

Governing Future Technologies

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Governing Future Technologies

Nanotechnology and the Rise
of an Assessment Regime

 Springer

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Introduction: Governing Future Technologies

Mario Kaiser, Monika Kurath, Sabine Maasen,
and Christoph Rehmann-Sutter

1 The Rise of an Assessment Regime

Unlike any other field before, nanotechnology has been the object of unprecedented “assessment hype.” Immediately after former U.S. president Clinton announced the National Nanotechnology Initiative in 2000, a high-level workshop took place at which scholars from the humanities and social sciences, politicians, and representatives from the nanoscience community discussed societal implications of nanotechnology.¹ Since then, numerous countries such as Switzerland (Baumgartner et al. 2003), Germany (Paschen et al. 2003), and the UK (Royal Society & Royal Academy of Engineering 2004) have mandated their technology assessment institutions to author reports on the hazards and risks of nanotechnology.

Beside these governmental initiatives, actors from other social domains responded as well: nongovernmental organizations (NGOs) with an environmental focus such as the Action group on Erosion, Technology and Concentration (ETC Group 2003) and Friends of the Earth (Miller 2006), think tanks such as the International Risk Governance Council (Renn and Roco 2006) or DEMOS (Kearnes et al. 2006), and reinsurance companies (Munich Re 2002; Swiss Re 2004) – in spite of pursuing different objectives – have all contributed to promoting risk awareness and the regulation of nanotechnology. Furthermore, academic fields, such as science studies² and applied ethics,³ also have begun to concern themselves with nanoscience and nanotechnology, which we will refer to here as NST.

Starting with the Human Genome Project, the idea that novel technologies should be accompanied by deliberations of the ethical, legal, and social issues (ELSI)

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¹ The report of the same name was published by Roco and Bainbridge (2001).

² Regarding science studies, cf. Baird et al. (2004), Hayles (2004); Nordmann et al. (2006), Rip (2006) and Schummer and Baird (2006).

³ Regarding applied ethics: Allhoff and Lin (2008), Bachmann (2006), Berne (2004), Best and Khushf (2006), Ebbesen et al. (2006), Grunwald (2004), Khushf (2004) and Nordmann (2007).

involved became important.⁴ In the case of NST, a new acronym has emerged (NELSI), which testifies to the fact that ELSI considerations have become an inseparable part of this emerging technology.

Because the stakes are higher for nanotechnology, because it is being touted as the transformative technology of the 21st century, and because it already touches so many industries and sectors of the economy, the exploration of NELSI on a broad and public scale is central to nanotechnology's success (Center on Nanotechnology and Society 2008).

For nanotechnology, in particular, the intensification and diversification of different assessment rationales and approaches has gained such magnitude that to refer to applied ethics *or* technology assessment *or* reinsurance companies in isolation would miss a unique point of importance: the emergence of what we suggest should be conceived of as an entire *assessment regime*. Despite the different organizations, methods, and actors involved in the evaluation, deliberation, and regulation of emerging technologies, they all adhere to an overarching scientific and political imperative: innovations are welcome if they are evaluated not only for technical and scientific soundness and feasibility but also for safety, justice, and sustainability, as well as for issues such as consumer desirability.

The “assessment regime” as a whole is concerned with those evaluation aspects that are regarded as crucial for the social acceptability of novel technologies. Each approach to assessment entails two dimensions: information (knowledge) and deliberation (values). Information is required for comparing nanotechnology to preceding technologies, in particular, with respect to their unintended consequences (David and Thompson 2008). Deliberation, on the other hand, refers to checking for a new technology's ethical or legal implications and its social robustness.

For most lay people, the latter aspect is pivotal: making sense of NST is inseparably linked to acceptable values. Thus, social scientists are being asked to examine the “values lying behind the ways people make sense of nanotechnology” (Gaskell et al. 2005), explore “public perceptions about nanotechnology” (Cobb and Macoubrie 2004), or reflect on issues such as “equity, privacy, security, and environmental impact” (Schulte and Salamanca-Buentello 2007). This task, however, is by no means confined to the academic discourse – on the contrary:

[T]he concept of “acceptability” is no longer the province solely of experts; [it] is a “polygamous marriage with business, politics and ethics” (Power 1997: 5).

For instance, the EU Commission has decided “to involve powerful NGOs (for example, Greenpeace) to attract a broader audience to dialogue” (EU Commission, cited in Wullweber 2008: 40). As this kind of participation has occurred more regularly, working toward the acceptability of a technology has become a task that is

⁴ The U.S. Department of Energy (DOE) and the National Institutes of Health (NIH) devoted 3–5% of their annual Human Genome Project (HGP) budgets to ELSI initiatives. The discussions accompanied the Human Genome Project even though the whole ELSI program was criticized as a mere “afterthought” with a blurry mandate and dismissed as a “welfare program for ethicists”. These comments were made by Troy Duster, former chair of the ELSI Working Group at the National Center for Human Genome Research (NCHGR), to Francis Collins, who succeeded James D. Watson as director of the NCHGR, respectively. Cf. Marshall (1996).

sui generis deeply entrenched in the *making of* the technology altogether: it has opened up a discursive space attracting various actors and enabling them to shape the technology in question by way of articulating their own views, values, principles, or goals. Taken together, the pursuit of “acceptability” has given rise to the proliferation of an overarching assessment regime. It turns acceptability from a regulatory idea into a regulatory practice, a political project even.

Most importantly, acknowledging the existence and role of an assessment regime means accepting that the landscape of governance⁵ is shifting, with new problems and actors coming to the fore. Notably, policy researchers, focused on science, technology, and innovation, as well as politicians have recently realized the importance of public deliberation of key technologies. ELSI, in particular, is regarded as a social innovation capable of overcoming (supposed) resistance against emerging technologies and improving their governance.

At this point, we step back and consider how ELSI is entrenched in the governance of key technologies, particularly with regard to NST. This broad view requires a careful examination of how regulatory strategies incorporate and interpret the concept of acceptability to develop the relationship between science and society. In fact, nanotechnology’s emergence has entailed specific transformations in the political and epistemic spheres as well as in the ethical dimension.

- In the *political domain*, we have witnessed an increasing demand for *democratization of science and technology*. With the emergence of nanotechnology, however, participation and dialogue have been intensified and integrated in governance structures so that we now talk about “hybrid governance.” Speaking back to science (Nowotny 2003) assumes the possibility of getting *involved in governing NST*.
- The *ethical dimension* is opened by recognizing the responsibility and accountability of science toward society. With the advent of nanotechnology, however, ethical deliberation has become a chief element in the politics of emerging technologies so that we now speak of “ethopolitics” (Rose 2001). Ethical concerns of individuals, groups, or institutions are increasingly connected with ideas of *good governance* of NST.
- Finally, the *epistemic dimension* is about a turn from *knowledge* to *innovation* or, in other words, from *supply* to *demand*. Thus, the emergence of a new mode of knowledge production explicitly includes extrascientific actors at virtually all stages of generating novel technologies. With the advent of nanotechnology, we observe an epistemic shift from manufacturing “socially robust knowledge” to the fabrication of “sustainable innovations”.

The analytical distinction of these three dimensions should not obscure the close and complex connections between them: Political techniques and instruments

⁵ Whereas *government* indicates a body of formal authority aimed at implementing duly constituted policies, *governance* suggests the processes and manner in which power is exercised by both formal and informal institutions (Rosenau 1992: 1–4).

always require knowledge for conceptualizing the problem to be regulated as well as for justifying their deployment. Likewise, the concrete ways in which knowledge is produced in the epistemic dimension greatly depends on what is valued as genuine or important in the ethical dimension.

The shifts that can be observed in all three dimensions (individually as well as combined) underline a central hypothesis of this book. Rather than being *ornamental* to technology development, in the case of nanotechnology the assessment practice in all three dimensions seems to have become an *integral* and *active* part of emerging NST. In many identifiable ways, they influence the strategies and the research practices in this field.

Let us briefly look at each of these dimensions of an assessment regime in turn. They all offer a choice between a pair of options: democratization *or* hybrid governance, ethics *or* ethopolitics, socially robust knowledge *or* sustainable innovations. Mostly, however, we find combinations of both. More often than not, the latter is supported and legitimated by the former.

1.1 The Political Dimension: Democratization or Hybrid Governance?

Beyond science policy, the idea to democratize science relates to broader aspects, such as a shift in democracy theory from a conventional representative model to participatory and deliberative models. For representatives of public administration, this shift entailed early on the prospect of overcoming the dual challenge of optimizing the economic and social impact of technology *and* the potential of public involvement in decision-making (Kloman 1974). By showing that scientific expertise in decision-making either neglects other kinds of relevant knowledge or transcends its domain of competence, historians and sociologists of science have drawn attention to a legitimacy problem of science policy (e.g. Jasanoff 1990, 1997; Smith and Wynne 1989; Nowotny 2003). To overcome it, they have pleaded for a democratization of science policy as well. For political scientists, in turn, democratization is seen as a cure for the political passivity and distrustfulness of the (non-)voting citizens. By actively involving the latter, more active forms of citizenship and democracy are expected to emerge, such as, for example, “technological” (Frankenfeld 1992) or “ecological citizenship” (Dobson and Bell 2005) and “strong” (Barber 1984) or “deliberative democracy” (Cohen et al. 1989). As a consequence, institutionalized technology assessment gradually incorporated democratic instruments into the traditional technocratic tool box, producing new models of technological citizenship.

Thus, participatory methods in technology assessment have been worked out as a micropolitical effect of democratizing science (Durant 1999; Joss and Bellucci 2002) – the instruments ranging from consensus conferences and citizen juries to public hearings and scenario workshops. On a macropolitical level, however, democratization has become almost synonymous with governance of science and technology. Probably the best-known example for the convergence of democratization and governance is the white paper “European Governance” (CEC 2001),

along with related working documents such as “Science, Society and the Citizen in Europe” (CEC 2000). In these and similar proposals, the dialogue between science and society and the notion of governance are not just linked but conceptually depend on each other: no dialogue without governance, no governance without dialogue.

Whether such a “politics of talk” (Irwin 2006) really affects and changes the traditional governmental structures remains an important question. However, we do not agree with the allegation that it is *just talk*. First, the semantics of governance and dialogue have inspired many actors and institutions, many of which are only loosely tied to government. Moreover, it creates real institutions, like the think tank *International Risk Governance Council*. By inventing new participatory strategies like “upstream engagement”, DEMOS could firmly establish itself as an active player in the governance of nanotechnology as well. In addition to such highly visible institutions, governance activities occur in a variety of other arenas: in small workshops, in which scholars from the social sciences and humanities closely interact with nanoscientists, in working groups put together for a report, and in both local and multinational efforts to mount initiatives like “nanologue” (Nanologue 2006).

Obviously, nanotechnology is full of governance(s), ranging from micropolitical exercises of participatory technology assessment to macropolitical strategies on a supranational level. The EU’s Sixth Framework Program, which allocated research funds for generating “knowledge about citizenship, democracy and new forms of governance”, was such an example. More generally, the emerging type of socio-political governance involves science, politics, the media and the public sphere, the market, as well as society in general. Concepts of collective or participatory governance are meant to describe a shared set of responsibilities (Kooiman 2003: 5). These tasks meet several key functions: supporting the transformative impact of new technologies, advancing responsible development that includes health, safety, ethical, and social concerns, encouraging national and global partnerships, and commitments to long-term planning. Such frameworks explicitly include principles of good governance, most notably the participation of those who are affected by the new technologies, transparency of governance strategies, responsibility of stakeholders, as well as effective strategic planning.

All these different levels, institutions, and settings, in which governance is announced, expected, or exerted, constitute a loosely coupled network of governance(s). Referring to this network as “hybrid governance” accounts for the diversity of the governance strategies involved, their different instruments, rationalities, and aims. At the same time, however, all actors operate based on concepts such as *accountability, transparency, responsibility, prudence, effectiveness, or open dialogue*, which account for a flexible unity of hybrid governance. This can be illustrated with the white paper on nanotechnology issued by the International Risk Governance Council. The council claims that its governance framework is unique because it distinguishes different forms of risks, ensures the early participation of all stakeholders, including civil society, and because it implements the principles of

good governance, including participation, transparency, effectiveness and efficiency, accountability, strategic focus, sustainability, equity and fairness, respect for the rule of law and the

need for the chosen solution to be politically and legally realisable as well as ethically and publicly acceptable (Renn and Roco 2006: 35).

The case of nanotechnology thus demonstrates that the ideal of a democratization of science and technology and its multiplying effects have given rise to an assessment regime, operating *on*, *with* and *by* hybrid governance.

1.2 The Ethical Dimension: Ethics or Ethopolitics?

Especially, the debate over human embryonic stem cells leaves the impression that the deliberation of novel technologies primarily rests on ethics: politicians around the world were asked to follow their conscience rather than party discipline; ethical councils mushroomed on national and regional levels; and concepts of human dignity and sanctity of life suddenly extended beyond philosophical seminars and became publicly contested issues.

We call that change in the framing of the problem an *ethicization* of technology controversies.⁶ With the rise of bioethics in the 1970s and the powerful support it received from the ranks of the Human Genome Project ELSI program, ethical deliberation has become one of the dominant frameworks for assessing future technological and scientific developments, foremost in the realm of biomedical technologies. By way of this ethicization,

“laws and regulations are losing importance in the shaping of medical and scientific developments. Instead, new institutionalizations and representations of conversation, confession and negotiation rituals become increasingly central in government technologies” (Gottweis 2005: 120).

However, ethicization also covers the change from a language of calculable risks to a language of uncertainty, in which emotions, trust, and morality gain in importance. With respect to policy-making, strategies of expertise, according to Gottweis, are complemented by strategies of conversation and confession that do not focus on proof but rather on credibility (cf. *ibid.*).

In nanotechnology, however, it seems that the traditional risk framework has reclaimed much of its lost terrain. Mundane risks such as the possible toxicity of nanoparticles seem to have exceeded ethical problems as raised by the issues of human enhancement, at least in current debates. However, does this mean that ethicization has come to an end?

The expansion and dissemination of notions like accountability, sustainability, fairness, or transparency, through which governance has created plausibility for

⁶ The term *ethicization* was developed by sociologists to say that science, technology, and academic research has not only become economized, commercialized, and instrumentalized in a knowledge society but also encounters intensified ethical assessment (ethicization) (Stehr 2005). Adapting this concept to science and technology controversies, other STS scholars argue that “ethicization” leads to new rationalities at the interface of science, politics, and society, involving technology assessment and science governance as well; Bogner (2005) and Maasen and Weingart (2005).

bottom-up modes of governing, indicate that ethics still plays an important role. For the time being, it might have retreated from the thematic level but in no way from a procedural one. Here, ethical concepts assume even more functions and roles: the production of a “nano code” of conduct, for instance, should not only provide a framework for establishing public confidence; it is also a “response to a perceived lowering of respect for the scientific profession in recent years and aims to restore the high standing that scientists had in society barely fifty years ago” (Pitkethly 2007: 5). Ethical principles like fairness, non-strategic action, or veridicality also play a crucial role in legitimating participatory settings, which give participants a safe forum to articulate their sentiments, hopes, fears, or anxieties. Finally, the (often hidden) task to ethically justify one’s political maneuvers has even led transhumanists to explain their attitudes and actions in terms of ethics, as the website of the Institute for Ethics and Emerging Technologies shows (IEET 2008).

On these grounds, Nikolas Rose (2000, 2001) has suggested that we live in an ethopolitical age where issues as diverse as crime control or emerging technologies are problematized in a similar way in terms of ethics. Not only in the life sciences, as Rose suggests, but also in other areas (NST and converging technologies, in particular) we notice extremely value-driven debates about technoscientific developments, always coupled with economic imperatives. In this perspective, the emerging assessment regime based on democratizing science and technologies co-evolves and interacts with the “ethicization” of emerging technologies. It shows in the

ways in which the ethos of human existence – the sentiments, moral nature or guiding beliefs of persons, groups, or institutions – have come to provide the “medium” within which the self-government of the autonomous individual can be connected up with the imperatives of good government (Rose 2001: 18).

In addition to the “autonomous individual,” the current deployment of ethics, however, has found further objects that are required to live up to the expectations of good government or rather good governance: businesses, firms, and corporations. All these entities are “required” to “voluntarily” follow particular codes of conduct. In fact, the ethical vocabulary (introduced earlier to define hybrid governance) not only hints at new ways of governing but also at new attributions of accountability. With regard to regulatory issues, accountability encourages “self-regulation”. Self-regulation is highly welcomed as a novel “regulatory approach,” one that replaces the tradition of “intervening states prescribing a policy which clearly indicates allowed and forbidden behaviour” (Führ and Bizer 2007: 327).

The case of nanotechnology thus illustrates that it is precisely the ethicization of science and technology and its multiplying effects that have given rise to an assessment regime that justifies itself in terms of ethopolitics.

1.3 The Epistemic Dimension: Socially Robust Knowledge or Sustainable Innovations?

The past few decades have seen a cascade of new proposals for conceiving the interplay of “science and society.” A fundamental change in this relation was observed

in a transition of knowledge production from “mode 1” to a “mode 2” (Gibbons et al. 1994). Science policy under the notion of “public understanding of science” was based on the idea that science takes place in a space that in a certain way is external to society, as research is conducted according to its own agenda, methodological principles, and its own quality assessment. Associated with the emergence of the idea of mode-2 knowledge production, new policy imperatives such as “public engagement” have led to reconceiving science as internal to society. Thus, society has switched from a passive end-user to an actively participating jury in knowledge production. Herein, society calls for good science – “good” defined as “socially robust knowledge” (Nowotny et al. 2001; Nowotny 2003).

In the example of NST, expectations continue to shift, and it seems that society has moved even more upstream. In current knowledge politics (Stehr 2005), the idea of social robustness seems to have been passed by the demand-driven (as opposed to supply-driven) side of knowledge production. In parallel, science policy has increasingly turned its attention to innovations and to systems of innovations (SI). What once began as a framework for “national systems of innovations” (Freeman 1987; Lundvall 1992) nowadays has gained credibility as the SI approach (Edquist 1997, 2005), which has been introduced to national governments and even to international organizations such as the OECD or the EU. The strength of this approach is to be found in its encompassing and interdisciplinary perspective, in its emphasis on the role of institutions and organizations, and in its capability to include both product and process innovations. In this vein, accounts of SI do not target technological innovations but instead look at the social conditions that enable and sustain them. Consequently, corresponding approaches aim at managing and improving the fundamentals of technology innovation and diffusion. These objectives may be achieved by changing the funding conditions in favor of excellence, by redefining teaching and learning processes at universities in favor of transferable skills, or by modifying policy environments in favor of (hybrid) governance.

Most interestingly, public engagement has become a major focus of SI research and policy, too. Within this context, however, the philosophy undergoes a significant change from knowledge to innovation. Once again, nanotechnology seems to be a case in point, as this field has enabled the articulation of increasing demands for sustainable innovations – demands that soon might outpace the ideal of socially robust knowledge.

In fact, striving for sustainable innovations in nano- and other technologies brings about a new quality in the science-society relationship. Society defines the ethical, social, or legal criteria that knowledge production has to take into account, even as it marks out the concrete directions that guide the development of *solutions*, i.e. innovations. While issues of social or ethical acceptability so far acted more or less as demarcations within which research and development had to be carried out, science and technology are now bound to take issues of desirability more seriously.

Innovation does not automatically lead to societal progress, as is implicitly assumed in *technology push*-oriented policies. This assumption is an inheritance of the enlightenment; i.e., the belief that science will automatically lead to a better quality of life. The push for sustainable development needs an approach towards innovation that can be characterised as

society pull: the society has to decide which (balance of) economical, ecological and social goals are to be met. Society pull can be organised by developing shared perspectives for the future, which are inspiring for public and private policy-makers and investors (Vollenbroek 2002: 215).

This exemplifies all the mentioned changes that have affected the object of science policy: from supply to demand, from knowledge to innovations, from technology push to society pull, from acceptance to desirability, and, in this vein, from ethical, legal, and social implications to economically, ecologically, and socially sustainable goals.

The case of nanotechnology thus illustrates that it is precisely the call for socially robust knowledge and its proliferating effects that has given rise to and legitimizes an assessment regime that increasingly aims at the production of sustainable innovations.

2 Assessing the Assessment Regime

In reviewing the changing conditions under which emerging technologies are deliberated and evaluated in their political, ethical, and epistemic dimension, a range of new policy offerings can be observed, particularly with regard to NST. These new policy trends range from requests for a “governance of sustainable socio-technical transitions” (Smith et al. 2005) or a “sustainable governance of emerging technologies” (Wiek et al. 2007) to petitions for a “responsible corporate governance” (Kuhndt et al. 2004) or for “an ethics of knowledge policy” (Von Schomberg 2007).

These new policies testify to the fact that the notions, practices, and institutions of hybrid governance, ethopolitics, and sustainable innovation have prepared the ground for the emergence of an assessment regime. Particularly, the interplay of these three domains has tied the heterogeneous set of deliberating, reflecting, and governing actors into a coherent framework: futurologists, ethicists, consulting firms, technology assessors, think tanks, NGOs, natural scientists, technicians, social scientists, transhumanists, and citizens all feed into the emerging assessment regime in its pursuit of reflecting and governing the acceptability of future technologies.

Traditional ELSI can no longer be seen as mere lip service for democratizing science, neither does it automatically lead to good or better governance of science. From a descriptive perspective – instead of a normative one – ELSI can be seen as having become part of hybrid forms of governing innovative technologies, thereby involving the moral sentiments of individual and collective actors and putting the responsibility on them for bringing about sustainable innovations. Therefore, it is high time for ethicists, scholars of STS, and those involved in technology assessment to critically review the political, ethical, and epistemic conditions that led to the “sustained innovation” of an assessment regime.

Speaking of an assessment regime as a social phenomenon opens up opportunities to see all-too-common things differently. As a general leitmotif, the

contributions in this volume share the methodological aim of challenging the “standard view” of technology assessment, reflection, or deliberation. Reflecting on the ethical, legal, and social implications of a new technology helps us to maximize positive and minimize negative effects as best and as early as possible: it is all about reducing environmental and social risks, improving preparedness, creating mutual understanding about the ethical limits, and more. Seen from this perspective, however, such activity is perceived as merely secondary to technology developments. Against such a view, the book advances the thesis that the assessment regime is not additive to but *constitutive* of the formation of novel technologies – either with regard to technology development proper or with regard to the societal context in which the technology is about to be embedded. The papers collected in this book draw a multifaceted picture of such interactions between nanotechnology and the assessment regime.

What is the nature of these interactions? In the first issue of *Nature Nanotechnology*, Toumey (2006) described the rise of public deliberation – in our words: the assessment regime – and the birth of nanotechnology as a coincidence:

Nanotechnology comes to public attention at an interesting time. The question of the role of the lay public in science policy has recently matured into a series of arguments and approaches, and nanotechnology is often thought of as a test case for experiments in democratizing science today. There is nothing about atoms and molecules that makes nanotechnology more suitable for this than other technologies: this is a historical coincidence, not a scientific result (Toumey 2006: 6).

We agree with Toumey in that there is nothing specific concerning NST that should attract so much assessment activities. We disagree, however, with Toumey's conclusion that the rise of NST and its impact on science policy is nothing but a historical coincidence. The importance of science and technology for today's knowledge societies (NST being a case in point) as well as the growing prominence of democratizing technology assessment both coincide such that the latter has become an integral part of generating future technologies. The articles in this volume explore different aspects of this thesis.

The first part assembles papers devoted to the question as to how particular organizations (research and testing institutes) as well as particular scientific disciplines (crystallography and toxicology) have selectively appropriated nanotechnology (Martina Merz; Monika Kurath; Christian Kehrt and Peter Schüßler). The patterns of adaptation are multifarious. In one case, a scientific discipline (crystallography) takes such a critical stance that it almost refuses to become “nano,” although its objects of research as well as its methods seem to be nano proper at first glance. In contrast to this, scientific communities that are involved in assessing and testing technological products, such as in the field of toxicology, are not only more receptive to nano but take it as an opportunity to induce organizational as well as epistemic changes that even affect the identity of the relevant community. Concerning these transformations, it seems that assessment actors may approach nano more easily, as nano allows redefining what assessment “really” means.

The second part places emphasis on the symbolic and material linkages that bind science and society together either in the form of images, visions, or video games.

In different ways, they all connect to the assessment regime (Joachim Schummer; Christopher Coenen; Andreas Lösch; Colin Milburn). By playing the role of mediators, futuristic images of nanotechnology allow for deliberation across the boundaries of science and economy. As they are shaped by popular discourse as well, they exhibit dynamics similar to those that have also marked the deliberation of dangers and risks of nanotechnology. Like images, visions for the future have structuring effects on what we may and should regard as ethical or societal implications. Moreover, as a means of representation they allow even contested actors to enter the ELSI debate and to shape the future according to their views. Video games, however, open up a new way of becoming familiar with future technologies and their societal implications. By playing them, we get in touch with the world of tomorrow in a bodily way.

The third part explores the interactions between nanotechnology and the assessment regime (Arie Rip and Marloes van Amerom; Armin Grunwald and Peter Hocke; and Mario Kaiser). In more detail, it links up to the normatively relevant discussion as to whether and how different forms of deliberation, such as technology assessment or ethical discourse, have framed nanotechnology. As we cannot expect direct and intended relations between the domains, all contributions elaborate concepts and models through which the framing effects become visible. While two papers focus on past events by highlighting the shift in deliberation from scenarios like *grey goo* to risks, one article reacts to the ways the assessment regime is bound to anticipate the future of nanotechnology.

The fourth part takes up the challenge of critically reviewing the ELSI landscape in a broad view (Alain Kaufmann et al.; Risto Karinen and David Guston; Christoph Rehmann-Sutter and Jackie Leach Scully). In contrast to the fifth part, however, it does so in a normative perspective. Consequently, the papers reflect the current status of ongoing assessment efforts. They pay close attention to deficits and shortcomings mostly of their own scientific disciplines. To overcome them, they see the hypothesis of a co-evolution and co-production as induced by the assessment regime not as an empirical fact but as a normative ideal that we should strive for by means of public participation *plus* specific other instruments: “proper expertise processes” in the first, “anticipatory governance” in the second, or a sort of procedural ethical questioning in the last case.

The fifth part distances itself from normative reasoning by trying to shed a descriptive light on the assessment regime (Alfred Nordmann and Astrid Schwarz; Matthew Kearnes; Sabine Maasen). All the chapters here are concerned with the puzzle as to how nanotechnology could unfold a kind of noncoercive coercion to participate in the ELSI and assessment endeavor. The non-oppressive force of seduction, the expansion of governance as “government without politics,” as well as new roles of and chances for intellectuality are deployed to explain why the “politics of talk” could gain so much credence, thereby leaving talk *behind* politics. In doing so, all contributions testify to the ambivalences with which the assessment regime is saddled.

Rethinking nanotechnology in the context of the concerned organizations, disciplines, symbolic and materialistic linkages, interactions, and deliberative efforts

reveals the emergence of an assessment regime in science and technology. It opens up a rich framework of incremental, ambiguous, and dynamic developments that goes far beyond assessing technology implications on a broader scale. Rather, by its emergence, the assessment regime not only shapes future technology developments by a hybrid mode of governance and predominantly ethopolitical considerations but also frames technology in society by enforcing knowledge production guided by the idea of sustainable innovation.

References

- Allhoff, F. and P. Lin (2008), *Nanotechnology & Society: Current and Emerging Ethical Issues*, Berlin: Springer.
- Bachmann, A. (2006), 'Nanobiotechnologie: Eine ethische Auslegeordnung', in Eidgenössische Ethikkommission für die Biotechnologie im Ausserhumanbereich EKAH, and A. Willemsen (eds.), *Beiträge zur Ethik und Biotechnologie*, Bern: EKAH.
- Barber, B.R. (1984), *Strong Democracy: Participatory Politics for a New Age*, Berkeley, CA: Univ. of California Press.
- Baird, D., A. Nordmann, and J. Schummer (2004), *Discovering the Nanoscale*, Amsterdam: IOS Press.
- Baumgartner, W., B. Jäckli, B. Schmithüsen, and F. Weber (2003), *Nanotechnologie in der Medizin*, Bern: Zentrum für Technologiefolgen-Abschätzung beim Schweizerischen Wissenschafts- und Technologierat.
- Berne, R.W. (2004), 'Tiny ethics for big challenges: calling for an ethics of nanoscale science and technology', *Circuits and Devices Magazine, IEEE* 20(3): 10–17.
- Best, R., and G. Khushf (2006), 'The social conditions for nanomedicine: disruption, systems, and lock-in', *The Journal of Law, Medicine & Ethics* 34(4): 733–740.
- Bogner, A. (2005), 'Die Ethisierung von Technikkonflikten. Politikberatung durch Ethikkommissionen', in M. Nentwich, and W. Peissl (eds.), *Technikfolgenabschätzung in der österreichischen Praxis*, Vienna: Austrian Academy of Science Press.
- CEC (2000), *Science, Society and the Citizen in Europe. Commission Working Document*, Brussels: CEC (Commission of the European Communities).
- CEC (2001), *European Governance. A White Paper*, Brussels: CEC (Commission of the European Communities).
- Center on Nanotechnology and Society (2008), 'NELSI GLOBAL', <http://www.nano-and-society.org/NELSI/> (accessed on August 31, 2008).
- Cobb, M.D., and J. Macoubrie (2004), 'Public perceptions about nanotechnology: risks, benefits and trust', *Journal of Nanoparticle Research* 6(4): 395–405.
- Cohen, J., J. Bohman, and W. Rehg (1989), *Deliberative Democracy: Essays on Reason and Politics*, Cambridge, MA: MIT Press.
- David, V.K. and P.B. Thompson (eds.) (2008), *What Can Nanotechnology Learn from Biotechnology*, Oxford: Academic Press.
- Dobson, A. and D. Bell (eds.) (2005), *Environmental Citizenship*, Cambridge, MA: The MIT Press.
- Durant, J. (1999), 'Participatory technology assessment and the democratic model of the public understanding of science', *Science and Public Policy* 26(5): 313–319.
- Ebbesen, M., S. Andersen, and F. Besenbacher (2006), 'Ethics in nanotechnology: starting from scratch?', *Bulletin of Science, Technology & Society* 26: 451–462.
- Edquist, C. (ed.) (1997), *Systems of Innovation: Technologies, Institutions and Organizations*, London: Pinter.

- Edquist, C. (2005), 'Systems of innovation: perspectives and challenges', in J. Fagerberg, D. C. Mowery, and R. R. Nelson (eds.), *The Oxford Handbook of Innovation*, Oxford: Oxford University Press.
- ETC Group (2003), 'The big down: from genomes to atoms. Atomtech: Technologies Converging at the Nano-scale', Winnipeg Manitoba (CA), <http://www.etcgroup.org/article.asp?newsid=375>. (accessed ...?)
- Frankenfeld, P.J. (1992), 'Technological citizenship: a normative framework for risk studies', *Science Technology Human Values*, 17(4): 459–484.
- Freeman, C. (1987), *Technology and Economic Performance: Lessons from Japan*, London: Pinter.
- Führ, M. and K. Bizer (2007), 'REACH as a paradigm shift in chemical policy – responsive regulation and behavioural models', *Journal of Cleaner Production* 15(4): 327–334.
- Gaskell, G., T. Ten Eyck, J. Jackson, and G. Veltri (2005), 'Imagining nanotechnology: cultural support for technological innovation in Europe and the United States', *Public Understanding of Science* 14(1): 81–90.
- Gibbons, M., C. Limoges, H. Nowotny, S. Schwartzman, P. Scott, and M. Trow (1994), *The New Production of Knowledge*, London: Sage.
- Gottweis, H. (2005), 'Regulating genomics in the 21st century: from logos to pathos?', *Trends in Biotechnology* 23(3): 118–121.
- Grunwald, A. (2004), 'Ethische Aspekte der Nanotechnologie. Eine Felderkundung', *Technikfolgenabschätzung – Theorie und Praxis* 13.
- Hayles, K. (2004), *Nanoculture: Implications of the New Technoscience*, Bristol, UK and Portland, Oregon: Intellect Books.
- IEET (2008), *Institute for Ethics and Emerging Technologies*, <http://ieet.org/> (accessed February 20, 2009).
- Irwin, A. (2006), 'The politics of talk: coming to terms with the “new” scientific governance', *Social Studies of Science* 36(2): 299–320.
- Jasanoff, S. (1990), *The Fifth Branch. Science Advisers as Policymakers*, Cambridge, MA: Harvard University Press.
- Jasanoff, S. (1997), *Science at the Bar: Law, Science, and Technology in America*, Cambridge, MA: Harvard University Press.
- Joss, S. and S. Bellucci (eds.) (2002), *Participatory Technology Assessment – European Perspectives*, London: University of Westminster Press.
- Kearnes, M., P. Macnaghten, and J. Wilsdon (2006), *Governing at the Nanoscale. People, Policies and Emerging Technologies*, London: DEMOS.
- Kloman, E.H. (1974), 'Public participation in technology assessment', *Public Administration Review* 34(1): 52–61.
- Kooiman, J. (2003), *Governing as Governance*, London: Sage.
- Kuhndt, M., B. Tunçer, K.S. Andersen, and C. Liedtke (2004), *Responsible Corporate Governance: An Overview of Trends, Initiatives and State-of-the-art Elements*, Wuppertal: Wuppertal Institute for Climate, Environment and Energy.
- Khushf, G. (2004), 'The ethics of nanotechnology: vision and values for a new generation of science and engineering', in National Academy of Engineering (ed.), *Emerging Technologies and Ethical Issues in Engineering. Papers from a Workshop, October 14–15, 2003*. Washington, DC: National Academies Press.
- Lundvall, B. (1992), *National Systems of Innovation: Toward a Theory of Innovation and Interactive Learning*, London: Pinter.
- Maasen, S. and P. Weingart (eds.) (2005), *Democratization of Expertise? Exploring Novel Forms of Scientific Advice in Political Decision-Making*, Dordrecht: Springer.
- Marshall, E. (1996), 'The genome program's conscience', *Science* 274(5287): 488–490.
- Miller, G. (2006), *Nanomaterials, Sunscreens and Cosmetics: Small Ingredients, Big Risks*, Friends of the Earth (Australia), <http://www.foe.org/camps/comm/nanotech/nano-cosmetics.pdf> (accessed on February 20, 2009).

- Munich Re (2002), *Nanotechnologie—Was kommt auf uns zu?*, Munich: Munich Re, http://www.munichre.com/publications/302-03533_de.pdf (accessed on February 20, 2009).
- Nanologue (2006), Europe-wide dialogue on social, ethical and legal impacts of nanotechnology, <http://www.nanologue.net/index.php?seite=4> (accessed on February 20, 2009).
- Nordmann, A. (2007), 'If and then: a critique of speculative nanoethics', *NanoEthics* 1: 31–46.
- Nordmann, A., J. Schummer, and A. Schwarz (eds.) (2006), *Nanotechnologien im Kontext: Philosophische, ethische und gesellschaftliche Perspektiven*, Berlin: AKA.
- Nowotny, H. (2003), 'Democratising expertise and socially robust knowledge', *Science and Public Policy* 30(3): 151–156.
- Nowotny, H., M. Gibbons, and P. Scott (2001), *Re-Thinking Science Knowledge and the Public in an Age of Uncertainty*, Cambridge: Polity.
- Paschen, H., C. Coenen, T. Fleischer, R. Grünwald, D. Oertel and C. Revermann (2003), *Nanotechnologie*, Berlin: Büro für Technikfolgen-Abschätzung beim Deutschen Bundestag (TAB) / The Office of Technology Assessment at the German Bundestag.
- Pitkethly, M. (2007), 'Seeking a nano code', *Nano Today* 2(6): 6.
- Power, M. (1997), 'From risk society to audit society', *Soziale Systeme* 3(1): 3–21.
- Renn, O. and M.C. Roco (2006), *White Paper on Nanotechnology Risk Governance*, Geneva: International Risk Governance Council.
- Rip, A. (2006), 'Folk theories of nanotechnologists', *Science as Culture* 15: 349–365.
- Roco, M.C., and W.S. Bainbridge (eds.) (2001), *Societal Implications of Nanoscience and Nanotechnology*, Dordrecht: Kluwer.
- Rose, N. (2000), 'Community, citizenship, and the third way', *American Behavioral Scientist*, 43(9): 1395–1411.
- Rose, N. (2001), 'The politics of life itself', *Theory, Culture & Society* 18(6): 1–30.
- Rosenau, J.N. (1992), 'Governance, order and change in world politics', in J. N. Rosenau and E.-O. Czempel (eds.), *Governance Without Government: Order and Change in World Politics*, Cambridge: Cambridge University Press.
- Royal Society and Royal Academy of Engineering (2004), *Nanoscience and Nanotechnologies: Opportunities and Uncertainties*, London: Royal Society.
- Schummer, J. and D. Baird (eds.) (2006), *Nanotechnology Challenges: Implications for Philosophy, Ethics and Society*, Singapore et al.: World Scientific Publishing.
- Schulte, P.A. and F. Salamanca-Buentello (2007), 'Ethical and scientific issues of nanotechnology in the workplace', *Environmental Health Perspectives* 115(1): 5–12.
- Smith, A., A. Stirling, and F. Berkhout (2005), 'The governance of sustainable socio-technical transitions', *Research Policy* 34(10): 1491–1510.
- Smith, R., and B. Wynne (1989), *Expert Evidence: Interpreting Science in the Law*, London, New York: Routledge.
- Stehr, N. (2005), *Knowledge Politics*, Boulder, CO: Paradigm Publishers.
- Swiss Re (2004), *Nanotechnology. Small Matter, Many Unknowns*, Zurich: Swiss Re. <http://www.swissre.com/INTERNET/pwswpspr.nsf/fmBookMarkFrameSet?ReadForm&BM=/vwAllbyIDKeyLu/yhan-5yucvt?OpenDocument> (accessed on February 20, 2009).
- Toumey, C. (2006), 'Science and democracy', *Nature Nanotechnology* 1(1): 6–7.
- Vollenbroek, F. (2002), 'Sustainable development and the challenge of innovation', *Journal of Cleaner Production* 10(3): 215–223.
- Von Schomberg, R. (2007), 'From the ethics of technology towards an ethics of knowledge policy and knowledge assessment', *Research Directorate General of the European Commission, Brussels, working document, Services of the European Commission*.
- Wiek, A., S. Zempa, M. Siegrista, and A.I. Waltera (2007), 'Sustainable governance of emerging technologies – critical constellations in the agent network of nanotechnology', *Technology in Society* 29(4): 388–406.
- Wullweber, J. (2008), 'Nanotechnology – an Empty Signifier à venir? A delineation of a technosocio-economical innovation strategy' *Science, Technology & Innovation Studies* 4(1): 27–45.

Part I

Going “Nano”: Opportunities and Risks

The first part of this book assembles papers that address the opportunities and risks of appropriating nanoscience and nanotechnology (NST) in organizations and in scientific disciplines.

In her contribution, *Martina Merz* analyzes organizational dynamics and in what way they account for the emergence of scientific fields. She argues that NST can be mobilized as a resource to reposition a research institute in a situation of crisis. As a case, she reflects on the Swiss national materials science and technology research institute Empa, whose shift to the nanoscale is interpreted as an organizational response to its insufficient degree of scientification as perceived by decision makers. Merz demonstrates that the appropriation of NST “solves” this problem at different levels simultaneously. First, the association with nanotechnology’s “economy of promises” grants scientific respectability to an organization and symbolically lifts its scientific reputation. Second, in the case of Empa, it enabled the testing institute to adjust the borders between its service (testing) and research (science) activities. Third, the organization makes use of nanotechnology as a topical area to promote itself as “a mediating instance between heterogeneous target groups.” She concludes by saying that these moves, individually and together, help to frame and continue the debate over what exactly is NST.

Monika Kurath focuses on the strategies and rationale that actors of the assessment regime use to negotiate questions about identities, boundaries, and potential technology implications in NST. Those strategies lead to transformations within the concerned science and technology fields. Analyzing the case of toxicology, she argues that the delegation of the risk assessment of NST to toxicology initiates new possibilities of reconstructing identities for toxicology as an academic discipline. While those in the field see the opportunity to get involved in basic research, the field may not entirely abandon its tradition as a testing, regulatory-oriented science. Jumping on the bandwagon of cutting-edge research could allow the classical testing sciences to undergo scientification and to dissolve the tension between research and testing.

In their article, *Christian Kehrt and Peter Schüßler* study how nanotechnology is received in crystallography in terms of “boundary objects” such as nano-instruments or nanoscale research objects. This allows Kehrt and Schüßler to draw a distinction

between scientists who remain within the boundaries of their discipline and *defensively appropriate* nanotechnology from those scientists who were forced to leave their disciplinary identity in order to explore new methods and realms of knowledge. Although the latter scientists may have new opportunities to explore molecules without asking whether they belong to biology, chemistry, or physics, they face a fragile and uncertain situation because they can no longer refer to the secure domains of the disciplines they left behind. For Kehrt and Schüßler, this disciplinary uncertainty is the main reason why scientists from different disciplines preemptively promote a new nanoidentity.

Negotiating Nano: From Assessing Risks to Disciplinary Transformations

Monika Kurath

1 Introduction: Identity Discourses and Assessment Dilemmas

A variety of discourses have been negotiating both promising visions and adverse implications of emerging nanosciences and nanotechnologies (NST).¹ But the “nano” future facing the assessment regime is unclear. While many possibilities of NST still in the making are imaginable, as their impacts become more knowable the options for dealing with them will become restricted. NST thus present Collingridge’s dilemma (Collingridge 1992) as we try to assess today what will appear tomorrow and have consequences the day after tomorrow.

As soon as potential implications of research and development fields are discussed, questions about characterization or definitions emerge. As almost all assessments of NST stress, knowing the identity of a scientific field is a precondition for further assessment.² Identity negotiation, including conjectured implications, can determine the future shape and implications of the negotiated scientific field (Schummer 2004: 3). As the nanosciences themselves have not given answers to open issues of identity and implications, the assessment regime first faces the simple question of what nanotechnology really is about. To cope with these uncertainties, the assessment regime uses different strategies and rationalities. These discourses of NST assessment also shape the nanosciences as an academic field and substantially frame disciplinary developments there.

This article aims at analyzing such transformation processes in the NST-related academic fields that are framed by the strategies and rationalities of the assessment regime in negotiating open identities and reflecting on potential implications of NST. A particular focus is held on the ways assessment strategies and rationalities

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¹Nanoterminology 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” (Drexler 1986); since that controversy, the first use of the term has been attributed to Taniguchi (1974).

²In addition to traditional technology assessment (TA), NST is assessed from a wide range of different perspectives. Therefore, the broader term “assessment” is used here instead of TA.

have been re-reflected and co-produced in the related scientific fields, what impact they have on disciplinary developments, and in what way this initiates disciplinary transformations.

First, an overview is given of the assessment strategies and rationalities used in evaluating identities and potential implications of NST. This is based on a discourse analysis that focuses on relevant assessment reports of different institutions and organizations, as well as participant observation at conferences, workshops, and participatory events on risk assessment in NST. Following this overview, the transformation processes in the negotiated science and technology fields and the effects on their disciplinary developments will be analyzed. Empirically addressing the delegation of aspects of NST risk research to scientific risk research fields – here toxicology – the disciplinary identity and boundary questions that toxicology faces through this delegation will be analyzed.³ Finally, ideas concerning how and why involvement in a cutting edge technology can lead to transformation processes in the involved academic fields will be discussed.

2 Strategies, Facing Problematic Identities

Compared to earlier technology discourses, we see not only an increase in and anticipatory establishment of assessment efforts in NST, but also the emergence of new rationalities becoming manifest in various assessment tools. In addition to traditional technology assessment (TA) approaches – as addressed by TA institutions, civil society organizations, industry, and researchers in the social sciences, humanities, and academic ethics – new rationalities have been established by foundations, councils, and think tanks. They distinguish themselves not only by following external orders, but by internally defining their subjects and goals, and communicating them through occasional interventions (see i.e. Kaiser 2006).⁴ Hence, they are not acting from a well-defined national position or focus on given issues, but rather react to self-identified problems. The assessment regime as analyzed in this context covers institutions using both traditional as well as new assessment rationalities.

To make the still open identity of nanotechnology comprehensible and to cope with the dilemma of the uncertain implications, traditional and new assessment institutions are acting with different strategies, such as

1. Relegating the dilemma to the future
2. Evading the problem through definitions and representations

³The empirical study was conducted as an individual project in 2005/2006 and consisted of qualitative interviews with German, Swiss, Dutch, and American toxicologists (Kurath and Maasen 2006a, b). The study was funded by the Cogito Foundation and the University of Basel, Switzerland.

⁴On traditional TA approaches see, e.g., Paschen et al. (2004), Royal Society and Royal Academy of Engineering (2004), Arnall (2003), SwissRe (2004: 83). Examples of new rationalities include the U.S. based Woodrow Wilson International Center for Scholars, the Swiss based International Risk Governance Council (IRGC), and the British think tank DEMOS.

3. Self-reflection within the social sciences and ethics
4. Asking the public
5. Delegating the problem to scientific risk research

Below, overviews of these five strategies will be given, with a deeper analytical focus on the fifth strategy, in which toxicology has turned out to be an instructive case to demonstrate how questions have been brought to the core of scientific disciplines and have produced uncertainty.

2.1 Relegation to the Future

NST are still surrounded by the future. The extent of this has been documented by a number of cultural and social-scientific analyses (Hayles 2004, López 2004, Milburn 2002). Ironically, representatives of the nanosciences not only affirm the critical diagnosis according to which nanotechnology is characterized by an inextricable “blurring of fact and fiction” (cf. Milburn 2002), they even promote it, and definitions and characterizations of NST are widespread on nanoscience research center websites. Such characterizations often focus on potential future beneficial applications of the technology. In several cases, quite futuristic scenarios have been drawn, such as that by the Center for Nanotechnology at the University of Washington, which announces that nanotechnology would turn science fiction into reality. Furthermore, it is often argued that NST will be able to offer cures for threatening diseases and in general make the impossible possible.⁵

Thus it is not astonishing that technology assessment reacts with the request to strictly separate speculation from fact. The chair of the Royal Society and Royal Academy of Engineering (RS&RAE) nanotechnologies working group, Prof. Ann Dowling, stresses that it is important to “separate the hype and hypothetical from the reality.”⁶ Further assessors, such as the European Academy, recommend distinguishing between “the merely speculative nature” of visions and “possible risks of nanoparticles” (Schmid et al. 2006: 14–15). But what effects attend this request for boundary work (Gieryn 1983) regarding what nanotechnology really is? What nanotechnology unifies at present is to a large extent clear: very little.

Considering this polymorphism and heterogeneity, one could be tempted to suggest that NST do not have an identity or unity at all, so that we should – according to a suggestion of Howard Lovy’s nanobot blog – refer to nanotechnology as “nanoscale stuff.”⁷ However, this impression is only correct for the present. In negotiating the future, in particular by anticipating converging effects, the term

⁵This science-fiction orientation seems quite astonishing for a well-reputed academic research center, which is part of the American National Nanofabrication Infrastructure Network (NNIN), funded by the National Nanotechnology Initiative. See <http://www.nano.washington.edu/index.asp> (accessed on December 21, 2007).

⁶See the press release for the RS&RAE report: <http://www.royalsoc.ac.uk/news.asp?year=&id=2147> (accessed on December 21, 2007).

⁷See <http://nanobot.blogspot.com/> (accessed on December 21, 2007).

“nanotechnology,” in the singular, is regularly used. Hence, difference between the unity and polymorphism of nanotechnology will be bridged by anticipating visions of converging effects. The argument of convergence appears in various assessment reports, e.g. that of Fleischer et al. (2004), who uses the terms “overlap” and “melting” in the context of the crossover to the nanoscale level. Frequently, these converging effects are attributed emerging features regarding the announced network of disciplines, which initiates new research approaches that transcend individual disciplines (see i.e. Laurent and Petit 2005).

In addition to referring to a potential future reduction of the current plurality of NST, the assessment regime also tries to make NST comprehensible through definitions or representations and materializations, such as consumer products already on the market.

2.2 *Evading the Problem by Definitions and Representations*

Hardly any research project description, strategy paper, technology assessment report, regulation manual, or media contribution lacks its own definitional approach for making the identity of NST comprehensible. A clear definition of a research field and its demarcation from external domains is seen as a necessary condition for the assessment of potential implications. As an example, the European Academy argues in its NST definition report that the term nanotechnology is less relevant for scientists than “reflection of the research process” by technology assessment and that here, first, the “object of reflection” ought to be defined (Schmid et al. 2003).

However, when it is asserted that NST are emerging, definitions acquire an ambivalent aftertaste. They leave compellingly undetermined whether the definition concerns the subject of NST themselves, or whether usage of the term “nanotechnology” is a given. Instead of describing NST, they prescribe the appropriateness of the term in a fashion such as that of the European Academy report: “In contrast to our definition, Nanotechnology is commonly also used for proceedings which would be better described by *scaling effects*” (Schmid et al. 2006: 13). Technically speaking, these definitions are not primarily forming real, but rather nominal definitions, in the sense that they normatively try to regulate and control the use of a term. The frequent use of “should” and “ought” stands for this normative/descriptive ambivalence as nanotechnology has to be understood. In addition, the definition also decides which implications to subsume under nanotechnology and which not. In this sense, the ethicist George Khushf, seeing the clarification of the term as a necessary precondition for the analysis of ethical implications, introduces an article with an elaboration on “how Nanotechnology *should* be understood” (Khushf 2004).

However, frequently enough the dilemma basically will be avoided. In this way, a distinct characterization of nanotechnology is set aside in favor of characterizing and visualizing the technology with exemplary consumer products or applications.⁸ These examples simply *stand for* nanotechnology, without the term

⁸See for example the consumer product inventory of the Woodrow Wilson International Center for Scholars (<http://www.nanotechproject.org/44> (accessed on December 21, 2007)).

“nanotechnology” receiving further explication. Another example of representation and demarcation on the product level is the German controversy involving the bathroom cleaning aerosol Magic Nano. In this episode, soon after the product appeared to show adverse effects it was pulled from the market. The removal of Magic Nano also was accompanied by the argument that the product “did not contain any nanomaterials.”⁹

2.3 *Self-Reflection in the Social Sciences and Ethics*

If the first two strategies largely deal with the unsettled identity of NST, the strategy of self-reflection relates more to facing the paradox of the asynchrony of technology shaping and its consequences. Observed mainly in ethical, legal, and social implication (ELSI) research, self-reflection involves critical reflection in the social sciences or humanities that has been initiated by the emergence of NST. In these domains NST compel such questions as, What can *we* learn from technology debate precedents? Do *we* need new concepts (independent of where NST lead us)? and What is *our* role in this debate? The fact “that the social and ethical implications of nanoscience and nanotechnology are difficult to anticipate” (Berne 2004) leads not necessarily to a more intensive analysis of NST, but rather to reflexive rethinking of subjects or disciplines. Examples for such disciplinary self-reflection are the establishment of new journals and magazines such as the journal *NanoEthics* and related edited volumes, and the initiation of related groups or schools, such as the Nanoethics Group.¹⁰

In addition to these discussions about disciplinary capacity, the necessity and inalienability of social and ethical reflections is emphasized in a variety of assessment reports (see e.g. European Commission 2004, or Royal Society 2004). A similar question is whether, faced with NST, an existing area of reflection should be expanded. These elaborate questions to a certain extent also reveal disciplinary deficits that extend beyond NST. Gaskell et al. argue, for example, that the debates on NST need a wider agenda that mainly focuses on the “ethical and societal aspects of technological innovation” (Gaskell et al. 2004).

2.4 *Asking the Public*

In the context of new rationalities and attributions in assessing the open identity and potential implications questions of NST, the public plays a major role.

⁹See http://www.giz-nord.de/php/index.php?option=com_content&task=view&id=122&Itemid=85/ (accessed on December 21, 2007).

¹⁰On the journal *NanoEthics* see <http://www.springerlink.com/content/120571/>. The Nanoethics Group is a US-based academic researcher network that produced the edited volume *Nanoethics: The Ethical and Social Implications of Nanotechnology* <http://www.nanoethics.org/>.

The idea of public engagement is prominently recommended in almost every assessment and strategy report.¹¹ Most prominently among these, the RS&RAE (2004) report advocated more upstream public engagement, and an editorial in the science magazine *Nature* further emphasized this idea (Nature 2004, Royal Society 2004). Subsequently, in many western European countries and most prominently in Britain a range of NST-related engagement projects started, including the NanoJury, the Lancaster-DEMOS Nanodialogues, and the assessment of such projects by the Nanotechnologies Engagement Group (NEG) (Gavelin et al. 2007).

However, the role and function of public engagement remained somewhat unclear. Critical voices argued that the claim for public engagement is mere fashion and a fund raising strategy, rather than a real interest in citizens' opinions, and that the public engagement amounted to mere public information instead of true exchange (Rogers-Hayden et al. 2007: 127). Others said that there was more talk about dialogue and engagement than there was actual dialogue and engagement (Hagendijk and Irwin 2006). In addition, it was argued that engaging people in discussion prior to public discourse on a subject raises a paradox of participation: at the very moment when a science or technology field is new, and decision making agendas are relatively open and could be influenced, public perception of the field is lowest (Rogers-Hayden et al. 2007). By contrast, public awareness tends to be much greater when both the development agendas of science and technology and the principles for regulating them are further developed, but less malleable. This perception was shared by opinion polls that said the public is little interested in nanosciences and nanotechnologies at the moment (see, e.g., Gaskell et al. 2004, Kahan et al. 2007).

The prominent recommendation of public engagement in almost every NST assessment report, at a moment when the public perception of the field is low, suggests that asking the public might be a strategy to cope with open identity and implication questions by delegating them to citizens. Recommending public engagement could even stabilize technology development by allowing proponents to argue that the public has been involved. Some participatory projects even try to achieve identity by consensus, one example being the Swiss Publifocus Nanotechnology project, which issued a brochure with definitions as a basis for the public consultation.¹² In this respect, NST are not what they evoke, but rather what the involved actors broadly agree upon.

¹¹Further examples of assessment reports supporting public engagement consist of Renn and Roco (2007), Schmid et al. (2006), Wood et al. (2007). On strategy reports see e.g., Commission of the European Communities (2005); Schierow (2008).

¹²The definitions of nanotechnologies in the brochure of the Publifocus Nanotechnology of the Swiss Centre for Technology Assessment (TA-Swiss) were adjusted with central stakeholders in NST in Switzerland, which include public authorities, regulatory bodies, scientists, and food and reinsurance firms (Cerutti 2006).

2.5 Delegation to Toxicological Risk Research

In the delegation of the identity question and the uncertainty regarding potential implications to scientific risk research, toxicology turns out to play a major role. As a traditional testing science, toxicology analyzes particles and materials for toxicity. In particular, particle and inhalation toxicologists have analyzed small-scale materials such as those from combustion processes for decades (Kurath and Maasen 2006b). When risk research is wanted, NST turn primarily to toxicology.¹³ This is comparable to the fourth strategy, in which ELSI research disciplines are involved in assessments. In both that strategy and the reliance of NST on toxicology, open NST questions initiate demarcation and identity-finding processes within these separate disciplines. The unique case of toxicology has turned out to be instructive by showing how outlying questions have been brought into the core of the scientific discipline and there produced uncertainty. This is not unusual. Traditional testing sciences have often been particularly concerned with the emergence of new technology. They see themselves confronted with the choice of whether to remain applied disciplines or use short moments of disciplinary openness, which occur in particular situations of technology emergence, to reconstitute themselves as basic research disciplines (see Merz, in this volume, Schüßler and Kehrt, in this volume). In toxicology's case, its studies were the first to describe nanomaterial-related adverse health effects. This has contributed to increased attention to and pressure on knowledge production in toxicology, which in turn has led to an identity shift or redesign within the field itself.

3 Transformation Processes in Toxicology

The establishment of a socially valued, cutting edge scientific field opens up both the possibility for certain academic disciplines to participate in innovative research questions, and sources of substantial funding. Within the field of NST, toxicology is contributing significantly to risk research through its epistemic and ontological tradition as a testing science. Because of its cognitive and institutional background in the investigation of bioreactivities of particles and materials, and its orientation toward externally given problem definitions, toxicology plays an important role in concrete statements on the health implications of nanomaterials, which are a basis for potential regulation.

The delegation of the vague identity and the uncertainty about potential implications of nanomaterials to toxicology is able to initiate processes in toxicology that are quite similar to the coping strategies of the NST assessment regime. The initially

¹³This commitment can be found in various assessment reports such as Arnall (2003), Commission of the European Communities (2005), Commission of the European Communities (2004), European Commission (2004), Paschen et al. (2004), Royal Society (2004: 85), Schmid et al. (2006), SwissRe (2004).

frugal demand upon toxicological risk research to investigate potential risks of nanomaterials leads to problematic questions about what NST *really* is, and in what way the toxicological community should enlist in NST. Should toxicology become a fruitful part of NST, or remain as a mere testing science, focusing on nano from a material testing perspective only? Still, in virtue of its tradition as a testing science toxicology initially acts as if it would analyze nanomaterials and their implications from an *external* perspective comparable to that of other assessment institutions acting as if they are not subsumed under the *virtual* nanotechnology.

The negotiation of NST by toxicology is organized along two principal axes of communication or conflict:

1. Concerning the investigative analytical scope, toxicology includes nanomaterials and focuses on the question of whether and how nanoparticles can be toxicologically understood as something new.
2. However, this negotiation of novelty is not simply an ontological problem. Rather, it leads to the center of the disciplinary self-conception of toxicology. Facing the challenge of NST, toxicology starts to rethink the relation between its scientific function and the societal expectations regarding its knowledge production.

How, then, does toxicology negotiate the terrain of NST and the dual question of ontological and disciplinary novelty?

3.1 The Significance of Doing “Nano”: Negotiating Novelty

For us, the term “nano” is old hat, we have been doing “nano” for more than 15 years—respectively work with ultrafine particles—although we did not know that this would be called “nano” later (Toxicologist 1, Germany).

Many inhalation or particle toxicologists speak in a similar, inclusion-strategic manner. They argue that by working with manufactured nanoscale reference particles for measuring health effects of the smallest environmental dust, they worked nanoscientifically before the term “nano” was established. As a reference for experience with the behavior and hazardousness of nanomaterials, they cite work with particles on the micrometer level and constitutive research on ultrafine environmental particles, for example, those resulting from combustion. Based on experience with bio-interactions of these particles, toxicologists infer the behavior of industrially manufactured nanoscale material.

Our experience with ultra fine particles is of high importance for analyzing the risks of nanoparticles. Along with ultra fine particles, we began to use nano-test particles to investigate certain mechanisms (Toxicologist 3, Switzerland).

The transition from the ultrafine to the nano-scale often happens inconspicuously. Alongside research with ultrafine particles, similar experiments are repeated with selectively produced nanoparticles.

Self-evidently, against this background there is no challenge toxicology cannot take care of; after all, “nano” is old hat for it. However, simply equating *nanotechnology* with *nanoscale material* seems to provoke irritations in the toxicology community. As will be demonstrated in subsequent citations, nanomaterials are expected to have specific characteristics. So, it is controversial whether the particular technological nature of nano is reduced by defining the investigated particles as a matter of size.

When I'd like to talk of risks of nanotechnology and then come to know that only environmental particles are discussed and no nanotechnological materials, then something is wrong (Toxicologist 2, Germany).

Seen theoretically, it does not seem implausible to react to such inconsistencies or irritations with differentiation. In the field of toxicology, an attempt is made to solve inconsistency with a differentiation regarding the origin of nanoparticles:

The term “nano-material” implies technical design and intentional manufacture. The size range of particular ultra-fine particles only coincidentally lies in the nanometer scale. Therefore, I would use terms like “combustion particle” or “environmentally relevant particle” for particles unintentionally released into the environment, and definitely not the term “nanoparticle” (Toxicologist 4, USA).

Institutionally, such suggestions for differentiation can receive additional support. Therefore, research projects for the investigation of health implications of industrially manufactured nanomaterials are generally more generously funded than those with particles resulting from combustion processes. Hence, interests are produced to broaden the research field of nanosciences, which means that to understand the analysis of environmental particles on the nanoscale level coincides with nanoscience. Last, but not least, the *bandwagon effect* also plays a role in this field, as the ability to subsume oneself under the less specific field of “nano” facilitates the acquisition of research funds:

“Nano”: this is a fashion and naturally also a funding strategy. If I applied for research funding on ultra fine dust at the European Union, that would be old hat. It was already done in the 1970s and the 1980s. However, if I applied for funding for a project on the influence of nano-particles, then everything looks quite different (Toxicologist 1, Germany).

The differentiation, as should be apparent here, does not necessarily result from demarcating something as less scientific, as Gieryn suggests with his concept of boundary work (Gieryn 1983). Quite the contrary, differentiations can also be adopted to specify uncertainties internal to a discipline in such a way that, subsequently, new, well paid research possibilities can be generated. This means an increase of epistemic authority in the sense of an expansive boundary work (see Gieryn 1995: 15–17) to incorporate unexplored ontological domains by differentiations. However, the expansion is only successful when a continuum can be established between ultrafine dust and “nanomaterial”, which is able to retrospectively level the originally drawn differentiation as fashion.

The same differentiation of nanoparticles according to their “unintentional and intentional sources” (Oberdörster et al. 2005: 823) or their structure, “physically and chemically heterogenous” versus “precisely constructed and entirely synthesized”

(Kreyling et al. 2006: 544) can at the same time be used to protect against excessive research claims. Thus, not rarely, but subliminally, it is demurred that with too wide a conception of the term nanoparticle the investigation of effects of all smallest particles will be assigned to the field of nanosciences. In particular, the comparability of nanoparticles with health-adverse particulate matter marks a controversial territory.

The fact that the particle size of particulate matter in the surrounding air comprises the area of synthetic nanoparticles can not be equated with their toxicity. Here, additional criteria play a role, like their chemical composition. Hence, the conclusion from particulate matter of the surrounding air to synthetic nanoparticles can not be carried out globally (Claus and Lahl 2006: 2).

While in the first case the differentiation of toxicology offers the possibility of expansion, it serves in the second case to restrict the field of expertise, and therefore to protect its future credibility. This differentiation therefore can, at first sight, serve to stimulate excluding processes of “expansion” as well as “protection of autonomy” (Gieryn 1995: 16).

As the fairly unemotional debate over the correct concept of nanoparticles demonstrates, more is at stake than the matter of a few nanometers. Rather, it is about specifying, denying, or, in contrast, establishing the novelty of nanotechnology within the field of toxicology. The difference between old and new is negotiated not least by the difference between intentionally manufactured material and passively accumulating particles. Regardless of how this “negotiation of novelty” (Hessenbruch 2004) might turn out, it is to be judged against the background of what toxicology scientifically dares: how far should it expand, and thus establish a continuum between old and new? How far should it exclusively engage in the new, which means the manufactured particles?

If options based on differentiations are at hand, they may be reconciled in a second step by a suggested compromise. This direction also takes the suggestion of a leading particle toxicologist in the US, Günter Oberdörster, to subsume both particle types – independently from their differentiation with “intentional” and “nonintentional,” which at the same time corresponds to the separation of “technical” and “natural” – under the term “nanoscale particle”:

Therefore, I’d suggest the term “nano-scale particle” as a comprehensive definition for environmental particles within the nanometer scale (Toxicologist 4, USA).

“Nano,” for most inhalation and particle toxicologists, is nothing new. It only subsumes their longtime work under a new term. This indicates a tendency of persistence in the disciplinary tradition. However, the irritations that NST is able to provoke in the field of toxicology reach even further than the question of to what extent toxicology dares to fill a field whose novelty is disputed. The negotiation of whether nano is old hat or new not only affects the research object of toxicology but also the discipline’s own self-conception.

3.2 The Significance of Being “nano”: Reflections on Function and Expectations

The emergence of NST initially leads to reflexive attitudes among representatives of the toxicological research community – on their focus, their mission, their lost chances, and last but not least, on their participation in science as a whole.

In toxicology, we are only able to publish negative results. When we find positive, or rather no effects, we cannot publish them. When we discuss that a particular substance is not toxic, this is fine for society but bad for us as scientists, since we measure research quality based on output (Toxicologist 5, Germany).

In my view, such reflections focus not only on the science’s habit of shaping its own objects. Such reflections comprise more than the question of whether a discipline could gain a new face by establishing a new journal. Additionally, these reflections are about new orientations and the reflexively customized identity of a discipline.

According to Luhmann (1992), reflections – when undertaken in single disciplines – orient themselves around two fixed points. First, they orient themselves to *performances* or *missions* that a *specific* science has to perform (Luhmann 1992: 635). In the case of toxicology, this means that it has to produce valuable knowledge regarding which substances are toxic and which are harmless. Such knowledge then can be selectively taken up by science policy or industry and built into their own decision-making processes. The second point of reference is given by the *function* of a particular science. And this function is for all sciences the same, namely to produce new truths.

The focus on the specificity of performances and the focus on the universality of function often generate a stress relationship that applies to toxicology. As toxicologist 5 mentioned in the interview, that testing a substance that proves harmless, which is in the interest of society, is *bad for the scientists*, since research quality is measured based on (published) output. It is precisely the socially expected function that is perceived in this self-assessment as a direct competitor to the scientific mission or performance. However, other disciplines also show such difficulties in their orientation. But for those that explicitly follow a regulatory-oriented social order – like ethics, toxicology, or recently also sustainability research – this option of closing ranks by positioning themselves as a less implication-oriented, yet more research-oriented basic science discipline is hardly possible.

However, exactly these efforts can be observed in toxicology in the context of NST. It is not only a question of getting a safety study published in *Science* or *Nature*, but rather to transform toxicology into a product-oriented, pure science. The new issue is, as we will see below, the development of biocompatible particles or materials.¹⁴ In that sense we can observe a tendency of scientization in the field

¹⁴The development of biocompatible or bio-inert, and thus artificially designed, material that is not irritating to biological systems is an important research area within NST. The aim of this approach is to develop mobile targeted drug carrier systems on the nanoscale level. A nanoparticle is designed to transport and apply a therapeutic agent directly to the site of pharmacological action

of toxicology. Doing this is killing two birds with one stone. As a testing discipline, toxicology relies on its rich experience, of which it profits as a nanoscience by the development of biocompatible materials. Or, in the validation of the prominent Rice University environmental toxicologist, Vicki Colvin,

The paradigm shift really is not seeing toxicology as a gatekeeper but seeing toxicology as a point of information that allows you to generate more biocompatible materials (Colvin after Monastersky 2004).

Hence, participating in the development of biocompatible materials enables toxicology's transformation from a regulatory-oriented into a research-oriented science. Several studies observe that traditional testing disciplines and institutions judge such transformation processes as desirable (see Merz, this volume).

In addition, the possibility of therapeutic use apparently aims at the new scientific character of toxicology. Importantly, so far, the aim of toxicology has been to test, not to heal.

A positive approach is therapy. We will find out how a nanoparticle should be designed, and what surface properties it must have in order to not cause any reaction in the organism. If I created such a particle, I could load it with a medicament or equip it with receptors such that these would then be carried into the cells (Toxicologist 6, Germany).

In short,

“Nano” offers an enormous potential for toxicology. For example, we are able to develop biocompatible particles (Toxicologist 4, USA).

While these attempts indicate a potential transformation of toxicology into a product-oriented basic research discipline, the negotiation of novelty addressed in the preceding section rather suggested a tendency of persistence in its disciplinary tradition. Therefore, our findings most likely indicate a development of “as well as”: as a testing *discipline*, toxicology can rely on its rich experience, of which it benefits as a virtual *nanoscience* in the development of biocompatible particles.

4 Assessment Transforming Disciplines?

4.1 Toxicology as a Nanoscience?

The delegation of risk assessment to toxicology, recommended by various assessments, initiates new possibilities of reconstructing disciplinary identities. These concern the risks of particles on the nanoscale level to a lesser extent than the question of whether NST pose an opportunity or a hazard for toxicology as an academic discipline. These negotiations can be characterized by two tendencies:

(Kreuter et al. 2002). Toxicology has acquired a lead in knowledge from in vitro and in vivo studies of particular features and structures of material, which it is able to use for the design of bio-inert particles with minimal health effects (see Kurath and Maasen 2006a).

1. On one hand, toxicology reconsiders whether and how it should turn to new ontological domains. How can nanomaterials become integrated into its research tradition? The observed dominant strategy indicates expansive boundary work, together with maintaining the disciplinary research tradition.
2. On the other hand, toxicology poses questions of disciplinary self-conception regarding the way emerging NST offer the possibility of a paradigm shift from distanced outside observation as a traditional testing science to active participation as a basic research oriented discipline.

Both crucially challenge the relationship between provision of a service, the performance of which involves the identification of toxic substances and academic knowledge production, and function, the pursuit of an academic career and publication in highly ranked journals. Current attempts to solve this dilemma indicate that toxicology experiments with achieving a more basic-research-oriented disciplinary understanding. However, this has only become possible through the emergence of NST and the associated need for more related risk research, which brought toxicology from the unloved position of a tester to nearer the center of an emerging cutting-edge technology. Furthermore, not only were its testing capacities asked for, but its experience also was sought in the development of basic medical research.

The question of whether toxicology has become a part of NST has an ambivalent answer. Although toxicology sees an opportunity for actively getting involved in product-orientation, it is not prepared to entirely abandon its tradition as a testing, regulatory-oriented science.

Finally, toxicologist 1's statement that "nano" "is a fashion and naturally also a funding strategy" leads to another observation: the attraction that cutting-edge research focuses hold for all sorts of neighboring scientific disciplines. This phenomenon, also known as the bandwagon effect, has been observed within several big science projects and research focuses such as biotechnology, the Human Genome Project, and the US war on cancer (De Solla Price 1974).

4.2 Disciplines Assessed

A variety of assessment discourses and institutions face the rather diffuse identity of NST and the difficulties of assessing potential risks that are captured by the Collingridge Dilemma. They are challenged by the difficult questions regarding where NST are located, of whom it consists, and how its potential impacts could be assessed in visions of the future, in definitions, in reflections, in the dialogue with the public, or in the delegation to scientific risk research.

The assessment regime that delegates the open questions about implications to scientific – or in this case toxicological – risk research produces two consequences in the related fields. First, answers to the health-implication question are being analyzed. In parallel, the related attention toxicology achieves by providing answers to a widely hyped and highly rated and funded technology provides a moment of

openness, vulnerability, and change. An incremental process of demarcation and identity-shaping opens the possibility for transformation and increasing prestige in the academic hierarchy. The case of toxicology instructively stands for the recursive relationship between nanotechnology, its assessment, and the existing system of scientific disciplines. In other words, nanoscience can only emerge or condense by its specific negotiation within particular disciplines.

For the tension in classical testing science disciplines between academic prestige and completing the task, the emergence of a cutting-edge technology functions as a welcome transmitter. Therefore, we can speculate whether or not technologies in contrast to sciences are better able to bridge the separation between performance and function at all. What argues for this speculation is, first, that technologies, in contrast to academic knowledge, are less concerned by a loss of authority (Luhmann 1992: 632). Second, looking at technologies, function widely coincides with performance. Hence, the provision of new technological artifacts instead of new truths is as accessible in science as in other domains of society.

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References

- Arnall, A. H. (2003), ‘Future Technologies, Today’s Choices. Nanotechnology, Artificial Intelligence and Robotics: a Technical, Political and Institutional Map of Emerging Technologies’, London: Greenpeace Environmental Trust.
- Berne, R. W. (2004), ‘Tiny Ethics for Big Challenges: Calling for an Ethics of Nanoscale Science and Technology’, *Circuits and Devices Magazine IEEE* 20: 10.
- Cerutti, H. (2006), Nano! Nanu? – Informationsbroschüre publifocus ‘Nanotechnologien und ihre Bedeutung für Gesundheit und Umwelt’, Bern: Zentrum für Technologiefolgen-Abschätzung, TA Swiss.
- Claus, F. and U. Lahl (2006), ‘Synthetische Nanopartikel – Entwicklungschancen im Dialog’, in Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (BFR) (ed), *Diskussionsbeiträge Synthetische Nanopartikel*, Bonn: BFR.
- Collingridge, D. (1992), *The Management of Scales: Big Organizations. Big Decisions. Big Mistakes*, London: Routledge.
- Commission of the European Communities (2004), *Communication from the Commission: To an European Strategy for Nanotechnology*, Brussels.
- Commission of the European Communities (2005), *Communication from the Commission to the Council, the European Parliament and the Economic and Social Committee: Nanosciences and Nanotechnologies: an Action Plan for Europe 2005–2009*, Brussels.
- De Solla Price, D. (1974), *Little Science Big Science*, Frankfurt (Main): Suhrkamp.
- Drexler, E. K. (1986), *Engines of Creation: The Coming Era of Nanotechnology*, New York: Anchor Books.
- European Commission (2004), *CORDIS: Nanotechnology Action Plan: Towards a European Strategy for Nanotechnology*, Brussels: Directorate General for Health and Consumer Safety.
- Fleischer, T., M. Decker, and U. Fiedler (2004), ‘Grosse Aufmerksamkeit für kleine Welten – Nanotechnologie und ihre Folgen’, *Technikfolgenabschätzung – Theorie und Praxis* 2(13): 5–9.
- Gaskell, G., T. Ten Eyck, J. Jackson, and G. Veltri (2004), ‘Public Attitudes to Nanotechnology in Europe and the United States’, *Nature Materials* 3: 496.

- Gavelin, K., R. Wilson and R. Doubleday (2007), *Democratic technologies? The Final Report of the Nanotechnology Engagement Group (NEG)*, London: Involve.
- Gieryn, T. (1983), 'Boundary-Work and the Demarcation of Science from Non-Science: Strains and interests in Professional Ideologies of Scientists', *American Sociological Review* 48: 781–795.
- Gieryn, T. (1995), 'Boundaries of Science' in S. Jasanoff, G.E. Markle, J.C. Peterson, and T. Pinch (eds.), *Handbook of Science and Technology Studies*, Thousand Oaks: Sage Publications: 393–443.
- Hagendijk, R. and A. Irwin (2006), 'Public Deliberation and Governance: Engaging with Science and Technology in Contemporary Europe', *Minerva* 44: 167–184.
- Hayles, K. (2004), *Nanoculture: Implications of the New Technoscience*, Bristol (UK) and Portland, Oregon: Intellect Books.
- Hessenbruch, A. (2004), 'Nanotechnology and the Negotiation of Novelty' in D. Baird, A. Nordmann, and J. Schummer (eds.), *Discovering the Nanoscale*, Amsterdam: IOS Press: 135–144.
- Kahan, D. M., P. Slovic, D. Braman, J. Gastil, and G.L. Cohen (2007), *Affect, Values, and Nanotechnology Risk Perceptions: An Experimental Investigation*, <http://ssrn.com/abstract=968652> (accessed on Januar 13, 2009).
- Kaiser, M. (2006), 'Drawing the Boundaries of Nanoscience – Rationalizing the Concerns', *Journal of Law, Medicine & Ethics* 43(4): 667–674.
- Khushf, G. (2004), *The Ethics of Nanotechnology Vision and Values for a New Generation of Science and Engineering*. Washington D.C.: National Academies Press.
- Kreuter, J., D. Shamenkov, V. Petrov, P. Ramge, K. Cychutek, C. Koch-Brandt, and R. Alyautdin (2002), 'Apolipoprotein-Medicated Transport of Nanoparticle-Bound Drugs across the Blood-Brain Barrier', *J. Drug. Target* 10: 317–325.
- Kreyling, W., M. Semler-Behnke and W. Möller (2006), 'Health Implications of Nanoparticles', *Journal of Nanoparticle Research* 8: 543–562.
- Kurath, M. and S. Maasen (2006a), 'Disziplinäre Identitätsbildung neu gedacht: Toxikologie als Nanowissenschaft?' in A. Nordmann, J. Schummer, and A. Schwarz (eds.), *Nanotechnologien im Kontext: Philosophische, ethische und gesellschaftliche Perspektiven*, Berlin: AKA: 397–418.
- Kurath, M. and S. Maasen (2006b), 'Toxicology as a Nanoscience? – Disciplinary Identities Reconsidered', *Particle and Fibre Toxicology*, 3, 6.
- Laurent, L. and J. Petit (2005), 'Nanosciences and its Convergence with Other Technologies. New Golden Age or Apocalypse?', *HYLE – International Journal for Philosophy of Chemistry* 11: 45–76.
- López, J. (2004), 'Bridging the Gaps: Science Fiction in Nanotechnology', *HYLE – International Journal for Philosophy of Chemistry* 10: 129–152.
- Luhmann, N. (1992), *Die Wissenschaft der Gesellschaft*, Frankfurt (Main): Suhrkamp.
- Merz, M. (2005), 'Knowledge Construction' in S. Restivo (ed.), *Science, Technology and Society: An Encyclopedia*, Oxford: Oxford University Press: 249–255.
- Milburn, C. (2002), 'Nanotechnology in the Age of Posthuman Engineering: Science Fiction as Science', *Configurations* 10: 261–295.
- Monastersky, R. (2004), 'The Dark Side of Small. As Nanotechnology Takes off: Researchers Scramble to Assess its Risks', *The Chronicle of Higher Education* 51.
- Nature (2004), 'Going Public', *Nature* 431: 883.
- Oberdörster, G., E. Oberdörster and J. Oberdörster (2005), 'Nanotoxicology: An Emerging Discipline Evolving from Studies of Ultrafine Particles', *Environmental Health Perspectives* 113: 823–839.
- Paschen, H., C. Coenen, T. Fleischer, R. Grünwald, D. Oertel, and C. Revermann (2004), *Nanotechnologie – Forschung, Entwicklung, Anwendung*, Berlin: Springer.
- Renn, O., and M.C. Roco (2007), 'Nanotechnology Risk Governance: Recommendations for a Global, Coordinated Approach to the Governance of Potential Risks' in International

- Risk Governance Council (ed.), *Policy Brief*, Geneva: International Risk Governance Council
- Rogers-Hayden, T., A. Mohr, N. Pidgeon (2007), 'Introduction: Engaging with Nanotechnologies – Engaging Differently?', *NanoEthics* 1: 123–130.
- Royal Society (2004), 'Nanoscience and Nanotechnologies: Opportunities and Uncertainties', *RS Policy Document*, London: Royal Society & Royal Academy of Engineering.
- Royal Society and Royal Academy of Engineering (2004), *Nanoscience and Nanotechnologies: Opportunities and Uncertainties*, London: Royal Society and Royal Academy of Engineering.
- Schierow, L. (2008), CRS Report for Congress: Engineered Nanoscale Materials and Derivative Products: Regulatory Challenges, Washington: Congressional Research Service.
- Schmid, G., H. Brune, H. Ernst, A. Grunwald, W. Armin, H. Grünwald, H. Hofmann, P. Krug, P. Janich, M. Mayor, W. Rathgeber, U. Simon, V. Vogel, and D. Wyrwa (2006), *Nanotechnology: Assessment and Perspectives*, Berlin: Springer.
- Schmid, G., M. Decker, H. Ernst, H. Fuchs, W. Grünwald, A. Grunwald, H. Hofmann, Heinrich, M. Mayor, W. Rathgeber, U. Simon, and D. Wyrwa (2003), 'Small Dimensions and Material Properties. A Definition of Nanotechnology' in Europäische Akademie zur Erforschung von Folgen wissenschaftlich-technischer Entwicklungen (ed.), *Graue Reihe*, Bad Neuenahr-Ahrweiler.
- Schummer, J. (2004), 'Societal and Ethical Implications of Nanotechnology: Meanings, Interest Groups and Social Dynamics', *Techné: Journal of the Society for Philosophy and Technology* 8: 1–14.
- SwissRe (2004), 'Nanotechnology. Small Matter, Many Unknowns', *Risk perception*, Zurich: Swiss Reinsurance Company.
- Taniguchi, N. (1974), 'On the Basic Concept of "Nano-Technology"', Proc. Intl. Conf. Prod. Eng. Tokyo, Part II, *Japan Society of Precision Engineering*.
- Wood, S., R. Jones, and A. Geldart (2007), *Nanotechnology: From the Science to the Social*, Swindon (UK): The Economic and Social Research Council (ESRC).