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Informing, involving or engaging? Science communication, in the ages of atom-, bio- and nanotechnology

Monika Kurath and Priska Gisler

Science communication has shifted considerably in Europe over the last decades. Three technology controversies on atoms, genes, and nanoscale sciences and nanotechnologies (NST) turned the style of communication from one-way information, participation and dialogues to the idea of an early and more democratic engagement of the public. Analyzing science communication developing over the three controversies, this article shows that what happened in one technology field fed forward to and contributed to shaping the subsequent field and that communication was initiated at a progressively earlier stage of technology development. The article concludes with an empirical analysis of six public engagement projects in NST, saying that the shift towards more democratic engagement of the public hasn't been as profound and complete as has been thought. This is particularly due to the continuing adoption of a simplistic contrast structure that opposes science and the public as two self-contained, antagonistic social entities.

Keywords: biotechnology, nanotechnology, nuclear technology, public engagement, PUS, science communication, upstream engagement

1. Introduction

At the September 2005 conference "Nanotechnology, the Media and the Public" in Bristol, the British environmental sociologist Matthew Kearnes, reported a shift in the public communication of science and technology:

> As we have seen, the science community has traveled a long way in a short time. In less than twenty years, the style of its conversation with society has changed from the patronizing tones of public understanding to the warmer banter of dialogue. Now it is changing again, to a more honest and reflective mode of listening and exchange. (Matthew Kearnes, then Lancaster University, September 2005)[1]

Kearnes observed a shift in science and technology communication toward an increased democratic involvement of society in Western democracies in the last two decades. He was referring to a more exchange and mutual learning oriented approach to public involvement, at an earlier stage of technology development; the concept of *upstream engagement*,

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advanced by UK social scientists and nanoscale sciences and nanotechnologies related policy assessments.[2] Meanwhile, also public authorities have internalized this new approach, as Brian Fullam from the British Health and Safety Initiative pointed out at the Nano Regulation conference in St. Gallen in September 2005 that, "in the end, the public decides on whether safe is safe enough."

Do these quotes really mark the beginning of a turn in science and technology communications in Western democracies? Until the end of the twentieth century, the public was allowed little input into decision-making in science and technology (Gregory and Miller, 1998; Nelkin, 1987; Wynne, 1991; Ziman, 1992). For a long time, public involvement in related issues mainly focused on information, public relations, and educational approaches to enhance the public understanding mostly at rather mature stages of technology development.

The supposed turn toward earlier and more democratic involvement of the public emerged in the context of the nanoscale sciences and nanotechnologies (NST) and fears among nanoscientists that the public response would be comparable to that against previous technologies such as agricultural biotechnology (Jones, 2008). In addition, a 2004 Royal Society and Royal Academy of Engineering (RS&RAE) report on nanoscale sciences and technologies advocated more upstream public engagement and an editorial in the science magazine *Nature* further spread this idea (Nature, 2004; RS&RAE, 2004).

Asking whether the turn toward more democratic involvement of citizens has really taken place in NST-related public engagement projects, this article gives a historical overview of science communication related to three major European technology debates of the twentieth and the early twenty-first centuries, including public understanding of science (PUS), participatory technology assessment (PTA) such as dialogue, consensus conferences and focus groups, and upstream engagement. These debates involved nuclear technologies, biotechnology, and NST of which each was prominently associated with a new phase in science communication. The qualitative analysis consisted of methods such as literature analysis, participant observation and a document-based analysis of communication and participation processes.[3] The main analytical framework focused on demarcations of communicators and recipients; how citizens and the lay public have been framed versus science, experts, and academic researchers; and in what way the boundaries between and the differing involvement of those actors were constructed and shifted over both time and technologies. This analysis used theoretical concepts such as boundary work (Gieryn, 1995) and civic epistemologies (Jasanoff, 2005).

In the following sections 2 and 3 a historic overview of the development of science communication in the ages of atom technologies and biotechnology including the UK, Germany, Switzerland, Denmark, the Netherlands, and the US will be given, acting as a prerequisite for understanding the development in NST, analyzed in Section 4. This section also consists of a small empirical study on six well-documented public engagement projects in the US, the UK, Switzerland and the European Union, analyzing the question, whether the claimed shift toward a more democratic approach in the notion of NST-related upstream engagement can be corroborated. Section 5 concludes with a reflection on the history and the current appearance and uptake of science communication.

2. Atoms, authorities and acceptance building

After World War II the problematic reputation of the sciences and an expanding scientific enterprise in need of more public funding led to the initiation of and significant increase in science advisory programs and public relations activities by scientists, first in the United States and later in other nations (Gregory and Miller, 1998: 3; Nelkin, 1987: 126). The declared aim of those activities was to improve the public image of science. At the same time, a strong link to post-war establishment of major national nuclear technology research and development programs in industrialized countries was observed (Felt et al., 1995).

The programs mainly concentrated on emphasizing the importance of scientific findings and scientific attainments for humanity (Felt et al., 1995) and on establishing science's credentials. However, another motivation arose in this context that later became one of the key assumptions in science and technology communication: the connection between public understanding of science and public support for science (Greenberg, 2001). This assumption was the epistemic basis of science and technology communication programs subsumed under the term of public understanding of science (PUS), which emerged in the 1980s. The conceptual origin of PUS lies, however, in the 1950s when large-scale public attitude surveys were undertaken with the aim to measure scientific literacy among the public (Wynne, 1995).

Parallel to the rise of public relations in the US, ideas of civil applications of nuclear technology, which were to a lesser extent linked with World War II and military use, became a dominant influence in the 1950s. President Eisenhower's "Atoms for Peace" speech to the United Nations in December 1953 marked a turning point in US nuclear policy. Visions of the civil use of nuclear energy were broadly articulated and a nuclear revolution along the lines of the industrial revolution heralding a new era was envisaged (Kupper, 2003b; Ratkau, 1988).

Alongside this disconnection from military use, the first European outreach of public education programs began in the 1950s and 1960s. Research results were presented to the public and made visible, for example, with the Atomium, a model of an atom built for the world's fair in Brussels. In contrast to current communicative efforts in Europe, the focus at that time was less on preventing opposition but more on justifying the increasing tax flow into science and technology development, both in Europe and particularly in the US (Nelkin, 1987; Wright, 1994).

In the 1950s and 1960s, optimistic views about nuclear technology dominated policy-making and research. Skeptical and critical voices were seldom heard and easy to ignore (Hagendijk and Terpstra, 2004). Parallel with the growing civil use of nuclear energy, concern mounted regarding a rise in global radioactivity and the dangers of radioactive emissions (Kupper, 2003a: 92). Furthermore, state-run promotion programs—often paid for with additional taxes (see Hagendijk and Terpstra, 2004)—paved the way for restricting liability and led to a perceived deficit in the legal regulation of nuclear energy technology in numerous industrial nations (Kupper, 2003a). In the late 1960s, public opposition emerged and formed the basis for a development with considerable impact on science and technology communication: the new social movements (NSM) in Western societies and particularly the environmental movement.[4]

The NSM contributed to a fundamental questioning of the perception of technology as an endless, vital source of social progress and human welfare (Kriesi, 1995; Rucht, 1994), as well as to a general movement for democratization (Hagendijk and Terpstra, 2004). Particularly after some major incidents involving high-technology systems like petrochemical facilities and nuclear power plants in the late 1960s through the 1980s, the awareness of the limits of technological development and its potentially catastrophic outcomes grew (Beck, 1986; Perrow, 1984).

In the late 1970s, opposition to nuclear energy technology became better organized, institutionalized, more powerful, and strongly linked with the environmental movement. Dissidence against nuclear energy increased in the 1980s, particularly after the Northern and Western European radioactive contamination by the Chernobyl reactor accident in 1986. In response to escalating protest against nuclear technology, first in the US and later in Europe "public hearings" were introduced that offered for-and-against discussion of the opportunities and risks of new technologies (Ratkau, 1988).

3. Biotechnology: experts between education and dialogue

While the controversies around nuclear technologies persisted despite varied attempts to gain public acceptance, a shift in another scientific field took place: molecular biology, which gained increased funding and importance since Watson and Crick's discovery of the double helix structure of DNA in 1953. Particularly after the development of recombinant DNA technology in the early 1970s molecular biology established itself as a leading field and nuclear technology and particle physics lost influence (de Chadarevian, 2002).

Public concern about biotechnology arose in the US after the development of recombinant DNA and the Asilomar controversy in 1975, the Cambridge City Moratorium in 1976, and the Ice Minus controversy in 1977.[5] During the same period, an intense commercial boom of the life sciences emerged (Kenney, 1986). In the late 1970s public opposition to biotechnology also hit Europe, and demands for stricter regulation and intense controversy about the potential risks of agricultural biotechnology emerged (Gottweis, 1998).

Science communication in the era of biotechnology was mainly framed by the traditional idea of educating a scientifically illiterate public under a strong and prevalent PUS paradigm in the early years. Later, the idea of facing public dissent became an important driver. Science communicators repeatedly referred to nuclear energy and it was argued that lessons needed to be learned to avoid similar controversies (Ratkau, 1988: 362).

The assumed connection between public understanding of and support for science, and the concern that funding for scientific research could become politically vulnerable framed the activities of science and technology communication in the 1970s and 1980s—the early years of the controversy (Miller, 2001). Tough questions about science and public interaction were raised in the social sciences (see e.g. Nelkin, 1976; Shils, 1974; Trachtman, 1981), and the notion that public dissent against biotechnology was based in science illiteracy became widespread in Western democracies and was nurtured by large-scale public attitude surveys reporting a significant low level of scientific knowledge in the public.[6] This led to deep concern in scientific organizations about the deficit in public understanding and nourished ideas about increasing the general level of public understanding through science and technology communication.[7]

A number of reports—among which a British Royal Society report (Royal Society, 1985) was the most prominent—initiated a range of science and political programs to improve the public understanding of science and the general level of education in the concerned nations (Hagendijk and Terpstra, 2004).[8]

Increased prominence of the biotechnology field and a growing media interest brought individual scientists to the fore. Within the setting of hearings or public talks, groups of citizens were increasingly exposed and opposed to scientific experts. Concepts of experts and laypersons emerged at the interface between communicator (science) and recipient (the public). Against this background, the representation of science shifted from a community to individuals. Single experts began to educate the illiterate public or laypersons in a setting of a one-way communication, in which laypersons acted as passive recipients of information in isolation from other social activities and structures (Whitley, 1985). Within this construct, both actors—science and the public—became separated by an imaginary boundary regarding their literacy and education (see e.g. Nowotny et al., 2001; Wynne, 1995). Ideas about a significant knowledge gap between experts and laypersons became incrementally fixed and criticized as indefensible by social scientists (see e.g. Irwin and Wynne, 1996; Nowotny, 1993).

Such critiques as well as the growing opposition to biotechnology in Europe in the late 1980s and 1990s opened up the claims of social scientists and civil society organizations for a shift or "democratic turn" (Hagendijk and Kallerud, 2003: 3) of PUS towards more deliberative, participative, and dialogue-oriented forms of public engagement in science and technology related decision-making (Wynne, 1996).

Out of such ideas and beside the ongoing PUS activities, technology assessment institutions and governments of various Western nations adopted a new form of public engagement: consensus-based participatory technology assessment (PTA) models, established as dialogues, consensus conferences, focus groups, or citizen juries.[9] While mainly Northern European countries established PTA as part of the political process, other countries including Germany and the US introduced similar models for decision-making on national, state or regional levels, mostly without a mandatory role in the political process. The limitations of participatory procedures were clear in the translation into the political process and their marginal consideration there. In reality, the plurality of opinion meant that a compromise was seldom found and the dialogue processes rarely fulfilled expectations.[10]

Incremental concern about the implications of technology for food, public health, the environment, and developing nations, which culminated in the European bovine spongiform encephalopathy (BSE), foot-and-mouth disease, and genetically modified organisms crises rapidly led to renewed interest in strengthening science and technology communication in terms of PUS after the late 1990s (Hagendijk and Terpstra, 2004). This meant information and education. And even though participative projects and dialogues have become fashionable and continued in European policy circles (Hagendijk and Irwin, 2006), a strong trend edged towards intensifying and professionalizing scientific publicity programs. From the late 1990s, large-scale education and information programs were also established outside of the anglophone world in Western Europe.[11] The attempt to bring scientific knowledge closer to a wider public continued with spectacular events such as science festivals, science weeks, and laboratory open days and acted as a kind of a "backlash" to the "democratic turn" of PUS in the early 1990s from participation towards large-scale information and education.

However, public skepticism of agricultural biotechnology remained high in Europe. Polls and studies showed that even in times of intense PUS activities the public acceptance of technology did not increase (Miller, 2001; Turney, 1996), and the credibility of science declined (Bauer and Gaskell, 2002; Durant et al., 1998; Gaskell and Bauer, 2001). The evidence for the correlation of public ignorance of specific scientific facts with collective responses to science and technology could not be established. In parallel scholars from the field of science and technology studies (STS) increasingly criticized the epistemic basis, conceptual framing, aim, and significance of PUS as "ill-defined" or as a "deficit-model."[12] They argued that laypeople can meaningfully engage in science and technology discussions and that the skeptical stance of the public is not—as advocates of biotechnology often suggest—due to public ignorance of scientific information and critical media reporting but rather a result of public mistrust of science, governments, and their official representatives (Wynne, 2001). And as this criticism brought confusion in science policy and science communication circles, a new technology had emerged: the nanoscale sciences and nanotechnologies (NST).

4. Nanoscale sciences are streaming up

Nanoscale materials emerged from interdisciplinary research fields that developed over the past two decades at the interface of physics, chemistry, biology, molecular biology, and material sciences, subsumed under the term *nanotechnology*.[13] NST are currently referred to as leading, innovative research fields. Besides revolutionizing a range of scientific and technological areas, research developments on the nanoscale level are promised as having favorable environmental impacts. On the other hand, adverse health implications of particles at the nanoscale level have been discussed and compared to those of asbestos (Poland et al., 2008).[14] Science and technology communication in the field of NST was from its beginning shaped by three factors:

1. The idea that science communication should have "learned lessons" from earlier science and technology related controversies such as agricultural biotechnology and, mainly in Britain, food scandals such as BSE and therefore should start earlier.
2. The idea that science communication in the notion of PUS was "ill-defined" and not the right way to create public acceptance.
3. The claim for a broader involvement of the public in decision-making of science and technology issues, in the notion of deliberative governance.

The public biotechnology debate has been pervasive in shaping science and technology discussion in the field of NST (Gaskell et al., 2005). The two fields show intrinsic similarities, not on a material level but regarding their scientific, commercial, and governmental framing, and the actors involved in science communication. Experts in science, social science, civil society organizations, and political institutions like technology assessment (TA) offices who had worked in public relations in biotechnology often became involved in the field of NST (Barben et al., 2008).[15]

Science communication in NST was influenced by the trend that sees policy-making in terms of interactions among a plurality of interested parties and engagement of the public in assessment and decision-making in science and technology related issues. Fashionable in European policy circles in the late 1990s, this has become known as deliberative democracy or deliberative governance (Hagendijk and Irwin, 2006). Against this background, new approaches in science and technology communications were developed and unprecedented exchange and collaboration among actors in NST subfields were established (Grove-White et al., 2004). A shared central idea was to intensify public involvement via dialogue and earlier and more exchange-oriented engagement in the decision-making process (Gavelin et al., 2007).

Early dialogues like those of the US Meridian Institute and Woodrow Wilson International Center in 2002 were soon followed by a range of similar communication and deliberation activities including actors in science, politics, industry, civil society organizations, and the public. They often shared the aim of articulating the societal and ethical implications of nanosciences and technologies and were initiated in almost every NST involved country in Western Europe, including Denmark, Spain, France, Germany, and Switzerland, as well as the US and Australia.[16]

Beside the rather traditional ideas about information, education, and dialogue with the public, science communication in the emerging NST has also taken a new path that delineates a boundary shift in the contribution options of the actors involved. Here, again, a Royal Society and Royal Academy of Engineering (RS&RAE) report had a formative impact. In their analysis they called for more democratic engagement of the public in early stages of technology development in 2004, referring to the approach of “upstream engagement” (RS&RAE, 2004). Upstream engagement aimed at engaging public knowledge as a central factor in emerging science and technology related decision-making and it entails a genuine and democratic science–society interaction enabling mutual learning.[17] Following the RS&RAE report and related *Nature* editorial, upstream engagement became a fashionable term in science communication and a variety of deliberative and upstream engagement related projects and communicative activities were initiated and advertised as another democratic turn in science communication (Kearnes et al., 2006).

To analyze the question of whether a paradigm shift in science and technology communication toward a more democratic engagement of the public had really taken place, we analyzed a sample of six well-documented public engagement projects of NST, in the US, UK, Switzerland and the European Union. We used participant observation (in the Swiss case and the UK Nanodialogue video screening) and a meta-analysis of literature, reports and documents of the other cases, focusing on the methods used, the discussion style, the framing of the main communicative actors, such as “science” and “the public,” the impact the project had on policy development and whether a project evaluation had taken place. Table 1 gives an overview on the analyzed aspects of the six projects.[18]

The US Nanoscale Informal Science Education (NISE) Network was organized by five US science museums, using the method of “forum events” which were attended by 30–50 “participants,” mainly consisting of science museum visitors. “Forum events” lasted two to three hours and involved speaker presentations by scientific experts and small group discussions. The methodological setting stands for ideas of education and understanding rather than mutual learning and engagement. In our view, the public was traditionally framed as laypersons while the role of speaker was assigned to scientists – “the experts”. Self-evaluation took place, however it focused on public attitudes, improving communication and public understanding rather than reflection on the method or the question of whether the aim of mutual learning had been achieved.[19]

The UK Nanojury was organized by the Cambridge University Nanoscience Centre, Greenpeace UK, the *Guardian*, and the Policy, Ethics and Life Sciences Research Centre (PEALS) Newcastle University and used the method of “two-way citizens’ jury.” For this purpose the traditional citizens’ jury method was enriched with a multi-stakeholder oversight, a science advisory panel and an inbuilt control mechanism for the jurors, allowing them to address a topic of their choice before turning to NST. As a result the jurors wrote recommendations for nanotechnology’s future development in the UK and received a promise from the Department for Business, Enterprise and Regulatory Reform of a response. The framing of the public as “citizens” and “jurors” and scientists as “witness” or “audience” reversed the traditional roles and thus supported the idea of mutual learning and two-way communication. The process was evaluated by a report, critically reflecting on the approach, the method, the process, and the concept of upstream engagement in general and suggested improvements.

The UK “Nanodialogues—four experiments in upstream public engagement” were organized by the British think tank Demos and the University of Lancaster with selected partners. The organizers used an experimental approach and a mix of adapted dialogue methods, such as people’s inquiry (three deliberative workshops with East London residents and input from scientists, environment agency staff, policy-makers and other stakeholders), a deliberative dialogue process involving scientists, research council staff and members of the public, a workshop involving policy-makers, politicians and representatives from two communities and a series of focus groups discussing scenarios developed by Demos and a commercial manufacturer. Results consisted of a set of recommendations and presentation to DEFRA (the

Table 1. Analytical frame of a sample of six documented engagement projects

Project	Method	Framing of science	Framing of public	Style of communication	Impact on policy development	Self-evaluation
NISE Network USA 2005	Forum events	Experts	Lay museum visitors	Teaching, discussion	Unclear	Reports on public opinion and communication
Nanojury UK 2005	Citizens' jury	Introduction to NST, witness, audience	Citizens/jurors	Two-way communication, mutual learning	Recommendations to scientists, policy-makers, journalists	Report/article reflection
Nanodialogues UK 2006	Small-scale experiments, inquiry, dialogue, workshop, focus group	Experts	Lay citizens	Discussion, teaching	Impact in corporations, foreign aid	Report/article reflection
Citizen Science Bristol UK 2006	Traditional science communication approaches	Experts	Lay students	Discussion, vote	Unclear	None reported
Publifocus Switzerland 2006	Focus groups	Experts	Lay citizens	Discussion, teaching, vote	Unclear	Report, no reflection on method
Nanologue EU 2005/6	Dialogue	Experts	Lay representatives	Discussion, dialogue	Unclear	Report, no reflection on method

UK Department for Environment, Food and Rural Affairs) and research councils. Particularly, the inclusion of a variety of actors and stakeholders and the idea of applying public engagement in new contexts such as corporations and in foreign aid projects contributed to significant and innovative uptake. However, with regard to public engagement in science and policy in general, the project persisted in a rather traditional framing of science and the public in the notion of expert (nanoresearchers) and lay (randomly selected citizens) (see Kearnes et al., 2006). A videotape documenting the Nanodialogues replicated this construction, for the public was almost entirely represented by women (concerned mothers) and science by men (informative teachers).[20] This particular and gendered setting might not provide ideal ground for reflective exchange and mutual learning. A final report evaluated and critically reflected on the project and discussed results (Stilgoe, 2007).

The UK "Citizen Science @ Bristol" project consisted of a program of activities, seeking to engage young people in discussions about the role of science and technology in society. Methods consisted of chat-show-style debates, website resources, teachers' materials and online games. Public participants (young people) were framed as "students" and science as "experts," which stands for an education – rather than mutual learning oriented setting. As a result the participants voted on areas of NST research to be founded and the degree of NST regulation. No project evaluation was reported and its impact on policy development remained unclear.

The SwissPublifocus "Nanotechnology, Health and the Environment" was organized by the Swiss Technology Assessment Organization TA Swiss and used the traditional method of focus group meetings, where randomly selected citizens discussed a particular topic, given by the organizers. The meetings were introduced by expert presentations of a toxicologist and an ethicist. In advance, the participants received a brochure, defining NST. The rather traditional framing of science as experts and the public as lay citizens and its focus on public opinion rather than engaging citizens did not provide ideal ground for mutual learning. As a result a report on public opinion of "Nanotechnology" was published, acting as information to parliamentarians but did not evaluate the project, its methods nor its policy impact.

The European Nanologue project was a collaboration of the German Wupperthal Institute, EMPA Switzerland, the UK Forum for the Future and the pan European organization triple innova. The dialogue part of it used methods such as public consultation and stakeholder dialogues, involving business, science and civil society organizations (open space conference and discussion at the German Museum in Munich with statement and vote). General results of the project consisted of a variety of documents, such as a web-based tool ("nanometer"), a scenario report, presentations and articles. Science and the public were framed as experts, introducing NST to the audience and lay museum visitors. As an innovative aspect of the engagement part, public consultation directly influenced the project and its results. However, the project focused more on consultation than real engagement and its impact on nanotechnologies as such and science policy is unclear. The website did not provide a project reflection or evaluation.[21]

In our analysis, we found a majority of rather traditional approaches of public upstream engagement, which seemed to be influenced by the old deficit model of information and education rather than exchange. Most of the varying methods and approaches looked similar to those used within participative programs of the 1990s, like citizen conferences, focus groups, or dialogues. None of those traditionally framed projects provided an evaluation or reflection on the method, the concept or the general aim and its policy impact in any visible form at the end of the project.

However, two of the analyzed projects used rather new and experimental approaches. They provided a final report, reflecting on aim, methods, process, policy impact and public engagement also in a broader context of science–society interactions. Those projects seemed to have reached quite an impressive level of exchange and mutual learning, particularly with regard to specific projects and contexts. Regarding more general science policy questions and decision-making on NST development, the translation of public engagement in the political process turned out to be rather difficult. Here, we observed that even within experimental and new approaches traditional contrast structures opposing science and the public with respect to an expert/lay divide were difficult to overcome. Such traditional framings of "the public" as a group of randomly selected citizens or lays, who are pitted against "science," mainly classic scientific experts remain problematic, particularly with regard to the idea of mutual learning and reflective exchange, which is a core premise of the upstream engagement proponent's claim for a more democratic involvement.

These findings contest the idea that deliberative, upstream NST projects exemplified a paradigm shift in science and technology communication toward more democratic engagement of the public. They correspond to studies, which observed that such projects still tend to limit public engagement to matters of values and social and ethical aspects, rather than to expose expertise to scrutiny (Hagendijk and Irwin, 2006: 175–6). Further critiques questioned the characterization of the public engagement projects as "upstream" since major investment decisions already have been made. Engaging people in discussion prior to public discourse raises a paradox of participation, as public perception of new and open scientific fields tends to be lowest and only increases when both the development agendas and the principles for regulating them are further developed and less malleable (Rogers-Hayden et al., 2007: 126).

5. Informing, educating or engaging science and the public in the notion of democracy?

As we have seen, science communication underwent transitions on various levels over the analyzed decades in the three technology fields. The communication approaches and strategies to enhance social exchange between science and society were influenced by a perceived need to learn lessons from prior technologies; nuclear technology, and then biotechnology. What happened in science communication in one technology field fed forward to and contributed to shaping what happened in a different field later. We observed that science and technology communication was initiated at a progressively earlier stage of technology development in each field.

Over the three technology controversies, the underlying epistemologies and notion of framings, aims, boundaries and strategies of communication, and the role the various actors played in the communication activities changed. Communication in the pre-PUS era was shaped by the aim of informing a general public. Public participation was not an issue at all in the 1950s when the focus was on informing the public and measuring its scientific literacy.

Concepts and settings of PUS related communication activities led to a paradigm shift in the aim as well as in the construction of the communicator—mainly science—and the addressee—the public—as well as to a fixing of an intellectual boundary between both. The original aim of promoting science *to* the public, was turned into science education *for* the public using a relatively one-sided, informative, sender–receiver communication style. Under the notion of PUS, the communicator (science) started to be represented by individuals, namely experts, who addressed an uneducated group of laypersons. Here, science and technology communication contrasted uneducated segments of society, laypeople, with a scientific elite, experts, and therefore contributed to an artificial boundary between these societal entities. This implied a clear division of expertise and ownership. While science had an active role in imparting knowledge, the public was seen as a passive recipient.

Criticism of the PUS approach led to a "democratic turn" toward participatory and deliberative approaches of public involvement, broadly launched in the context of the agricultural biotechnology controversy. Criticism of participatory approaches that could not be translated into a political process, and persisting agricultural biotechnology resistance in Europe turned into a backlash to large-scale information and education aspects of PUS. Intensified criticism of the underlying epistemic logic of PUS as ill-defined and a deficit model together with the emergence of a new technology, NST, likely to raise public skepticism again, led to the call for more egalitarian public engagement at earlier stages in science and technology development. Under the notion of upstream engagement, a new conceptual approach to science and technology communication was launched, promoted as more democratic and resulted in a range of public engagement projects, organized in Western democracies.

Our analysis showed that despite promotion of upstream engagement as a more democratic approach, most projects did not go beyond the epistemic basis of consensus formation or measuring public opinion. Apart from a few innovative and experimental approaches such as the UK Nanojury and Nanodialogues, providing a quite substantial level of exchange and mutual learning, most projects used traditional methodological approaches, following the conceptual framing of the old deficit model of public understanding and participatory technology assessment. In particular, the notion of a boundary dividing science and the public into two intellectually separated social actors, and the setting of old contrast structures of opposing a unified science to an illiterate public with respect to an expert/lay divide, persisted in most projects and replicated the epistemic weakness of PUS concepts. As well as the problematic use of this cognitive divide, which might be a major obstacle for reflective exchange and mutual learning in the notion of a more democratic public involvement, also the translation of public engagement into policy impact seems to be rather difficult and remained unclear in most of the analyzed cases.

To provide the epistemic basis for a more democratic involvement of citizens in science and technology related issues would mean that—according to the conclusions of the reports on the UK Nanojury and Nanodialogues (Singh, 2007; Stilgoe, 2007)—the related engagement projects would create collective or socially robust (Nowotny et al., 2001) knowledge and consider all actors as members of sophisticated civic cultures (Jasanoff, 2005: 247 seq.). Just a few methods and experimental approaches followed this notion, particularly in creating collective knowledge in corporate or project related contexts. However, they showed that dissolving the line between traditional framings of science and the public and creating opportunities for policy impacts pose major challenges to the epistemic framing and the methodological design of such an endeavor.

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Notes

1 See also Wilsdon and Willis (2004: 56).

2 On upstream engagement see Kearnes et al. (2006), Macnaghten et al. (2005), Nature (2004), RS&RAE (2004), Wilsdon (2005), Wilsdon and Willis (2004) and Section 4.

3 The authors participated as observers in public engagement projects such as the Runder Tisch Science et Cité on water issues and a Publifocus on Nanotechnology and Health in Switzerland (see Section 3), and attended various

expert panels and meetings on risk assessment of NST such as the International Risk Governance Council Conference on Nanotechnology in Zurich, 2006; the International Nano Regulation Conference in St. Gallen in 2005, 2006 and 2008; and the 9th Conference on Combustion Generated Nanoparticles at ETH Zurich, in 2005.

4 On the new social movements, see Kriesi (1995), Rucht (1994).

5 On the Asilomar discussions see de Chadarevian (2005), Krimsky (1982). On the Cambridge City Moratorium and the Ice Minus controversy see Weiner (2001).

6 Those surveys were developed in the US, Japan, and several Western European countries to measure and compare levels of "scientific literacy" (Hagendijk, 2004: 43; Wynne, 1995).

7 On PUS see Durant et al. (1989), Gregory and Miller (1998), Lewenstein (1992, 1995), Turney (1996), Wynne (1995), Hagendijk (2004), Irwin (2001), Meinolf and von Grote (2000), Miller (2001), Sturgis and Allum (2004).

8 The Royal Society Report was seen as the initiator of the PUS movement in Britain, having shaped science and technology communication and policy in the anglophone world for decades (see e.g. Miller, 2001; Turney, 1996).

9 The idea of involving broader expertise and comments from the public originally grew in the US National Institutes of Health, where the NIH Consensus Development Program (CDP) was established in 1977. In the 1980s Western European institutes such as the Danish Board of Technology and the Dutch Rathenau Institute adopted this idea and developed the consensus conference approach.

10 On participatory technology assessment (PTA) approaches in Western Europe, see Abels and Bora (2004), Bora and Hausendorf (2006), Joss (2000), Joss and Durant (1995); for the USA, see Guston (1999); for related approaches such as constructive technology assessment, see Rip et al. (1995).

11 Those programs were established mainly at ministerial levels and then imposed on academic institutions and professional organizations. Examples are the German PUSH project (Jasanoff, 2005: 252) and the Swiss Science and Cité activities.

12 On PUS criticisms from an STS perspective see e.g. Hagendijk and Irwin (2006), Irwin and Wynne (1996), Jasanoff (2005), Miller (2001), Sturgis and Allum (2004), Wynne (1995, 2001).

13 Nanoterminology has its own complicated history. Before the grey goo controversies in 2004, Drexler (1986) was usually referred to as the creator of the term "nanotechnology"; since that controversy, the first use of the term has been attributed to Taniguchi (1974).

14 On adverse health implications see Limbach et al. (2007), Linse et al. (2007) Oberdörster et al. (2005).

15 In addition to institutions already known from the biotechnology discourse, a variety of new organizations provide discussion platforms on the nanosciences, such as the Woodrow Wilson Center, Demos or the International Risk Governance Council.

16 For a substantial overview on such projects internationally, see Gavelin et al. (2007). On US projects see Kleinman and Maria (2005); on Switzerland, Cerutti (2006), Rey (2006); on Germany, Zimmer et al. (2007); and on France, Callon et al. (2005).

17 On upstream engagement see Note 2.

18 On these projects see also Bell et al. (2006), Gavelin et al. (2007), Rey (2006), Singh (2007), Stilgoe (2007), Türk et al. (2006).

19 See Flagg (2005), Hsi (2006) and http://www.nisenet.org/community/groups/forums (consulted 5 December 2008).

20 The videotape was shown by Phil Macnaghten at the conference "The Risk Governance of Nanotechnology: Recommendations for Managing a Global Issue" on 6–7 July 2006 hosted by Swiss Re in Rüschlikon Switzerland.

21 See http://www.nanologue.net (consulted 5 December 2008).

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Authors

Monika Kurath is at the Program for Science Studies, University of Basel and Collegium Helveticum, ETH and University of Zurich, Switzerland. Her research interests are: social, political, and cultural implications of science and technology, involving topics like comparative analysis, social framing, risk, and governance, especially in the fields of science and technology studies, cultural studies, environmental sciences and public policy, biotechnology and emerging technologies. Correspondence: Collegium Helveticum, ETH and University of Zurich, Schmelzbergstrasse 25, CH-8092 Zurich, Switzerland; e-mail: monika.kurath@collegium.ethz.ch

Priska Gisler is at Collegium Helveticum, ETH and University of Zurich, Switzerland. Her research interests are: politics of mediation, practices of collecting and exhibiting, histories of biological material collections, involving topics like the intersection of biomedicine and society, discursive and narrative production of legal norms and social framings, especially in the fields of science and technology studies, cultural studies and gender studies.