms, and online behaviour foster closed gates, echo chambers and filter bubbles. Researchers are quite vigilant when it comes to changing established formats of publications and communication. Ambiguous reward systems, liquid formats, fear of loss of reputation, fear of plagiarism, blurred boundaries between audiences in- and outside academia, and new ways of evaluating research outcomes are the notable reasons for the coexistence of a flourishing practice and continued resistance with regard to scholarly use of social media. What has become clear throughout last year's research and discussions is that social media in academia is an emotionally sensitive subject, touching the fundamentals of our research culture, as they are questioning the ways in which scholarly communication and publication processes are organised and evaluated.

This article gives an overview of scholarly practice that utilises social media, with a particular focus on internal scholarly communication and publication. What has changed, and what is radically new within these digital practices? What are the challenges, limitations, and affordances of social media in knowledge production? This article will firstly look at current research on social media and science. Part 2 will deal with reasons why scholars do or do not use social media in research along with researcher's strategies before turning to questions of participating and reaching out to new audiences in part 3. Part 4 will exemplify three fields in which social media has had an impact: information gathering and curation; scholarly blogs; evaluation and altmetrics. As a conclusion (part 5), we will deal with perspectives and future trends of scholarly communication in social media – focusing on internal scholarly communication of individual researchers in the humanities and social sciences.

## 1 Research on the scholarly use of social media

Until today, definitions of social media remain ambiguous, likely due to the dynamic character of the field with a landscape of tools and platforms constantly changing. Social media is mostly used as an umbrella term for media that are highly divergent with regard to their functions and diffusion. In general, they include online tools and platforms that allow users to generate content and interact with each other and each other's content (Schmidt 2018: 11; Sugimoto et al. 2017: 2039). There is a puzzling multitude of social media, differing in technical and legal aspects as well as in function and purpose. Often, the following categories are used to classify social media: Social networking, social bookmarking, blogging, microblogging, wikis, media and data sharing. Next to platforms for a general public like Facebook and Twitter, used by

a growing number of scholars, other platforms exist solely for scientific purposes: Academia.edu and ResearchGate for social networking, Hypotheses, Researchblogging and SciLogs for scientific blogging, Zotero and Mendeley for collaborative social bookmarking, Slideshare for presentation sharing, Figshare for dataset, video and other file sharing, or Github for software code sharing, to name a few. Platforms are designed for public or semi-public interaction. They can be non-commercial and open to everyone with Internet access. They can be closed upon acceptance of a personal demand or application, or they can be hidden behind paywalls following a commercial aim through advertising or selling of membership lists, products, services, and subscriptions. Depending on the different platforms and their settings, following other accounts (personal or institutional) can be unilateral (Twitter, Academia.edu) or must be reciprocal (WhatsApp), with some SNS such as Facebook, recently offering unilateral subscriptions. The way of “following” or getting in touch with each other in a professional scholarly environment must be tactful; as colleagues or students are not “friends” and some researchers hesitate to use platforms for scholarly purposes when they had been designed for personal exchange originally. An important feature of many commercial social media platforms is their monopoly position; they exercise a stronger attraction the bigger they are. Generally, communication outside a social media platform is prevented or barely possible, unlike email, where open protocols allow communication between independent or competitive networks and providers. Users usually have no influence on technical, organisational and legal developments of the platforms.

Despite being a rather recent phenomenon, research on scholarly use of social media has grown significantly during recent years (for a comprehensive overview see Sugimoto et al. 2017). Empirical research on the use of social media is done through questionnaires, qualitative interviews and participant observation studies. These studies explore practices from the inside, asking scholars about their methods, preferences or resistances with regard to scholarly use of social media (see for instance Ponte and Simon 2011; mostly for UK, Bader, Fritz, and Gloning 2012 and Pscheida et al. 2013 for Germany). Other fields of research explore digital practices and online communities from the outside; for instance, analysing content and language used in social media or studying networks via links, replies, retweets, or other digital and hermeneutical methods. Both types of study generally show a wide range of different uses, purposes and motives, depending on platform, on academic rank and status of a scholar, on gender and age as well as varying across disciplines, countries and geographic regions. Furthermore, due to different data gathering methods, data samples, time of analysis and platform analysed, results presented in the studies are contradictory or even incomparable and call for cautious interpretations. Studies agree that social media is more widely used in hard sciences than in the humanities, and that although women do use social media extensively, social media in science is mostly male-dominated (Sugimoto et al. 2017: 2046). But there are differences: On the platform ResearchBlogging, only 18 % of the blogs were written by female scholars

(Shema, Bar-Illan, and Thelwall 2012) whereas on the German blog platform Hypotheses for humanities and social science the gender ratio was equal (König 2013b: 187). Percentages of scholarly use of Twitter also fluctuate, ranging from 5 % to 32 % according to different studies, a difference that can partly be explained as studies mostly do not distinguish between personal and professional use of social media by scholars, with the former being much higher than the latter (Sugimoto et al. 2017: 2039). German researchers seem to be more reluctant than researchers from the UK regarding the use of Twitter: Whereas Wikipedia was used by up to 98.9 % of German researchers answering a survey in 2013 (Pscheida et al. 2013: 18), in 2017 only 13 % of German researchers used Twitter for professional aims compared to 17.7 % of scholars from the UK (Ponte and Simon 2011: 150). Furthermore, several studies suggest that scholarly use of Twitter varies greatly across disciplines: Scholars from social sciences tweet more often (1.40 Tweets per day) compared to scholars from the natural sciences (0.61 Tweets per day) (Haustein, Sugimoto, and Larivière 2015). Whereas, in biochemistry researchers retweet more often, scholars in digital humanities and cognitive science discuss more, and researchers in economic sciences share links more often than scientists in other disciplines (Holmberg and Thelwall 2014; see also Pscheida et al. 2013: 33). In summary, findings so far can hardly be generalised, and more specified research on scholarly use of social media is needed.

Communication and media research has underlined that internal science communication has always been shaped by technical settings (see for instance Gloning 2011: 7). This also applies to social media, where platform settings, algorithms, features as well as legal questions open up possibilities for scholarly communication and at the same time close other possibilities. In some mailing lists for instance, sending attachments with a mail is not possible. Social media platforms are not just channels for transporting information, but are environments in which we live, they do not simply reflect the world but generate it (Stalder 2016: 225–226; see also Chapter 28, this volume). Furthermore, there is an unspoken cultural code that defines the rules of participation, the necessary technological and linguistic knowledge, knowledge on informal culture, humour and preferences when using social media (Stalder 2016: 157). Most social media formats present a wide scope of use scenarios and are relatively open concerning their functions, as can be seen with blogs for instance. This partially results in unclear formats and undefined practices, that are somewhat seen as a threat to more traditional publication channels. The uncertainty along with the fear of engaging in time consuming practices and issues of assessment and changing evaluation practices, is one of the main reasons why social media has not been fully accepted in academia. At the same time, it is one of the reasons why avid users of social media experience it as a fundamental liberation in the hitherto highly regimented academic communication ecosystem.

## 2 Reasons, strategies, and reluctance

What would we do without social media? Sitting alone in our rooms, brooding, writing for 2–3 readers, keeping private and academic work much more separated [...] for those who still remember. Not having met so many people! And having missed so many friendships. (Demantowsky 2018, transl. MK)

Engaging with social media is time consuming, therefore researchers have a pragmatic attitude and only use social media for scholarly reasons if they see a concrete benefit. Use rates of social media in academia might differ as we have seen, but studies unanimously highlight that scholars chose their social media and platforms thoroughly, and follow individual strategies with diverging motivations (Van Noorden 2014: 127–128; Pscheida et al. 2013: 1, 6, 24–26; Gloning 2011: 20–21). Different formats and media are coordinated by researchers in a tactical and intentional way. Concepts of motives for the use of social media are similar, and include consuming (information), participating (social interaction, community development), and producing (self-expression, self-actualisation) (Linek et al. 2017: 3). Mainly, researchers use social media for information motives, researching, networking and reputation. They want to share and discuss ideas and content, disseminate their research results, get higher citation rates, engage with scholars all over the world working on similar subjects or sharing the same beliefs, foster new cooperations and publications, and discover research output of other scholars. Even if social media does play an important role for networking and community development, social aspects like maintaining relationships seem to be less developed amongst academics compared to the non-academic world (Linek et al. 2017: 3). Still, social media is widely used for informal communication similar to exchange and discussions in front of the coffee dispenser. It can serve as a “social lubricant” for spatially separated research groups, allowing real-time exchange and daily virtual chatter.

In addition, researchers engage with social media to manage their digital identity and create an academic online *persona*. Especially for young scholars who often change jobs at the beginning of their career, social platforms can be a means to gather information on their academic life at one place. In this regard, sites like Academia.edu serve as an “online business card”, and are instruments to “construct and display scholarly identity” (Sugimoto et al. 2017: 2039; see also Van Noorden 2014: 127), despite the growing critique towards Academia.edu after having turned parts of its services into paid features. To be aware of potential audiences and to shape one’s self presentation according to certain strategies is an important aspect of handling social media competently and in a self-determined way (Schmidt 2017: 94). Thus, it has become a strategic tool for researchers how to present oneself online, what to share, with whom to share, with whom to connect, what to tag, what to delete, and when to maintain privacy.

Higher education and research institutions, funding agencies, publishers and journals have also increasingly adopted social media in recent years (see Chapter 22,



this volume). They follow their own strategies and mostly aim at disseminating research results of their scholars as well as publications or other products to a wider audience. Some institutions encourage their researchers to use social media, as institutions depend on their scholars to demonstrate societal impact and relevance of their studies through communication with society. Social media is an efficient means of achieving this goal, for blogs, wikis, Twitter and other media are open and can be read by everyone, whereas publications on other SNS are usually only accessible for users of that platform, depending on privacy settings. Nonetheless, some institutions perceive social media use by their researchers as a potential risk as they have no control over scholars claiming affiliation and communicating via social media. The majority of scholars tweet and blog under their real name, as they want to be identified and recognised, receive credit for their engagement and use the media for networking (Sugimoto et al. 2017: 2041).

Research studies also highlight why scholars are reluctant when it comes to academic use of social media: Firstly, there is a lack of rewarding social media activities in academia, and researchers are concerned that engaging in social media can be time consuming without any return on investment. Career opportunities especially in the humanities depend on monographs and peer reviewed articles; while a blog-post might bring attention, it merely holds reputational significance. 31 % of German researchers, taking part in a survey 2013, stated that they simply do not see any added value in using social media, and 22 % quoted that they see no need for technological support in the areas covered by social media (Pscheida et al. 2013: 26). Other researchers in that same study showed concern about privacy settings in social media, also criticising terms of use of some SNS, stating the wish to separate professional and private life (Pscheida et al. 2013: 16). With regards to the increasing amount and speed of communication, some researchers are afraid of suffering from information overload and fear that colleagues mainly discuss irrelevant and insignificant bits and pieces on social media. Furthermore, researchers fear plagiarism if they communicate openly about current research projects, especially in highly competitive research areas such as climatology or medicine. These fears are directly linked to four main characteristics of digital networked media: communication in digital media is mostly persistent (the Internet does not forget); digital data can easily be copied; the range of online information is potentially unlimited; digital media are searchable (Schmidt 2018: 36–37). Consequently, it is almost impossible to control information once published, leaving scientists uncomfortable. Hence, they prefer to control information regarding themselves or their published works due to the profoundly pertinent linkage to reputation and career.

### 3 Social relations and reaching out to new audiences

Social media has been heralded a means to overcome traditional academic hierarchies. However, a study based on analysing replies, mentions, retweets and following behaviour of computer scientists underlines that offline hierarchies remain influential in the online world. As connections on Twitter are not reciprocal by default, the study proved that more prominent users “are more likely to maintain reciprocal relationships among each other than with non-elite users” (Linek et al. 2017: 4). Hence, a large number of PhD students unilaterally follow professors, whereas only few professors unilaterally follow PhD students. Moreover, gatekeepers curating newsfeed can create similar structures online than in the offline world. Even if there are no rules established from above and no formal hierarchies, those who can add to online communities gain authority and capture a central position within as it is advantageous for the whole community (Stalder 2016: 163). Still, to contact or address scholars on social media is often perceived as less intimidating for students.

The online world has changed the relationship between science and the interested public in several ways concerning knowledge access, knowledge reception and knowledge production: Content previously restricted to specialists is now available to a wider audience; direct and continuous communication between scholars and the public is possible; active participation in research is simplified and expanded. Specifically, social media may – in theory – build bridges and provide a knowledge transfer to the interested public. Scholars using social media can also reach out to journalists and politics, creating diverse networks with media. So far, however, “social media has opened a new channel for informal discussion among researchers, rather than a bridge between the research community and society at large” (Sugimoto et al. 2017: 2060). Studies show that researchers do not write for the unknown masses but for their larger social network and mostly for their peers, a small, but interested and knowledgeable circle of colleagues (see e. g. König 2019: 19). Social media thus mostly serve the internal scholarly communication. However, a study on Twitter followers based on 116 marine scientists shows that around 55 % of followers of these scientists are science students, scientists or scientific organisations whereas non-scientists, media and the general public make up 45 % (Darling et al. 2013: 10–11).

As for external science communication, universities and research institutions actively use social media to communicate research findings to society but also to get in contact with young scholars. Next to Instagram, Facebook is playing an important role in that form of external science communication (Lobin 2017: 233). Boundaries between internal and external communication blur just as much as between external science communication and public relations. The corrective and monitoring role of science journalists in this system has recently been recalled by a German working group, formulating recommendations for science communication in social media. Science com-

munication might degenerate into a “fight for public attention” (Weingart et al. 2017: 23). Moreover, social media arrived at a moment when the central position of academic science in production of knowledge and findings was diminishing and science needed to prove its capacity to find answers to urgent societal matters. Doubts in neutrality of science arose as traditional channels of assured information dropped out, and the new actors and channels have not gained authority, leaving it sometimes unclear who communicates in what interest. Social media therefore does not seem to strengthen confidence in objectivity and neutrality, but generates distrust of experts and facts that are politicised (Darling et al. 2013: 24–25). Until now, the expected changes in the relation between science and society did not take place the way it was suspected.

Social media creates possibilities for the lay public and amateur scientists to participate in research (citizen science) and to co-finance science projects (Crowdfunding). They allow the use of technology to involve a wider audience and to co-create knowledge through distributed labour and public engagement. Despite academia being a relatively closed social system, citizen science is not a new idea, but contributing to a larger scientific project in the age of digital media has become much easier to organise (Dickel and Franzen 2016: 2). Crowdsourcing – a word mix of crowd and outsourcing – is a widely used practice, ranging from contributing to Wikipedia, proofreading texts on Project Gutenberg, tagging images on Flickr, to contributing to open-source-software (Terras 2016: 421). The Open Air Laboratories (OPAL) in the UK, a network of citizen science projects, gives an overview of the diversity of projects with volunteer participation. A well-known example is Galaxy Zoo, nowadays including over 30 projects, that started with the classification of galaxies by more than a million citizen scientists (Dickel and Franzen 2016: 4). In the humanities, the public can participate to complete online collections like the World War I collection of the European online library Europeana through uploading of texts, pictures and objects. Citizen science projects even entrust society with more complex activities generally carried out by scholars like transcribing, translating or correcting text scanned and automatically detected through optical character recognition (OCR). It is not only the shared labour, but the shared expertise that contributes and enriches scholarly content, ranging from little to high level of expertise (Dickel and Franzen, 2016: 6–7). The history project PhotosNormandie (<https://www.flickr.com/photos/photosnormandie/>) for instance, consisting so far of 3000 black and white photos on Flickr and 300 films on YouTube of the battles in Normandy during World War II, has managed to identify persons, streets and buildings shown on these pictures through tagging by the lay public. Within these projects, boundaries between producers and recipients are fading and a new type of interconnected knowledge is produced that can lead to a deeper understanding of coherence and connection of certain topics. However, participation in research is limited due to often high degrees of specialisation, and some see the blurring boundaries between professional and general public as a risk if this comes along with circumvention or repeal of traditional control and assessment mechanisms which weakens the confidence in expertise (Weingart et al. 2017: 23).

## 4 Scholarly social media practices: three examples

Social media does not replace traditional ways of communication. Online communities overlap with communities in the physical world meeting at standard academic outlets such as conferences, workshops and common publication venues. Instead, social media acts as a complementary component, expanding the community. The long-time highlighted dichotomy between real and virtual world is wrong, as online and offline interaction take place in the same social realm (König 2019: 3, 19; Fernback 2007: 54). What people do on the Internet has real consequences, be it anger, joy or pride, that the person feels in front of the screen (Schmidt 2018: 22–23). It is the offline counterpart that adds the stability to online communities (Salah, Scharnhorst, and Wyatt 2015: 87). In addition, researchers who use digital technologies often hold more face-to-face meetings (Scheliga 2015). In general, researchers appreciate the flexible, fast and immediate forms of communication enabled by SNS and social media tools. Scholarly networks, therefore, are multifaceted and transcend sites, lists, applications, and infrastructures as well as digital and analogue spaces. Social media can be used in all steps of scholarly activities, ranging from information gathering, data management and cooperation to knowledge circulation and distribution, along with teaching and learning (König and Netwich 2012: 12–13). In the following, we will look at three main fields in which social media has had an impact over the past years: first, information gathering and curation, second, communication and publication and third, evaluation of research output. These spheres are intertwined and are not meant to be definitively separate categories as they might appear through the chosen chapter sectioning for analytical reasons.

### 4.1 Information gathering and curation

In an environment where information seems to be endlessly available, filtering mechanisms and curating services become highly important. Researchers must stay up to date on developments in their research fields and filter potentially relevant information in a rapidly increasing influx of information. This, however, is not new: in the late 1940s scientists feared being overwhelmed by the sheer amount of potentially relevant publications, which led to the creation of citation indexes and bibliometric methods (Haustein, Sugimoto, and Larivière 2015: 1). Since then, the flood of scholarly publication and information has increased exponentially. Social media is on the one hand, part of this process (and problem) and on the other hand, offers a solution for it: curation, a “central component of digital media practice” (Davis 2016: 770), is to choose and highlight what is important, noteworthy or relevant to oneself or to the community one belongs to. In general, the interest group itself is the best device to filter and curate information. What we read on the social web is defined by our increasingly complex community as well as by algorithms and the design of platforms

that determine beyond our influence what is shown to us in our “timelines” at a given moment. Organised around a subject, online communities offer high-grade personalised information, which result in their value for the researchers. With every status update, blogpost, or slides and pictures uploaded, researchers filter, sift, collect, sort, and share, and give meaning to topics and the academic world around them. The value of this action is the time optimisation: Researchers validate something that is excessively available: information, with something that is scarce and precious: their lifetime (Stalder 2016: 118). Along with filtering interesting and relevant information, curation allows serendipitous discoveries, i. e. unprecedented information that becomes profoundly inspiring and beneficial to the research.

Twitter proved itself to be a valuable system of recommendation, where subjects can be filtered and concentrated and where one’s own “personal public” can be reached, i. e. the larger social network of friends, colleagues and acquaintances based on shared scientific interest or on sympathy (Schmidt 2018: 29; Schmidt 2017: 94), a network that is considerably enlarged on the social web into substantially larger “virtual departments” (Darling et al. 2013: 8–9). On Twitter, researchers follow accounts from scholars and institutions they are familiar with or accounts that post relevant information. They are likewise followed by people interested in their curated news-feed. As a result, every researcher has the timeline he or she has chosen herself for informational, social or strategic reasons. Reading one’s Twitter feed or the postings on SNS-groups in the morning can therefore be of greater interest for the individual researcher than leafing through the morning paper. In their timeline, scholars get to know the latest publication from a befriended scholar. They see the programme of a conference related to their research topic, taking place far away on the other side of the planet. One may notice a retweeted blog post by an unknown researcher giving advice for a new digital method they are interested in. An offer for an interesting summer school might pop up just after the Tweet of a loosely known colleague about the funding she got for a new project. The university library may be announcing today’s unforeseen closing of the reading room. And a journal sends out the table of contents of its latest issue. Scrolling through their timeline, scholars will also have to skip publicity, cat pictures, Tweets from bots (up to 15 % of active Twitter accounts), and Trump-bashing-Tweets, unless they take effort in using lists and muting specific hashtags to get rid of unwanted content.

Timelines and groups, however, are not only a place to gather personalised information and to share own research findings, but also to ask questions of the assembled experts. On Twitter, a question using the hashtag #followerpower can travel far across a wider personal connected network. Social media can therefore have a high benefit for research, and substantially stimulate and enrich researchers intellectually. Active members of an online community derive the most benefit and satisfaction from their participation, whereas passive members highlight the information benefits they get out of communities (Stalder 2016: 118). In general, large parts of community members stay passive and only read or receive blogs, wikis and multimedia, just the same way

they did when using traditional media like print, radio or TV (Pscheida et al. 2013: 17). This is symbolised in the somewhat rough, but noteworthy 90-9-1 rule: 90 % of users stay passive and only read information, 9 % occasionally participate through postings or comments, whereas 1 % of users are responsible for up to 60 % of all the content on social media (Schmidt 2018: 93).

In some disciplines, Twitter is increasingly used at scientific events and serves as a digital “backchannel” communication, that is non-verbal, real-time communication that does not interrupt the speaker (Ross et al. 2011: 215). This is due to the fact that scientific conferences often present an unsatisfactory communication situation: one person talks while the others have to listen and remain passive. Discussion, exchange and interaction often fall short. On Twitter, participants may make notes, comment on talks, share resources via URL, hold discussions, widen their network through adding of contacts, and publish pictures of the event. In doing so, they provide extended information and create a second level of discussion. The assembled Tweets create a live, polyphonic and multimedia conference report for the interested researchers (König 2013a: 408; Ross et al. 2011: 214). Moreover, following the hashtag of an event allows researchers not attending the conference not only to get an impression of the event, but even to participate in the discussions. Thus, Twitter is said to be the most interactive of all social media also regarding its scholarly use (Van Noorden 2014: 127).

## 4.2 Communication and publication: scholarly blogs

The easy accessibility of publication media such as blogs, from the turning of the millennium onwards, made it possible for researchers to take over the decision when, where and what to publish. This self-determined adoption of a scientific publication space is a spectacular move, similar to the invention of “essays” by Montaigne in the 16th century or the emerging of the “Republic of Letters”: a scholarly network exchanging letters and journals from the middle of the 17th century onwards (König 2015: 58). Scholarly blogs are a place to publish and discuss ongoing research between peers as well as channels of self-promotion. They allow insights in the laboratory or the workshop of a scholar and therefore show “science in the making”. Scholarly exchange through blog posts, comments and links is interactive, rapid and direct in a unique way that is not possible or not practised in other publication formats like mailing lists or journals. Blogs can be seen as the missing link between oral communication in conferences or university seminars and written communication in traditional articles or reviews published in a journal. Blogs enable scientists to make a direct connection to their peers and students, while bringing them closer to the general public at the same time. Thus, blogs can enhance scholarly exchange by allowing informal and more permanent communication accompanying teaching or research projects from early stages on.

The scholarly uses of scientific blogs are numerous, depending on the researcher's strategy and aims when opening a personal online journal, a *carnet de recherche* (research notebook), as it is called on the French blog portal Hypotheses. Going through the category "About" on blogs on the German speaking part of the platform for instance, scientific bloggers state as their first motivation the wish to share and discuss their research topic, to enhance online reputation, position themselves in academia and to cultivate networks (König 2015: 59; see also König 2019). Furthermore, researchers want to practise and improve writing and express themselves creatively, beyond the formal criteria and limits of peer review articles. Since ideas are often only put in order when written down, blogs serve the clarification of thoughts, the reason why Torill Mortensen called her blog "thinking with my fingers" (Mounier 2013: 58). Some researchers state that blogging provides a feeling of being connected in their work to other researchers (Mewburn and Thomson 2013: 1107; Kjellberg 2010). Blogs can act as a documentation for research projects, a sort of digital card box, accessible via tags, keywords and categories. Some blogs function like journals: they have an editorial board to invite authors, correct and edit articles and to make sure that blog posts are catalogued in traditional bibliographies and library catalogues. Since blogs can be assigned an ISSN the acceptance of blogs as scholarly publication channels has increased, as libraries treat them in the same way as ongoing publications like journals or series (König 2015: 62).

There is a wide diversity of content published in scientific blogs. Some scholarly bloggers strictly only write about their research topic. Others discuss academic work practices, give career advice or use the blog to accompany their teaching. Very often, scholarly blogs focus on academic culture critique (Mewburn and Thomson 2013: 1110), although this seems to be less the case in the humanities (König 2019: 15). All in all, blogs make researcher appear as hybrid *persona* and prove that academic interests of a scholar are much wider than her or his funded and published research (Mewburn and Thomson 2013: 1114). Moreover, the different and informal style used in blog posts highlight the diversity of scholarly writing and the variety of perspectives. In scholarly blogs, it is possible to write in first person singular, to write committed, witty, creative and in essayistic style, to use smileys or strikes, to embed code, pictures and video. Researchers are freed from the rigorous stylistic and formal constraints of traditional academic publication. Thus, blogging is a "fun practice" since blogs are publication spaces that can be freely designed by the researcher. The other side of the coin, however, is that blogs are not protected spaces, they are openly visible on the web. Many researchers find it difficult to publish unfinished or emerging ideas. They are afraid of being mistaken and do not want to make individual erroneous paths public. The fear of plagiarism also holds scholars back from being too open about actual findings and current projects.

Exploratory studies suggest that neither in the choice of language nor in the selection of topics, blogs adapt to lay audiences (König 2019: 19; Mahrt and Puschmann 2014: 4). Blogging scholars mainly want to communicate with their peers and do not

actively address the general public. Researchers are mostly writing for themselves (Mewburn and Thomson 2013: 1113). However, blogs like “The Recipes Project” (<https://recipes.hypotheses.org/>) that publishes on the history of recipes between food, medicine and magical charms, reach out to more than 12,000 unique users a month, thus certainly exceeding the narrow circle of expert colleagues. Given blogs are open access, they are also noticed by lay audiences. Scholarly blogs benefit from high ranks in search engines – enabling topics with societal impact from fields like medicine, psychology and social sciences to receive high traffic and thus high visibility. Just like Twitter, scientific blogs are read by journalists and often get high media attention (König 2015: 72; Mahrt and Puschmann 2014: 14; Darling et al. 2013: 18). Blogging researchers also participate in reviewing and discussing scientific research published on other blogs as well as in journals. An article published in the journal *Science*, for instance, received severe critiques on blogs so that eight “Technical comments” were published next to the article in the printed issue (Mahrt and Puschmann 2014: 1; Gloning 2011: 28).

Blogging is seen as a highly interactive practice (Mahrt and Puschmann 2014: 6) although comments seem to have become more scarce on humanities and social science blogs, given discussion has been moved from blog articles to Twitter, Facebook or other SNS from which the post was advertised (König 2019: 12–13; König 2015: 72). On the blog hub SciLogs hosting a majority of researchers from the natural sciences, articles get five comments an average. Blogging stars like the Austrian astronomer Florian Freistätter, in turn, regularly hosts between 50 and 100 comments per article (Lobin 2017: 226).

Although blogs have the potential and certainly did enhance the exclusive structure of the scholarly publication ecosystem, they have not replaced traditional publishing nor inverted academic power hierarchies. Several studies show that researchers remain sceptical about blogs both as a place for discussion and as a new place for publication (Mahrt and Puschmann 2014: 2). Most scholars do not want to invest their time in publications that do not contribute for their career, despite “anecdotal evidence of the use of blogs in promotion and tenure” (Sugimoto et al. 2017: 2041). However, almost 30 % of researchers surveyed in the already mentioned German study of 2013 claimed to use blogs (reading, commenting, publishing), a relatively high number. And a more recent survey underlines the strategic use of blogging as a scholarly practice (König 2019).

### 4.3 Evaluation and altmetrics

Activities on social media have been identified as a potential means to measure impact of scholarly research, referred to under the neologism *altmetrics* (see also Chapter 28, this volume). Altmetrics is a short form for “alternative metrics” or “article level metrics”, describing the fast, dynamic and crowdsourced evaluation of research



based on activity in digital media and online environments (Priem et al. 2010). To show the impact of an article, international publishers as well as leading journals such as *Science* and *Nature* not only display downloading and viewing statistics next to journal articles but also indicate how often a given article has been commented, cited, mentioned or shared on social media, adding up to the altmetric score. The non-commercial open access publication project PLoS (Public Library of Science) groups data providers according to the different actions scholars have performed around an article: view, save, discuss, recommend and cite. This classification represents the growing grade of interaction recipients perform with a publication (Franzen 2015: 229). Data is mostly taken from bookmarking services like Mendeley and Connotea, or from blogs, Twitter, Facebook, Wikipedia and also include traditional citation services like Scopus, CrossRef and Web of Science. Several service providers like Altmetric.com, ImpactStory.org, and Plum Analytics are calculating and visualizing altmetrics based on data coming from different sites, using different algorithms (see Franzen 2015). The increasing interest in altmetrics is reflected in the rapidly growing research literature (for an overview see Sugimoto et al. 2017; Franzen 2015).

Different to the traditional journal impact factor, altmetrics do not measure the impact of the place of a publication – the journal – but the impact of the article or in some cases the scholarly product; since altmetrics can even be used to measure the impact of presentations on slideshare or software code on Github (Franzen 2015: 225, 230; see also Chapter 28, this volume). Furthermore, unlike citation indices, the data is automatically generated and includes data from scientific and lay audiences alike, as a Tweet mentioning an article can be from a scholar or an interested non-academic person. Altmetrics therefore not only consider scientific, but also societal dissemination of research. Service provider ImpactStory attempts to filter the author and distinguish between scholars and the lay public (Haustein, Sugimoto, and Larivière 2015).

Altmetrics have been subject to criticism. According to several studies, for instance, Tweets mostly only mention the article title (42 %), or give a short summary of the content (41 %), but hardly ever participate in active discussion about the research findings (Sugimoto et al. 2017: 9). Papers with funny, controversial or interesting titles (sex sells!) and curious topics are mentioned more often and therefore get higher altmetrics scores (Haustein, Sugimoto, and Larivière 2015: 6). Furthermore, critics of altmetrics underline that these scores hardly show the impact or relevance of an article but rather indicate its attention, dissemination and maybe popularity. Some take critiques even further, stating that altmetrics do not even measure traffic rates but show a researcher's performance on social media platforms. Similar to bibliometrics, altmetrics also do not differentiate between positive or negative resonance of a publication, and the danger persists in the misinterpretation of resonance for quality (Franzen 2015: 233).

In addition, data collection techniques and variability among sources and time of collection also cause concerns regarding the reliability of altmetrics. Much more than bibliometrics, altmetrics can be manipulated. A problem thus is found in the heteroge-

neity of the collected data coming from different platforms, where half or completely automated accounts (“bots”) can cause strong bias (Haustein et al. 2016), while platforms like ResearchGate and Academia.edu are not taken into account in altmetrics due to missing API, the requirement for data retrieval. Consequently, altmetrics might, similar to bibliometrics, be mostly “driven by data availability rather than by crafting indicators based on specific concepts” (Haustein, Sugimoto, and Larivière 2015).

Even if there seems to be a link between the mentions of academic articles on Twitter and downloading statistics and citation numbers (Schmidt 2017: 97; Franzen 2015: 233), the majority of studies have so far mostly shown little correlation between citations and different social media metrics. For now, altmetrics are rather seen as complementary than as alternative to traditional impact measurement, therefore other designations such as “social media metrics” are under discussion.

## 5 Perspectives

Scientists use social media in flexible and creative ways, allowing new forms of communication, collaboration and publication. Scientists follow their own strategies, choose their social media tools thoroughly and combine them corresponding to their respective and changing communicative goals and needs. Their knowledge on the positive and also negative effects of social media is based on experience, and it is difficult to hand on this knowledge to other researchers. Scientists have to try out social media and take action themselves; advantages and benefits are barely comprehensible and palpable just in theory. Social media is highly dynamic and subject to constant changes. Even though some of the tools and platforms will certainly become outdated, the “multi-directional exchange of information” will probably continue to be of long-term importance for scientific communication (Darling et al. 2013). However, the platform-based architecture has led to a dependency of the users on the services. As platforms are constantly being revised and improved – a state of “perpetual beta” (König and Nentwich 2014: 2) – routines for their use will only be able to adjust to a limited extent in the future. Furthermore, the lack of interoperability of services prevents cooperation and exchange of content. Therefore, users must be active on multiple platforms at the same time. They must communicate content several times and potentially read it several times.

We will not deal with technical developments in this short outlook – which will probably take place in the areas of automation, data integration and networking (Lobin 2017: 235) – since such technical outlooks as well as use scenarios almost always prove wrong. The focus is rather on future research concerning social media use in science. Thus, it will be of great interest to see how the blurring of boundaries between public and private, internal and external science communication, between expert and layman, between journals and blogs, etc. will develop in the future. Future

research on communicative processes in science will find important subjects therein (see Chapter 28, this volume). Whereas research on social media in the first years often focused on potentials of social media – not infrequently trying to advertise its benefits – other research fields have meanwhile opened up, not yet extensively explored. More research is needed for instance on gender related differences and perception in the use of social media. Although gender disparities are documented, studies so far provide mixed results regarding use, content and perception (Sugimoto et al. 2017: 2046). Another topic of research will be dysfunctional communication forms like defamation, online mobbing, bots and fake news and their effects on internal and external science communication. More research is also needed to make well-founded statements on the interrelation between physical and virtual spheres including the reproduction of social structures of the physical in the online world. Processes and phenomena from both worlds are recorded in each other. But are they being transferred back in a changed and hybrid form? If old practices can be seen in the new environment, do they also lead to new practices in an old environment? Are conferences, personal communication, articles, reviews, etc. influenced by the new communication forms in social media? It is a well-known fact that in general language is changing in social media. But are there effects back on language and structure of scientific texts published in traditional publications? Do scientists write in a more dialogical way, use shorter sentences, integrate more pictures and illustrations also in their printed work? Is there a tendency to more collaborative writing – including in the humanities? It will also be of interest to see which new methods and analysis methods in social media will prevail in the areas of impact assessment and quality assurance, and not least which measures are taken to prevent manipulation. Moreover, the new forms of communicative and social interaction come along with several changes with regards to the production of knowledge and thus epistemological processes. Social media change the way we work, the way we get and organise information. These new ways of how we treat knowledge also lead to a change in how we think about knowledge. We only begin to grasp the epistemological changes coming along with the use of social media in science.

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Annette Leßmöllmann

## 31 Current trends and future visions of (research on) science communication

**Abstract:** Never in the history of mankind have so many people been working in the scientific realm. Information and knowledge are, for everyone with unrestricted Internet access, abundantly available. But at the same time, the grand challenges of humankind, like climate change, are pressing, and fake news and distrust in scientific institutions and methods are on the rise. In this chapter I address both internal and external science communication, and both science communication practices and research on science communication, to first put together the diagnoses of current developments, second collect trends and third sketch visions for the future.

**Keywords:** trends – visions – research on science communication – trust – truth – mediatization

### 1 Introduction

Science communication has undergone massive changes during the last century, but especially with the advent of the Internet and digital communication. Changes will continue due to digitalization, economization, mediatization and globalization, and they will also alter communicative practices further on in the scientific realm. This will modify practices of information, collaboration and community building, and critique or controversy (e. g. Gloning 2018) between scientists but also teaching and exchange with students as well as communication with other stakeholders within academia, like funding agencies, expert associations, or academic administration. It will also alter communication and collaboration within research teams which function like *invisible colleges* (Crane 1972): networks with aligning research interests distributed over the globe. Practices like taking notes, collecting and sharing data, searching literature and sources, and visualizing findings will be further developed.

These changes will also alter communication with the public: as the role of the intermediaries (like journalists and PR professionals) between science and public are modified, new platforms and channels keep emerging, and publics differentiate and maybe disintegrate. The media landscape is undergoing a massive change, as is the production and usage of media content.

Hence, both so-called internal or scholarly science communication with a link to epistemic practices as well as external science communication with a focus on exchange with the public underwent massive changes and will continue to do so. One transformation process concerns the boundary between external and internal, epistemic-bound and public-bound, which seems to be blurring: the “grey zone”

between internal and external science communication has already been diagnosed as an enlarging field (see e. g. Chapter 4, this volume): such diverse practices like open science, citizen science, or blogs, to name just some areas and examples, are relevant both for the epistemic work of scientists as well as the exchange with other audiences in society.

These changes will also challenge science communication research, which is both in the role of describing and explaining phenomena and of giving impulses for a better science communication (National Academies of Sciences, Engineering, and Medicine 2017).

The chapter is organized as follows: Starting out from a diagnosis of changes challenging the scientific system (section 2), section 3 addresses changes in the way scientists communicate nowadays. Section 4 retraces some trends and section 5 formulates visions both for internal and external science communication and for practice and research in the field. All sections take the multidisciplinary perspective of the present volume and integrate trends and visions noted in contributions within and beyond this handbook.

## **2 Current challenges to science communication**

Which current conditions might be influencing or even shaping internal and external science communication, assuming that it is strongly tied to developments in science and society? Starting out from trends in science I will sketch accompanying trends and challenges stemming from globalization, mediatization and economization in many sectors.

### **2.1 Science dynamics and some of its consequences**

Many areas of social and societal life are undergoing massive changes at the moment, and as the nature of science communication consists in touching many – if not all – of these areas, they have to be considered in order to grasp in which direction practice and research of science communication may be heading.

First of all, science as the object and subject of communicative processes is undergoing fundamental changes: more people than ever are working in the science realm. The last quinquennially published UNESCO Science Report from 2015 counts 7.8 million full-time equivalent researchers in 2013 – 0.1 % of the world population – which means that the number grew by 21 % from 2007 (Schlegel 2015: 53). The numbers of publications rose from 1,029,471 in 2008 to 1,270,425 in 2014 (Schlegel 2015: 36). In countries like Germany, higher education expanded vastly: in 2016 55.9 % of the birth cohort took up university studies, compared to 36.1 % in

2001.<sup>1</sup> Diversification and internationalization of university studies for example in Germany had a wide impact on language use at institutions of higher education (e.g. Ammon 2015; Eichinger 2010; Fandrych 2018).

Growth of scientific activity also generated a global increase in publications by 23 % between 2008 and 2014, listed by the Thompson Reuters' Web of Science. The increase was strongly driven by an accretion of Chinese publications by 151 % during that period of time. This abundance forces everyone, both within and adjacent to science, to monitor more publications than ever: scientists and scientific institutions, but also politicians, think tanks, journalists, economists, administrations, NGOs and so on. It is a challenge to the scarce resource of attention, pressuring every author, institution or publishing company to get through the bottleneck and make him- or herself read, heard, and cited. Assuming that we live in an *attention economy* with the exchanged goods being attention and information (Davenport and Beck 2001; Franck 1998), the hazard is two-fold – inside science, it challenges the epistemic precept of science: declaring a result to be new is only possible when the existing publications have been thoroughly combed through. And outside science, it might allure scientific institutions or scientists to market results in a flashy way (e.g. Sumner et al. 2014).

A second important change is that new global players have reached the scientific world. The entrance of China as a very productive science nation also changed the scientific landscape concerning higher education. The Times Higher Education Ranking (2019)<sup>2</sup> shows a Chinese university being a top university in Asia for the first time, with Tsinghua University rising to 22nd place worldwide. Hence, an authoritarian state, fostering the Great Chinese Firewall and a system of social credit for behaviour adapted to the aims of party and state, is a player in science, and it will be interesting to see if this has an impact on the international science community and its values.

But China is not the only area where questions concerning the influence of the political system towards science arise: Europe has to deal with authoritarian parties and political figures gaining strength who overtly question some scientific endeavours and institutions<sup>3</sup> and so does the US (e.g. Gopnik 2017). Political figures like Donald Trump with an agenda of ignoring scientific expertise, as the Union of Concerned Scientists put together in a report (Carter, Goldman, and Johnson 2018), and the collection of downloadable “attacks on science” on its website<sup>4</sup> seem to fit into this picture.

1 Statistisches Bundesamt [German Federal Statistical Office], <https://de.statista.com/statistik/daten/studie/72005/umfrage/entwicklung-der-studienanfangerquote/> (accessed 9 April 2019).

2 [https://www.timeshighereducation.com/world-university-rankings/2019/world-ranking#!/page/0/length/25/sort\\_by/rank/sort\\_order/asc/cols/stats](https://www.timeshighereducation.com/world-university-rankings/2019/world-ranking#!/page/0/length/25/sort_by/rank/sort_order/asc/cols/stats) (accessed 15 May 2019).

3 <https://www.reuters.com/article/us-hungary-academy/hungarian-scientists-fear-for-academic-freedom-with-new-government-interference-idUSKBN1QQ0A4> (accessed 10 April 2019).

4 <https://www.ucsusa.org/center-science-and-democracy/attacks-on-science> (accessed 2 April 2019).



As thriving as science seems to be in many areas, so challenging are threats by cuts in funding and some people's tendencies to follow conspiracy "theories", pseudo-science, or denialism (e.g. Einstein and Glick 2015; Lewandowsky, Cook, and Lloyd 2018).

Another example for possible interrelations between societal or political movements and science: in African countries, with a small, but in some parts rising scientific output (Schlegel 2015: 32), the topos of research and university curricula loaded with a colonial heritage is, sometimes violently, debated: i. e. the #sciencemustfall movement in South Africa with its demand to "de-colonize the curriculum".<sup>5</sup> Besides, the role of science as a booster for national development assigned in countries like South Africa determines the allocation of funding and hence the choice of scientific topics. How these choices challenge the normative ideal of knowledge acquisition (see Chapter 1, this volume) is an open question. They might also affect the way science communication is done, internally and externally (Du Plessis 2012, 2017). Moreover, political, economic, or societal factors of a country can influence if and how scientists engage in public communication (Joubert 2018).

These observations seem to further question the notion of a detached, just curiosity-driven scientific enterprise, which has already been challenged (Jasanoff 2011), thus showing, again, that science is dependent on science cultures. Hence, the dependence of science and science communication on society and politics is a global question – and still open for comparative investigation.

Some authors also observe a heterogenization of knowledge production (e.g. Franzen, Chapter 28, this volume). Research done with citizen science projects, in action groups, in fame labs or real-world labs, in transdisciplinary research and with the help of and even by artificial intelligence (e.g. Falk 2019) could change science and lead to new epistemic tasks and functions of science communication with different publics.

## 2.2 New public actors, mediatization, and a pressure to leave traces

At the same time, a rising pressure to fulfill quantifiable objectives imposed by scientific institutions seems to boost communicative activities both in internal and in external communication (Kohring et al. 2013). They are induced by principles of *New Public Management* (Friedrichsmeier and Fürst 2012; Friedrichsmeier and Marcinkowski 2016; Kohring et al. 2013) and an expanding grant sector (i. e. institutions of higher education in Germany got third-party funding in 2015 by about 50 % as opposed to 23 % in 1995 (Dohmen and Wrobel 2018: 119). Quantifiable activities like "having pub-

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5 <https://www.youtube.com/watch?v=C9SiRNibD14> (accessed 8 April 2019).

lished in high impact journals” or “being visible in public outreach activities” have an impact on scientists’ activities and the choices higher education institutions make (see Maasen and Weingart 2006; Weingart 2001). All these developments can be seen as signs of an increasing role of economic factors, leading to an orientation towards the logic of the market in the scientific realm too (Weingart 2008; Schimank and Volkmann 2008; Popp Bermann 2013). Aberrations like predatory journals (Beall 2016) could be concomitants of this development.

These changes are in line with a heterogenization of public communication, as many actors participate in science communication (Könneker 2017) with a high potential for interaction with users and among users: Science influencers use Instagram,<sup>6</sup> YouTubers explain everything from basic science knowledge to relativity theory or engage in demystifying hoaxes (e. g., VSauce<sup>7</sup> with hundreds of thousands of commentaries. Facebook pages attract millions of followers (i. e. the Facebook page *I \*\*\* love science* has 25,402,602 followers as of 8 April 2019), and Subreddits like *rTrueAskReddit*<sup>8</sup> with over 180,000 followers worldwide and a very active moderation team to discuss topics on a high level.

Hence, discussing, influencing, nudging, storytelling, entertaining and so forth are all an integral part of science communication actually happening on many channels. The contacts with science topics are manifold: it can be via fascination, amusement, learning, interest in critical thinking or sense making – but also by denial, i. e. rejecting or devaluating it. Ways of communication about science diversify. Many daily decisions and acts of sense making or knowledge acquisition are touching science issues (Fishhoff 2013), and they are highly mediated: from apps suggesting (possibly on the basis of scientific consensus) what to eat or when to sleep, to search engines with algorithms influencing which information about climate change or vaccination the user is seeing first – all of it with possible changes in attitude or action (Bonfadelli 2017; Metag 2017). As there might be echo chambers (evidence for which is currently under review, e. g. Bruns 2017), communication is fed by algorithms. The challenge to science communication arises from the way we communicate nowadays. We experience fundamental changes in how we get into contact with linguistic or multimodal representations claiming that something is a fact, or with knowledge and information in, of and about the world.

A condition of these contacts is that many – if not all – processes of information exchange or communication are mediatized (Lundby 2014). Hepp (2013) is pointing out that nearly every public communication is part of symbolic negotiations within society. Krotz (2007) proposes mediatization as being a “meta-process” which, together with globalization (Giddens 2000), individualization and commercialization

6 <https://influence.co/category/science> (accessed 9 April 2019).

7 <https://www.youtube.com/user/Vsauce> (accessed 8 April 2019).

8 <https://www.reddit.com/r/TrueAskReddit/> (accessed 8 April 2019).

is shaping societies on a micro, meso and macro level; with commercialization being the “the basic process, as here the people get continuous pulses to act” (Krotz 2007: 260). Mediatization offers a conceptual framework for a core aspect of worldwide academic communication research (Hepp and Krotz 2014; Krotz 2017), dwelling on the idea of a *network society* (Castells 1996). This means that information and communication about science are closely interrelated with the logic of media and their usage (Schäfer 2014). Besides, mediatization has a potential to change science as a societal subsystem itself (for the scientific system: Franzen 2014; Weingart and Schulz 2014; see also Chapter 18, this volume; for politics: Kepplinger 2002). The changes these processes are bringing to modern societies and politics have been lucidly foreseen by Blumler and Kavanagh (1999) who anticipated, for example, a shift to populism and anti-elitism.

Parallel to an ongoing intensifying process of mediatization, well established ways of connecting science to public are threatening to withdraw from the public arena. Especially journalism is challenged due to the lack of a sustainable business model (see Chapter 20, this volume). Will there be a world without journalism? Meier’s (2012) trend calculation showing the number of dying newspapers every year, with the prospect that 2034 will see the last print newspaper will go out of print in Germany, has been chillingly exact to date. If this becomes true: who will offer a navigational device through the information jungle, who will guarantee participation, community and identity building, and who will control the powerful (Meier 2019)? The global picture is less depressing, showing that everywhere the transformation to a digital journalism is ongoing; sometimes journalistic values being put into practice also in formats like blogs. Paradoxically it is again China, with its authoritarian system of a controlled and partially suppressed public, that nevertheless is developing new journalism formats on WeChat, a social network much more powerful in functionalities than WhatsApp or Facebook (Simons 2017). Elsewhere in the world, as in Germany, the transformation from print media and linear broadcasting to apps, podcasts and streaming channels like YouTube is under way. Accompanying processes are, to name just one: a new view on the user as participating agent, with crowdfunding as a valid resource (Salaverría Aliaga, Martínez-Costa Pérez, and Breiner 2018; Dunwoody 2014; see also Chapter 20, this volume). Journalism has become an experimental field for people with ideas in search of new platforms and communication styles (Leßmöllmann 2017), i. e. a digital journalism which hopefully commits to journalistic values and quality requirements, based on a sustainable business model. This also affects science journalism and its training for example at institutions of higher education (see e. g. Chapter 21, this volume).

## 2.3 The “silent revolution” goes on

Other processes challenge both science and other societal systems. The “silent revolution” (Bunz 2012) called digitization (as a technical transformation) and digitalization (as a social one) is changing the way we work, acquire knowledge, buy goods, communicate, interact, organize public life, etc. The consequence is a datafication of many aspects of life (Cukier and Mayer-Schoenberger 2013). It is both changing science, the way science communication is done, and also the way it is investigated. It will also change the way journalism is done, with many tools developed to monitor news, topics, or sentiments on social media, manage the comment section online or even write stories (Underwood 2019). Datafication being the process which incorporates (communicative) acts into big data is both fuelling and challenging science. On the one hand, many people engaging in individualized communication processes and leaving traces in the digital space can generate research material which had previously been fugitive – like some written conversations which before had been oral and personal. On the other hand, written exchanges between scientists via e-mail (instead of letters) will rarely be filed for future editions of scholarly correspondence, hence rendering this important kind of scholarly communication opaque to research.

A big question is if and how social bots will change the digital public life (e.g. Keller and Klinger (2018) on social bots in election campaigns and Klinger and Svensson (2018) on non-neutral algorithms) and if ubiquitous and automatized knowledge challenges the role of the human expert (Bunz 2012: 40). An obstacle for communicative research is that not all data collected by Facebook or Google etc. are open source data – hence, the question arises, if research is still done in public institutions with a clear interest of publishing the results, or if the relevant research questions are tackled by well-funded research departments within companies, including Huawei, Samsung, etc. (Meyer-Guckel 2019)? And do communication scientists and linguists in public institutions get sufficient access to the data (Schlobinski 2019)? An open question is if big data research is running the risk of being theory blind (e.g. Coveney, Dougherty, and Highfield 2016).

Another digitally based development, artificial intelligence (AI), has gained considerable momentum after the last “AI winter” during the 1990s, as computational power increased immensely during the last 25 years and many marketable innovations could be implemented on widely used interfaces like the smartphone. This is because of the disruptive impact the development of deep learning technologies had: recognizing patterns in language, in faces, or in the traces everybody leaves in the digital space and big data analysis in all kinds of areas are developed and used by companies, by scientific research, and also by journalism. The challenge today doesn’t seem to be a technical one any more, maybe not even one of public acceptance of the technology proper, as the smartphone is full of AI applications. But there remains an ethical and legal one, with the question of implications for personal freedom and integrity.

All these changes are also touching basic functions of how knowledge and data are dealt with in *knowledge societies* (Stehr 1994). The relationship between analogue and digital resources and practices is transformed: digital reading and note taking as one of the basic knowledge activities can leave traces and thus transcend traditional privacy of the act of reading. It connects the reader to the notes of others while she is reading, which can influence her thoughts. And as reading on screen seems to be less effective with regard to memory and learning outcome (Jabr 2013), it also changes the mindset of knowledge workers. Storage of data, done only digitally without an analogue backup, opens up questions of data security and safety as well as dependence on hard- and software and infrastructure.

Artificial intelligence is, due to the reasons sketched above, one of the “Global catastrophic risks 2018” according to the Global Challenges Foundation (2018), ecological collapse or catastrophic climate change being others, and all of them are endemic to the core of science and science communication. They are not only extremely important topics for research and communication, but also subjects for societal conflicts or even revolutions: either, when they happen – or, during the phase we currently live in – when they are debated prospectively, as they touch convictions, attitudes and values of people. This can, when thoroughly manipulated by “merchants of doubt” (Oreskes and Conway 2011), lead to a polarized public and a perceived devaluation of scientific expertise precisely concerning the big (and very possibly fatal) questions like climate change. The challenge to those scientific areas which touch the interests of citizens (e. g. concerning health, energy use, mobility, housing, food, etc.) is to be found on an epistemological level: how will disciplines work together to find sociotechnic solutions (Hausstein and Grunwald 2015), not technology-only ones, and how will they integrate relevant “local” knowledge of the laypeople and parties concerned (Wynne 1992)?

## 2.4 Truth and trust

A challenge which is touched by all those aforementioned is the question of how societies handle truth and trust. Maybe changes concerning these two basic notions are the base of other changes noted above.

Starting with truth: the notion of a “post-truth era” (Keyes 2004) is a challenge for science, science communication and society (e. g. Lewandowsky, Ecker, and Cook 2017). If aiming to assign the truth value “1” to propositions is not considered to be of any relevance any more, political and social life as we know it could probably end. Frankfurt’s (2005) *On bullshit* noted that uttering falsehoods to impress others is even worse, as it means devaluating truth itself. Many scientists since 2017 took to the streets at “Marches for Science”<sup>9</sup> to oppose post-truth politics, not without being

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<sup>9</sup> E. g. <https://marchforscience.de> (accessed 27 May 2019).

accused of naïve, fact-believing positivism.<sup>10</sup> One of the empirical challenges will be to find out about the nature of misinformation (e. g. about fake news, Zimmermann and Kohring 2018) and how to handle it, and to continue the reflection among scientists about the conception and value of truth for their work.

The second fundamental notion, trust, is even more relevant for science communication, as trust in science, experts or communicating protagonists is the base for it. A full grasp in detail of today's specialized science findings are scarcely reachable, hence, trust seems to be in charge as the basic relationship between communicating parties in order to facilitate an exchange on science topics (Kohring 2004 for the function of trust in journalism from a system theoretic perspective and Kohring 2010 for an adaption to science journalism; Schäfer 2016 for an overview on desiderata concerning trust research for science in a mediatized environment). It might be the case that distrust in political or societal institutions is challenging democracy, not mediated misinformation or fake news (Zimmermann and Kohring 2018). Thus, theoretical and empirical work on how current political systems handle distrust is needed – as a basis for work on science and science communication.

All these diagnoses point in the direction that science communication is embedded deeply into the configurations and changes scientific and societal institutions undergo. These changes affect both internal and external science communication practices as well as the science of science communication.

### 3 How scientists communicate today

The challenges noted in section 2 affect all kind of actors and roles with science communication: journalists as well as PR professionals, higher education institutions as well as museums. I will pick out scientists here, as they are actors both in external as well as internal science communication and as they will have to deal with changes in other fields, like journalism, PR, etc.

The way scientists work, communicate and construct (or co-construct) knowledge has changed immensely since the advent of the digital era. Concerning science communication within scientific institutions like institutions of higher education, new cultures of academic publishing and communication have emerged, and the *invisible colleges* (Crane 1972; Lüthje 2017) of research networks use new tools for communication, collaboration, presentation, publication and reception – and for “community building” (Gloning 2018: 12) as an important part of collaboration on many levels. Research infrastructures contain mailing lists, project management systems, digital repositories, tools for collaborative writing and video conferencing (Gloning 2018: 15).

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<sup>10</sup> <https://twitter.com/astefanowitsch/status/851837317039968260> (accessed 10 April 2019).

Platforms like ResearchGate and even Amazon, and of course also library software, use algorithms suggesting reading material or colleagues to interact with. The peer review and grant system as well as the work of academic societies is widely done via digital interfaces with their special use of language to guide users. International research projects are managed with the help of tools like Slack and Wunderlist or customized tools for managing tasks, files and discussions. Using social media channels during conferences or accompanying research projects opens up flanking discourse spaces and interfaces to the public. And analogous to other areas of science communication, also in formal science communication (Taubert 2017) a tendency towards video usage is showing, as journals ask now for abstracts by video.<sup>11</sup> Another tendency is to present papers online with additional animations and a multimodal embedding and, as a paper package, with access to the underlying research data and the scripts used in processing data.<sup>12</sup> A “digital postliterality” (Brandtner and Reuter 2017) not only tightly concatenates the usage of texts with visual representations and data, but also offers closer (digital) interaction of scientists with each other.

The changes of internal science communication may be illustrated via a platform like ResearchGate: started only in 2008 (two years after Twitter), it counted 4.5 million users in 2014 (Van Noorden 2014, according to the founders) and now, in 2019, is used by 15 million.<sup>13</sup> ResearchGate opened up a digital communication space for multiple uses. Many of these uses happen simultaneously in just one and the same communicative act: one post may involve self-presentation, reputation management, community building, career management, networking, reviewing, pre- or post-publication debate, defining own research projects, etc. (Schmidt 2018; Krämer, Eimler, and Neubaum 2016). Besides, it offers a means for the measurement of reputation, the RG score (Orduna-Malea et al. 2017), which includes not just publications, but also informal science communication (e.g. Lüthje 2017) on the site. Hence, it introduced an alternative metric for measuring the communicative value of scientists, in case they use ResearchGate (or analogous platforms) at all. At the same time it makes participants leave digital traces, which are algorithmically usable: to bring together topics and scientists, but, of course, also to support the economic aims of ResearchGate. As a social media platform for scientists, it tracks formal and informal communication and is therefore a valuable resource for communication research.

In short: ResearchGate infused science communication with communication habits from social media, an amalgamation that can be seen as one of the sub-processes of mediatization (Schulz 2004; Schäfer 2014: 574, see also Chapter 3, this volume). Grappling with the communication types used on different social media

11 E. g. <https://www.cell.com/video/video-abstracts> (accessed 8 April 2019).

12 See e. g. <http://super-ms.mit.edu/rum.html> (accessed 16 May 2019).

13 <https://www.researchgate.net/about> (accessed 27 May 2019).

platforms (Schmidt 2018), including to have to live with an insufficiently transparent algorithm, is nowadays an integral part of scientific life for many scientists, even for those who use no other channel but this one. And it has also become a resource for research (Goodwin, Jeng, and He 2014; Thelwall and Kousha 2014), but still lacking insights into the epistemic functions of this special kind of internal science communication (Gloning and Fritz 2011).

Another major change in publication behaviour might already have been initiated by the introduction of *altmetrics* (see Chapters 28 and 30, this volume). These alternative metrics assess impact by means of counting communicative acts concerning a paper (or any other format, e.g. a data set, a video, a web page, etc.) like “viewed”, “discussed”, “saved”, “cited” and “recommended”. It looks at very typical communication activities within science (see Chapters 14 and 15, this volume), which were transferred, especially by the use of social media, into digital communication. Thus it measures the value of research by way of accounting for communicative success in the digital communication space – with the effect, or threat, that maybe those papers gain most of the attention with the most effectively written tweet announcing it. Although the relevance of altmetrics depends on publication cultures of scientific subjects and their intensity of publishing digitally, a changing rationale on how to assess value of publications, using techniques known from social media, might change science communication and even science. In case this is a trend, it might shape choice of research topics and even personnel – if fluency in social media use starts counting as a quality criterion for young talents. Hence, a rising pressure to leave digital traces, to make oneself noticeable as a scientist, and a notably higher performance pressure could alter scientific work (see Chapter 28, this volume).

At the same time, publishing papers together with the underlying research data or sharing and discussing these data among scientific(ally interested) publics (Bartling and Friesike 2014: 9), offers opportunities to interact with the public inspired by the open science movement. Crossing the boundaries of strictly internal science communication by digital means might change the epistemic function of science communication. Many hopes had been tied to a new openness of publication and science itself (e.g. Bartling and Friesike 2014). With the traditional subscription model of scientific publishing companies under fire (e.g. University of California cutting ties with Elsevier<sup>14</sup>), open access publication might gain even more momentum in the future. These developments together with open science activities or citizen science foster ways of (digital) communication way beyond expert-to-expert exchange (Heigl et al. 2019). Whether this “second scientific revolution” (Bartling and Friesike 2014: 12) will be good or bad, setting fruitful or hindering incentives, is still an ongoing debate. Concerning communication, the trend to change is underway, as the open

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<sup>14</sup> <https://osc.universityofcalifornia.edu/open-access-at-uc/publisher-negotiations/uc-and-elsevier/> (accessed 10 April 2019).



science movement gained considerable momentum with the European Commission and other major funding organizations planning to require open access publishing for all funding recipients.<sup>15</sup> Even highly competitive fields such as biomedical research are opening up, as “having data nobody else has” is now topped by “we need to work together”. But open science, with all its opportunities to discuss and co-construct scientific findings with the public, is also restricted by economic and social reasons – from publication fees for open access journals to challenged careers, because someone took your data (Bahlai et al. 2019). Questions of power relations and communicative control are still open for research (Lüthje 2017), and if digital communication was a vision and is now a trend, it is not just a blue-eyed dream. The new role of the libraries as a navigator and facilitator through the digital information space is part of this development (see Chapter 29, this volume).

As journalism lost its gatekeeper function (Neuberger 2014), and NGOs, politicians, think tanks, parties, researching corporations, consultants, coaches, etc. – and amateurs – are publishing online, the digital information and data space is getting confusing for all users. This is also true for scientists: They can use many channels and formats and hence follow many different communication aims, i.e., just one example, post-publication peer review on blogs or Twitter (Yeo et al. 2017). The whole development means for them to need fluency and decision competence on which channel to use for what communicative aim – a competence formerly assigned to the intermediaries.

Besides, the changes in academia noted in section 2 also affect internal communication: Fandrych (2018: 145) points out that parameters like New Governance, internationalization, management by indicators and quotas, external funding, etc. change language choice and language use in academia. Concerning up-and-coming scientists, internationalization put scientific writing and presenting skills of students with different mother tongues into focus (e.g. Redder, Heller, and Thielmann 2014). Students today deal with digital and multimodal genres presented in e-learning tools or Internet channels (Krämer et al. 2014) which they use for independent research and knowledge building (Redder and Thielmann 2015).

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<sup>15</sup> <https://eur-lex.europa.eu/legal-content/DE/TXT/HTML/?uri=CELEX:32018H0790&from=EN> (accessed 15 April 2019).

## 4 Some trends in research on science communication

Many research trends have been noted in the chapters of the present volume and elsewhere (e.g. Akin and Scheufele 2017; Rhomberg 2017). In this section I focus on some of those located at the interface between several disciplines.

With regard to external science communication, a major trend concerns the science of science communication itself. Schäfer et al. (in this volume, Chapter 4, for an overview on research topics) note several trends from the perspective of communication science: internationalization, diversification of research objects, institutionalization of research and expanding the extension of the term science communication to humanities and social sciences. Schäfer et al. (in this volume) also note an extension of research activities. In addition, a consolidation of the field is underway, with, to mention one criterion, several handbooks (like this volume) mapping the area from different points of view (e.g. Bonfadelli et al. 2017; Bucchi and Trench 2014; Jamieson, Kahan, and Scheufele 2017). There are still matters of debate, for example if there will be one leading discipline for the field, and if more interdisciplinary work could be a promising intent (see Gascoigne et al. 2010; Rauchfleisch and Schäfer 2018). As a desideratum, a fruitful collaboration between big data research from computational social science on the one hand and detailed qualitative studies on the other might prove useful to grasp new communication and interaction modes online.

Turning to the question on how people interact or deal with medialized science, acting communicatively within and about science in the digital space is being intensely studied (Anderson 2013; Dunwoody 2014; Fahy and Nisbet 2011; Dickel and Franzen 2015; Holliman 2011; Neuburger 2014), with a growing urge to find out what digitally communicating really is (see Chapters 28 and 30, this volume; Anderson 2013; and as a reader for communicative practices Georgakopoulou and Spilioti 2016). A trend towards research of newer and interactive digital, analogue and hybrid formats is noticeable (Bucher and Niemann 2015; Könniker 2017; Metag 2017; Schäfer 2017; see also Chapter 24, this volume). How people handle multimodality online, offline or in hybrid formats is one of the basic questions of communication research (Bucher 2010). Empirical research on phenomena which are not digital-only, but digitally prevalent and shaped, like memes (for a typology see Shifman 2013) or fake news (Zimmermann and Kohring 2018), is on the rise.

Since the *visual turn* both in science and science communication, research on the communicative and epistemic functions of visualizations can be found in many fields from science studies, linguistics, media and visual studies to art history (e.g. Shifman 2013; Bredekamp, Schneider, and Dünkel 2008; Holländer 2000; Chapters 11 and 25, this volume), showing that visualizations are used to yield or construct knowledge.

From a laboratory science perspective Knorr-Cetina (2001) dubbed the scientific work with visualizations “Viskurse” (‘Viscourses’) and stated that they shape *Denkstile* in the sense of Ludwik Fleck (Fleck, Schäfer, and Schnelle 1980; see also Bubenhofner 2018). “Like the microscope” (Bubenhofner 2018: 44), the interaction with diagrams and other visualizations support and shape the epistemic process. As scientists more and more rely on algorithmically produced data, visualizations grow even more in importance for epistemic work: when a software transforms unfathomable data into a diagram, with the choice between noise and relevant data left to the algorithm, the question arises how strongly the decisions of a software programmer determine scientific knowledge. Visual analytics tries to systematize this relationship between big data, data mining, visualization and the eye of the observer to render it fruitful for scientific research, e. g. for linguistics (Bubenhofner 2018; Keim et al. 2010).

As pictures and visualizations have the potential for a high impact in public discourse (e. g. Liebert and Metten 2007 on “lying with pictures”), they have been widely studied, for example for the polarized discourse on climate change (Harold et al. 2016; Schneider 2012), to point out just one example. Visualizations have different communicative functions, as they can exemplify, explain, support an argument, give evidence, but also suggest evidence where there is none. As all media grow more and more into visual ones (e. g. the growing use of pictures on Twitter) the potential of pictures and visualizations for attention, understanding, but also trust, emotions or values connected with scientific topics gain importance.

Watching the scenery from the perspective of actual media formats and channels, there is a danger that journalistic and PR products become indistinguishable, hence, the special journalistic mission of “Fremdberichterstattung” (‘coverage by others’, as opposed to “Selbstberichterstattung”, ‘coverage by the own institution’, e. g. by public relations) might evade users – or, worst case, become irrelevant for them. PR is getting stronger (Chapter 21, this volume), but also challenged by their new role in changing research institutions (e. g. Hauser, Schwetje, and Leßmöllmann 2019). Research on the “blurring boundaries” (Chapter 22, this volume) on the level of products, reception, and changing institutions is under way. This concerns also the question of whether the powerful tool of storytelling plays a fruitful or harmful role in science communication (e. g. Dahlstrom and Scheufele 2018).

The Public Engagement of Science-Model assumes that people’s dealing with science is not only a question of scientific literacy, but also of attitudes, beliefs and trust and the communicative context and products the users are engaged with (Metag 2017).

As some publics show clear signs of denialism concerning certain scientific topics, or even science as an institution (e. g. Dunlap and Jacques 2013), and immerse into pseudoscientific argumentation, the question is: How can this be explained, assuming that people might have good reasons (for them) to adopt these positions (Scott 2019)? And is science communication under these conditions possible (Bubela et al. 2009; Kahan 2015)? Research of the psychology of conspiracy theories shows that

epistemic motives (the urge to understand what is going on), as well as existential (the need to feel safe and in control of one's environment) and social motives ("maintaining a positive image of self and the social group", Douglas, Sutton, and Cichocka 2017: 538) encourage the adoption of conspiracy theories, as they seem to fulfill these needs.

The *cultural cognition* approach has been brought into play (Kahan 2010, 2012; Kahan, Jenkins-Smith, and Braman 2011) in order to explain why people oppose, for example, findings concerning human-made climate change. Empirical research suggests that it is not a failure of science literacy, or of understanding the science, which gets some people to go into opposition, but a perceived threat to identity (e.g. Kahan et al. 2012). Hence, the worst case could be, that more communication leads to more opposition (Kahan et al. 2012), which led Kahan (2015) to suggest an alternative way science communication research should be done. He has been criticized for overgeneralizing findings mainly drawn from a polarized US public and for lacking theoretical funding concerning its basic notions, "culture", "cognition", etc. (Van der Linden 2016). Yet, the approach points out imbalances in science communication research which only concentrate on scientific literacy. The question of motivated and flawed reasoning (which is not the same – see Hendriks and Kienhues, Chapter 2, this volume) in every day sense making persists, as well as the question on how to do science communication in a polarized public sphere.

Gierth and Bromme (forthcoming) point out that encountering scientific knowledge is neither limited to understandability nor certainty, and that practical problems on a personal and societal level are often drivers for such encounters. Due to epistemological and psychological reasons, science can remain opaque to understanding by laypeople. Hence, "epistemic trust" (Sperber et al. 2010) comes into play as a relevant factor. To trust a scientist, the audience relies on his or her expertise (which should be relevant for the topic at stake), integrity (i. e. sticking to rules of good scientific practice and intending to contribute to unbiased knowledge), and benevolence, i. e. with a perceivable urge to serve society (Bromme and Thomm 2016; Hendriks, Kienhues, and Bromme 2015; Peters, Covello, and McCallum 1997; for an overview see Gierth and Bromme forthcoming).

Hence, reasoning about science by laypeople seems to be motivated by attitudes, values, group norms, religious or political beliefs, self-concepts, and personal interests (Gierth and Bromme forthcoming; Kunda 1990). Research on the conditions of human reasoning shows how public understanding of science is formed by the minds of everyone (including the scientists' minds) dealing with scientific information and knowledge. Knowing how people make sense of their environment, protect and nourish their identity and react to information coming from science, can help to understand effects of science communication (Chapter 2, this volume). Science communication practice will have to address the question of how to deal with some communicative paradoxes: ease of understanding can lead people to devalue the explanatory power of science ("easiness effect", Scharrer, Stadtler, and Bromme 2014;

Scharrer et al. 2017), and over confidence in one's abilities to understand science (Atir, Rosenzweig, and Dunning 2015) could also devalue scientific experts or expertise.

## 5 Future visions

As this is an openly visionary chapter, let me start with stating core issues that many actors in the field of science communication – including scientists, but also including the public – will have to tackle, and which I will pick up, step by step, in this section. One fundamental observation is that many scientists and science communicators will have to decide for themselves if and how they address the grand challenges for humanity, as they concern everyone on the planet. Alongside, the question of quality both in science and science communication is at stake: how will scientists engage in scientific endeavours of high quality, despite challenges like “publish or perish” and a rising global scientific competition – and how do internal communicative processes assess quality, given the abundance of publications and the unstable quality of sources one finds in the Internet? A follow-up task will be to fuel valuable, reliable knowledge and information into public debate, and to support, also by algorithmic means, a constructive public discourse in the context of medialized science. This implies that everyone (including scientists) needs to know a lot about the functioning of the current media system. Finding reliable sources, monitoring societal topics – be it within science or on the (social) media agenda – in order to be able to weigh in public debates, and many other needs will lead to the fundamental question: How can artificial intelligence be used intelligently to support these tasks?

### 5.1 Science communication as debate about the grand challenges of humanity

Starting out from the diagnoses in section 2 and elaborating the trends from section 4, one major task for scientists in the future could be to answer the question if, and how, their scientific approach faces the huge challenges for the planet and humanity. The role of public communication with and about science could change or maybe is already changing, as many non-scientists have doubts if all the problems are manageable with the help of science and technology, or if the outcomes of scientific endeavours will be per se good ones – or, if they will be fairly distributed among people (Smallman 2016, 2017). As Smallman (2016) notes, people do not oppose the enlightening enterprise of modern science, but they point out the discrepancies between scientific promises and everyday shortcomings they struggle with, like unequal pay or poor healthcare. They seem to perceive a dissonance between the things promised and effects they see in their daily life. A public role for scientists from all fields which acknowledges the

(perceived) dissonance and addresses it openly might change external science communication. However, scientists and communicating scientific institutions will have to tackle the question if, and how, they get committed to change their communication style for a global change process – or not.

In a world of polarized publics, a vision for science communication of the future could be that medialized and actual debate with publics and stakeholders gets to be a more prominent way of dealing with topics both within and external to science. Where people question the fundamental approaches of scientists, the cultural techniques of argumentation in discourse with diverse audiences might come to the fore, challenged of course by those who deny rationality in discourse in the first place (Jaster and Lanius 2019). Being able to debate on science will be a part of science literacy both on the side of scientists and non-scientists. Critical thinking and critical debate culture are at the core. Spoken (as well as written) language is not only a tool for information exchange, but “a resource used interactively to co-construct knowledge and arrive at shared understandings” (Jaworska, Chapter 13, this volume, p. 282), and it is also a field where power and sovereignty of interpretation is performed. What is considered to be a fact, reliable information, a non-disputable basis, etc. is very often a matter of controversy between actors from various societal fields. The practices of debate about “good” or “relevant” knowledge, of “who is the expert” in actual interactions, could be a very interesting object for new research strategies, given that a lot of interaction is happening in online polylogues (Kerbrat-Orecchioni 2004): at what point do participants share the view that something is true, or correct, or reliable? The same is true for interactions between those professionals working within the “blurring boundaries” (see also Chapter 22 this volume) between journalism, PR and other fields of science communication, which also comprises scientists themselves: How do they build – or undermine – trust, how do they interact and establish what a good and relevant scientific finding is? Although a debate is language-based, it will be highly multimodal and driven by visualizations, moving images and memes. Hence, the participants of these debates – including scientists – will need skills and knowledge about medialized platforms, channels and practices.

## 5.2 Ubiquitous media

Future visions of how scientists will communicate about science and interact with the public should take into account at least three factors of the future media usage: (1) It will be highly mobile, (2) in the era of “Internet of things”, these things will become media interfaces and (3) communication with artificial intelligences will become prevalent. Trend (1) will force everyone working in science communication to catch attention on mobile devices. Trend (2) is already to be found in objects of daily use, like cars: their media interfaces are online and mimic media usage known from the smartphone (with apps). Thus, the “Internet of things” can influence science communication.

German science journalist Jacob Vicari is currently experimenting with the journalistic fridge (Vicari 2019). His vision: Not only will traditional radio and television use be obsolete, but also the Smartphone, because Alexa will play music and news, and the mirror in our bathroom or the fridge in our kitchen will display customized news and feature programmes. Not only will journalism be ubiquitous, but also highly customized and its use individualized. Journalists will direct their activities towards how, when, where and with which object their users are consuming journalistic products.

If it will be journalism that people consume by mirror, is an open question. But the idea of media usage being attached to everyday objects is not far-fetched at all. Car drivers already use communication interfaces in the same way they use their smartphones, or Alexa: opening apps by touching screens and talking to them. Media usage will be ubiquitous, and so will artificial intelligence, with artificial news anchors<sup>16</sup> and pop stars<sup>17</sup> already “at work”. As gaming thrives (2.21 billion gamers worldwide in 2017,<sup>18</sup> virtual worlds become interesting also for serious games and science communication (e.g. Fuchslocher, Niesenhaus, and Krämer 2011). Although text will still be at the core of media usage, it will be giving way to rich multimodal formats with a strong impetus on moving images.

Legacy media are looking for alternative platforms and will have to struggle not to be overlooked in digital space (and they are still struggling in search of a valid payment model). New actors like YouTubers or Instagram influencers are on the rise and reach their audience. Science journalists, scientists and communicators will have to show that they can do this too – or even better. Concerning the professionals of science communication, journalism research will find interesting research areas in the rising field of science-in-news: the phenomenon that, with many societal areas becoming more scientific, science reporting enters other areas than the science beat, e.g., news. Elements of science journalism – like analysing and using studies for reporting, talking to scientists, fact checking, weighing different scientific approaches competently, etc. – are to be found in TV shows like John Oliver’s *Last Week Tonight* and combine comedy, critical thinking, sense making and in-depth journalism. In the realm of digital communication, many alternatives to journalism flourish. Hence, online research should take web videos and podcasts – both as singular objects as well as channels and forms of usage – into focus. It seems that digital publics form “the fifth power” as critics and protesters (coined by media scientist Bernhard Pörksen<sup>19</sup>), the digitally interlaced publics who can perform political sway, needs more attention.

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16 <https://www.theguardian.com/technology/video/2018/nov/09/worlds-first-ai-presenter-unveiled-in-china-video> (accessed 11 April 2019).

17 <https://www.youtube.com/watch?v=Nfhuj60cJjk> (accessed 11 April 2019).

18 <https://www.statista.com/statistics/748044/number-video-gamers-world/> (accessed 9 April 2019).

19 <https://re-publica.com/de/session/funfte-gewalt-macht-vernetzten-vielen> (accessed 8 April 2019).

### 5.3 AI vs. bullshit

In the context of attention economy (see above) and a digital information sphere where bullshit – in Frankfurt’s definition (2005) the uttering of nonsense to impress others – can appear even on well-curated timelines, there is a challenge to everyone fighting bullshit: those who have good reason to believe that they are conveying qualitatively high information and who communicate on a high level instead of spreading fake news or wrong information, will have an urge to prove why their messages should be assumed to be more credible than others (see Chapter 21, this volume). As not only journalists, but also PR practitioners from institutions of higher education, non-university science institutions, think tanks or NGOs will claim to diffuse valuable information, the battle on the prerogative of information quality and interpretation sovereignty will become more intense. For the science of science communication, it will be interesting to look at the linguistic and communicative techniques actors and institutions will use to certify their messages as reliable. This already challenging task gets further pressure considering that a higher need of legitimizing one’s work seems to not only reinforce communication activities, but also to fuel a more strategic communication (Raupp 2017).

The question on how to find reliable information and experts concerns both the question of “information overflow”, which scientists and people alike experience in their daily lives, as well as the question of who can be considered as an expert.

Information overflow is affecting both internal and external science communication, and every communicative practice, be it tackling global changes, doing appropriate science communication, or doing good research is challenged by the question how to find relevant and reliable information, sources or experts. To filter out relevant and valid information is a task everyone, in every realm, has to master – and here, again, AI and data mining will play a large role. Information overflow affects everyone from laypeople in their everyday decisions and scientists navigating through an abundance of publications. This is leading to demand of algorithmic support, for example in the organization of library research much in the way Google works (Chapter 29 this volume). Take a traditional publication format, the book. When it is used as the genre “bibliography”, it collects relevant literature and is both a guide and a structured repository. As getting an overview of scientific publishing is a pressing need in science, and as publication numbers explode, big data and AI techniques come into play: Writer (2019) is an example of a machine-generated book on chemistry summarizing current research on lithium-ion batteries (Vincent 2019).

Another need is the search for the best talents in research labs, so called rising stars, i. e. young scientists who, in a growing and competitive global scientific environment, research groups will contest to recruit for themselves. Algorithmic tools could be useful for that task. Search tools also support external science communication: science journalists looking for the best expert for a certain question or field could globally search for them with the help of the right algorithmic tool (Lehmkuhl 2019).



Such “expert explorers” are currently developed for Science Media Center Germany (Halbach 2018). Hence, the traditional working style of science will be supported by algorithmic tools which help to find the right co-worker or cooperation partner. They will also help science journalists to find the right expert.

The problem of how to tackle information overflow is linked to the era of the so-called “cult of the amateur” we live in, as it was polemically termed by Keen (2007). It has, maybe, not destroyed our culture, as Keen assumed, but it did definitely alter it. Take an “amateur”, bottom-up and grassroots project like Wikipedia, which, although far from being flawless, has still proven to be a very valuable knowledge source open to everyone. Wikipedia is thus part of the science communication realm: both in external and internal science, it is widely used as a source for orientation.

However, the Wikipedia’s strength lies in rules and quality management, punishing misuse and making criteria of publication and editing transparent. This is not the case of other social media platforms: with anybody being able to open up a YouTube channel on whatever scientific topic he or she is interested in, and with only severe misconduct being banned from the platforms, quality of science communication is an open question. This can be both good and bad. On the one hand, citizen science gained momentum during the last years, hence fostering scientific epistemic practices in civil society. And, indeed, lay experts often have a fundamental say in topics that concern them, their families and their neighbourhood, as for example Wynne (1992) has shown for Cumbrian sheep farmers affected by nuclear fallout. On the other hand, self-proclaimed “experts” can get a voice, and even traditional media might succumb to their mimicry of scientific argumentation, whereas thorough fact checking can unmask them as opinion mongers (Kreutzfeld 2019). The challenge to distinguish between real and fake scientific expertise or reliable and non-reliable information is a major issue, as a disability of publics to distinguish reliable sources could shrink the credibility of science.

The more challenging it gets to sort out quality from flawed or misleading information, the more an intelligent algorithmic support to find reliable information and experts could be helpful. Also, knowing who is legitimately calling her- or himself an expert will be part of the toolbox of cultural techniques that everybody will have to handle and, in best case, learn at school.

An urgent topic in science communication is how (and if) to address the non-addressed or difficult-to-address audiences (Schrögel et al. 2018) and shape the messages and use the formats to this aim. It should be thoroughly analysed if and how habits and language use in science communication repel people or even send them into denialism.

For the professional fields, there will be an ongoing and intensifying discussion about blurring boundaries or a strict separation of science journalism, science communication, and strategic public relations or marketing (Chapters 21) and 22), this volume).

## 5.4 Communication practices in science

As noted above and in many contributions in this volume, the communication practices in a medialized environment change internal science communication as well: communication, collaboration, presentation, publication and reception of science adopt and sometimes push technological and sociotechnical changes in communication modes (Gloning 2016, 2018). For example, in the same way scientists use tools like Slack or Wunderkind to manage projects or build communities using Twitter and weblogs today, they will adapt communication practices developed for other domains for their own work in the future. It will be interesting to see how deep learning and AI will support library search, text recognition, big data research and visual analytics. In any case, AI will be used to personalize science communication. Just one example: the German research centre for Artificial Intelligence (DFKI) and several institutions of higher education in Germany collaborate in developing AI applications for a more personalized higher education teaching, especially in blended learning environments,<sup>20</sup> AI can also help writing summaries, as Dangovski et al. (2019) show with their “Rotational Unit of Memory” (RUM).<sup>21</sup> Deep learning’s disruptive effect on the development of tools for text or pattern recognition, etc. will have an impact on science communication, be it internal or external. Scientists seize opportunities to engage in open science activities, for example in hackathons where they use deep learning techniques to programme tools for automatic pattern recognition, i. e. of pictures from animals, and using for simple taxonomic tasks by users.<sup>22</sup> Pages like <https://www.inaturalist.org><sup>23</sup> work like interfaces for crowdsourcing data collection fruitful both for science and public engagement with science.

It will be an open question how internal and external science communication interact, if the grey zones will be widening or if it will be narrowed down. Open publication practices stemming from the open access movement show that public access to science can be possible. However, this seems to depend very much on the scientific subjects and cultures involved: on the one hand, MINT subjects entered very early into an open pre-publication culture ([www.arxiv.org](http://www.arxiv.org) started 1991<sup>24</sup>). On the other hand, some humanities and social sciences embrace open publication repositories only reluctantly. Altmetrics as one of the fields where external and internal publication mechanisms interlace will have a different impact, depending on the respective field. However, informal internal science communication is still a desideratum for science

<sup>20</sup> <https://www.fernuni-hagen.de/universitaet/aktuelles/2018/12/kooperation-zu-kuenstlicher-intelligenz.shtml> (accessed 15 April 2019).

<sup>21</sup> <http://super-ms.mit.edu/rum.html> (accessed 16 May 2019).

<sup>22</sup> <https://simonwillison.net/2018/Oct/29/transfer-learning/> (accessed 15 May 2019).

<sup>23</sup> Accessed 28 May 2019.

<sup>24</sup> Accessed 28 May 2019.

communication research (Lüthje 2017), as mediated, multimodal, inter-medial and complex communication modes are on the rise in this domain as well.

## 5.5 An integrated “theory of science communication”?

Researching science communication touches many aspects of social life, social institutions, and linguistic and cognitive prerequisites of humans as individuals as well as populations. Hence, social theories (Görke and Rhomberg 2017) are applicable, as well as theories of social change (see Chapter 28, this volume) and the linguistic-pragmatic approaches from an action theory perspective (Fritz 2016; Gloning 2016, 2018; Gloning and Fritz 2011). Evaluation theory and research (e. g. Stufflebeam and Coryn 2014), decision science (Fishhoff 2013), or theories of mediatization lend themselves as coordinate systems for further research. Also approaches assuming basic functions of communication, as, for example “epistemic vigilance” (e. g. Sperber et al. 2010) could function as reference points for further research. An epistemological approach could help to enlighten basic notions of science communication, like, e. g. Knauff and Spohn (forthcoming) do for the notion of rationality. Epistemology could also help to sort out normative and descriptive approaches to science communication and science communication research and specify the role of truth, trust, and values for science and science communication (e. g. Chapter 1, this volume). Some of these approaches are overtly multidisciplinary. A uniform theory of science communication might not be possible for the manifoldness of phenomena and approaches, but theories of meta-processes like mediatization seems to offer a fruitful berth for science communication research. Maybe there are others as well.

The transmission, adaption and usage of notions from other fields for the analysis of science communication has been proven very useful for the concept of mediatization; as an example: coming from political communication studies (Asp 1986), it entered media sciences and the field of science communication. Some empirical areas rather neglected by science of science communication can be fruitfully cultivated by using findings from fields like political science or pedagogy, for example researching the field of exclusion and hard-to-reach audiences (Schrögel et al. 2018). Another field for cooperation could be the fruitful marriage of big data analysis of large sets of communicative acts, collected on platforms like Twitter or ResearchGate, with small-scale, qualitative analysis on (new) forms of communication to formulate hypotheses which then can be tested on a large-scale basis. Hence, transcending the frontiers of disciplines could be an option to be able to grasp digital communication.

In times of a fragmentation of publics, a blurring of boundaries between institutions and social systems, an individualization of communicative practices and usages, and an interaction-oriented media system, the dialogues (Hanauska and Leßmöllmann 2018), which actually mostly are polylogues (Kerbrat-Orecchioni 2004) between actors – individuals as well as institutions – could become the least common denomi-

nator of research. Science communication is a non-deterministic endeavour, with the sender not being able to control the outcome, i. e. the interpretations, conclusions, changes (or non-changes) of attitudes or actions his audience could draw or experience. Science communication can lead even into communicative paradoxes: more information can mean less acceptance (see section 4), or produce boomerang effects (Hart and Nisbet 2012). Science communication is much less a transportation of information or signals but a negotiation of meaning, relevance and attitudes towards conveyed messages or institutions – especially as in the digital age preliminary, uncertain and false knowledge is abundantly accessible. Hence, dialogue, controversy, argument, dispute, and also communicative breakdowns could be the objects of research. It might be a trend that findings will be discussed with stakeholders (communicating scientists, funding agencies, politics, etc.) in order to work out a less naïve and more adequate and scientifically funded model of science communication in and for society.

## 5.6 How to use the results of science of science communication

Many insights on visualization, writing, multimodality, spoken language and dialogue, controversy and conflict, about facework, biases, values, etc. could and should have a stronger impact on university curricula or life-long learning measures. In fact, science communication – or more precisely: social negotiation about science – should be part of curricula in general. Being prepared for tough discussions about what science is about, what values it is based on and where values stop and methodological work begins will possibly happen more frequently, online or offline. To know how to discuss and argue about the basics, not only about the actual findings of one's work, might become more virulent in the future for all scientists.

The challenge will be if and how evidence-based science communication – in the sense promoted by The National Academies of Science, Engineering, and Medicine (2017) – will be possible, as many findings from the science of science communication do not easily translate into tips for actual communication. The same gap between science and its transfer to practitioners or laypeople that other fields grapple with is of course also noticeable in this field. Not every practical problem is examinable with scientific methods, and not every scientific outcome from science of science communication research can be translated into practical advice. Apart from students and young researchers, also science journalists, PIOs, politicians, funding agencies, etc. should be addressed by up-to-date science communication research.

As influencing, nudging and storytelling are becoming quite prevalent communication modes, science communication research and teaching will need to position itself towards their use – where to push the frontier to manipulation, which would contradict scientific content? And can good science stories compete with the many non-evidence-based storytellers out there on the Internet (e. g. Dahlstrom and Scheufele 2018)? Science communication research should speak up to these questions.

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