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Co-creating Nano-imaginaries: Report of a Delphi-Exercise — Source link

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REPORT

NANOSOC (SBO-IWT project)

CO-CREATING NANO-IMAGINARIES

Report of a Delphi-exercise

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Abstract

In the first phase of the research project Nanotechnologies for tomorrow's society (www.nanosoc.be)*, the research consortium explored a variety of futuristic visions or techno-scientific imaginaries. This exploration took the form a Policy Delphi, adapted to the particular objective of jointly constructing nano-imaginaries, taking participants 'personal' visions of possible future applications and societal issues as a starting point. The participants were nano-researchers, as well as societal experts and primary involved citizens. In this article we describe the theoretical frame which inspired our methodological approach, we present the analytical results we obtained, and we bring some reflections to the fore that arose as a result of the performance and analysis of this Delphi-exercise.*

Introduction

This paper describes the first of four 'action' phases of the interdisciplinary research project *Nanotechnologies for tomorrow's society, NanoSoc* (www.nanosoc.be), that engages innovation networks in the region of Flanders, Belgium, to discuss and influence future nanotech developments in three fields of nanotechnology development: smart environment, bio-on-chip and new materials[1]. Smart environment, which is more or less synonymous with "ubiquitous computing" and "ambient intelligence", refers to visions on the converging future of consumer electronics, telecommunications and computing, in which devices and technology are integrated into our surroundings until only their user interface remains (Van Doorn et. al, 2006). The Bio-on-Chip case deals with biosensors: measuring instruments that couple biological molecules ("soft" matter) with a micro-electronic part ("hard" matter), so that both parts retain their function. The New Materials case focuses on applications of zero-dimensional nano-particles and meso-porous materials.

NanoSoc counts as the largest Flemish Technology Assessment project to date. It is funded by the Flemish Institute for the Advancement of Innovation through Science and Technology, IWT, for a four year period, ranging from 1 February 2006 to 1 February 2010. The Technology Assessment division of the University of Antwerp acts as its central coordinator, and works in close cooperation with the Centre for Technology, Science, and Ethics of the University of Leuven, CWTE, the Physics Department of the University of Antwerp, EMAT, and the leading independent research centre on micro-electronics and nanotechnology, IMEC. The research consortium thus consists of nanotechnologists and natural and social scientists. NanoSoc is meant to discuss and reflect on the opportunities and challenges involved in the constructive social shaping of nanotechnologies, more specifically in the previously mentioned three fields of application.

As the project aims to provide scientists, technologists and engineers with incentives to systematically reflect on the social and ethical dimensions of nanotechnology development, it initiates four successive participatory steps with various actors in nanotechnology, including several nanoscientists and nanotechnologists at IMEC and

[1] For an extended description of the *NanoSoc*-project see **Goorden, L., Van Oudheusden, M., Evers, J. and Deblonde, M.** 2007 'Nanotechnologies for Tomorrow's Society: A case for Reflective Action Research in Flanders, Belgium' *Paper contributed to the Yearbook of Nanotechnology in Society 2006-2007*: Center for Nanotechnology in Society, Arizona State University.

EMAT, as well as stakeholders in government, industry and civil society, and ordinary citizens. The first two steps are designed to ascertain which future nanotechnology trajectories actors deem possible and therefore merit further societal consideration. The third and fourth step consist of further interchanges with stakeholders and scientists respectively, and deal with the question which trajectories these actors consider worthy of elaboration, and if possible, actual implementation.

In this article, we successively lay out the objectives of the first step in NanoSoc's action research component, the theoretical perspective which guides the research, the methodology that the consortium of social scientists and nanoscientists developed, the analytical results that it obtained, and some further research questions and reflections that arose from these results.

Objectives

The first phase of the NanoSoc project aimed to explore visions or imaginaries of possible futures with nanotechnologies. This exploration was not meant to learn to 'know' the future in a scientific sense, as the future is not fixed and is, consequently, not susceptible to social-scientific discovery. The research consortium did not intend to predict the future. Such an intention contradicts its assumption that the future - and nanotechnologies that play a role in their construction - is continuously shaped and reshaped by initiatives and interactions of a multitude of human and non-human agents in various and evolving contexts. The present holds the potential for a variety of futures. The exploration exercise within NanoSoc was meant to 'visit' possible futures. From these 'visits' the consortium wanted to learn which elements – expectations, hopes and fears, co-operation networks, interests, infrastructures, institutions, and so on in our actual situation prepare for the various possible futures. Our exploration exercise should help to make links between possible futures and our actual situation more explicit.

Visions or imaginaries regarding possible futures based on a variety of nanotechnological trajectories, were meant to function as instruments for communication and debate about the present, about possible futures and about links between both. In the first phase of NanoSoc's action research section, visions are conceived as communication instruments between the participants. Structured debate regarding a wide variety of visions should help to construct, in the final stage of this first phase, socio-technical scenarios that depart from actual research agendas and technological developments. The results of this structured debate - three jointly created nano-imaginaries for each case - were meant to be deployed as communication platforms in the second phase of NanoSoc, in which secondary involved citizens discussed the plurality and flexibility of actual values and appreciations in view of the nano-imaginaries provided to them[2].

Theoretical frame

Why did the consortium focus on "futuristic visions" or "techno-scientific imaginaries" in this first phase of NanoSoc's action research? From the beginning, it was clear to us that

[2] For more on the outcomes of the second round, see: Evers, J. & Van Oudheusden, M., "Assessing Flemish citizens' moral argumentations on nanotechnologies: an incentive to rethink the interactive Technology Assessment approach to new and emerging technologies", Paper presented at the STGlobal Conference, April 5-6, 2008, Washington, DC, USA, 15 p.

we wanted to explore possible futures with nanotechnologies[3]. This means that we did not simply aim to explore future nanotechnologies, but future societies with nanotechnologies. We wanted, moreover, to stimulate as wide a variety of possible futures as is feasible in an experimental setup. Furthermore, the futures described should be suitable tools to explore, in the second phase of NanoSoc's action research and with a group of citizens, how it feels to live and to live together in these projected futures. Given these objectives, we found several indications in the literature that "visions" or "imaginaries" are appropriate theoretical concepts for our research aims.

Visions and imaginaries as intermediaries between the present and possible futures

Futuristic visions or techno-scientific imaginaries are suitable starting points to critically examine links between the present and possible futures in which nanotechnologies play their part. The concepts of "futuristic vision" as found in more recent TA-literature (Fiedeler, et al.?; Glimell 2004; Grunwald 2004; Lösch 2006) and of "technoscientific imaginary" (López 2004; Lösch 2006; Macnaghten, et al. 2005; Marcus 1995) have the same connotations.

Marcus defines technoscientific imaginaries as imaginaries of scientists (Marcus 1995). They look to the future and to future possibilities through techno-scientific innovation. An "imaginary" shares the sense of vision and fantasy implied by the term "imagination", but it dissolves the opposition of the imagined and the real (Macnaghten, et al. 2005). Whether an imaginary is based in fantasy or in evidence remains an empirical question rather than one to be settled a priori. Imaginaries are socially and culturally embedded. They are constrained by the present conditions of scientific work. They are tied to scientists' current positionings, practices, and ambiguous locations in which the varied kinds of science they do are possible at all.

Grunwald situates futuristic visions between *Leitbilder* and Science Fiction stories (Grunwald 2004). *Leitbilder* (or guiding visions) are more technical in nature and close to ongoing technological development. They show a close relation with designing, planning and implementing new technologies. Science Fiction stories, on the other hand, show no relation to ongoing technology developments of science and technology in these fields, nor a motivation for a scientific analysis or for reflections on the impacts (chances and risks) of those fictitious technologies. Futuristic visions show differences and resemblances with both guiding visions and Science Fiction stories. They include long-term, utopian aspects (SF) as well as the claim of feasibility by scientific and technological means (guiding visions). They differ from Science Fiction stories because some scientists are convinced that futuristic visions - like enhancing human performance or using nano-robots for medical purposes in the human body - might be realised, in some future, because scientists and engineers are already working in the direction of their realisation, because milestones for the realisation of the visions are being proposed, and because not SF authors but scientists and science managers are pushing forward such visions. Futuristic visions also differ from *Leitbilder. Leitbilder* have been regarded as more hidden and tacit ideas orientating technology development, not as being pushed forward by scientists and

[3] With 'possible' futures, we refer to futures that are coherent and consistent and that can, according to our present knowledge, evolve out of our present situation. Possible futures do not refer to their plausibility, i.e. to an estimation of the chance that they will become real.

engineers explicitly. They have to be uncovered retrospectively – their promised use for shaping technology in a prospective sense has not been realised. Futuristic visions go far beyond the time frame of *Leitbilder*, they are more speculative in nature and show a high degree of uncertainty, and they are more revolutionary with regard to the predicted or implied impact on individuals and society. Futuristic visions are, as are technoscientific imaginaries, hybrids between fact and fiction.

To conclude, visions and imaginaries are suitable tools to explore *possible* futures, because, as intermediaries between *Leitbilder* and Science Fiction stories, they guarantee *links* between the present and the future.

Visions and imaginaries as narrative forms

Futuristic visions or technoscientific imaginaries have a narrative form. Characteristic of a narrative form is that it comprises more than one event and/or state of affairs (Carroll 2001). These events/states of affairs are about a unified subject and are represented as being perspicuously ordered in time. This ordering relates to a kind of causality. Narratives are not so much strings of causal entailments; instead, the earlier events in a sequence underdetermine later events[4]. Earlier events are at least contributions to causally necessary conditions for the causation of later events. Events are gathered together by a plot. Plots always rely on human intentionality and context (Czarniawska cited in (Dawson and Buchanan 2005)).

Narratives intend to convince their audience, not of their truth, but of their lifelikeness and believability. They are linguistic constructions that are tied to the way the author understands and orders his or her own reality and identity. They are a way of arranging people and values into a moral order: we make sense of a new reality by putting it into stories (Toumey 2004). Those stories then enable us to say that one hero is better than another; or that one thing is the most important thing, and other things are less important; or that some features are good, while others features are evil; and so on.

To conclude, visions or imaginaries can shed light, because of their narrative form, on both technological and societal dimensions of possible futures. Consequently, they are suitable tools to evaluate – in a normative sense – not a possible technological application taken on its own, but as it is embedded in a societal context. Since visions or imaginaries do, moreover, not claim that the described technological and societal dimensions are necessarily completely causally linked, they leave room for reflection on technological and societal preconditions for embedding new technologies in society.

Mythic versus Science Fiction interpretations of visions and imaginaries

Myths and Science Fiction (SF) stories are both narrative forms that are relevant for the analysis of futuristic visions and technoscientific imaginaries. According to Malinowski, myths are narratives intended to order reality for specific reasons (Toumey 2004). Myths actively shape events in the past in order to retroactively justify certain conditions in the present, rather than provide an accurate record of those events. They are more likely to arise in certain tense circumstances: when one group has to justify its treatment of another group, when people suddenly experience profound historical changes, or when

[4] The concept of “underdetermination” indicates that the determination is not complete, that a particular “cause” does – or particular causes do - not fully define the characteristics of the outcome.

contemporary events seem especially disturbing. They are meant to justify, legitimize, or rationalize the current circumstances in which people find themselves. They are an exercise in coming to terms with present-day tensions. They are, therefore, reflections of conditions and problems in the present: the past is reconfigured to serve the present.

While, in the case of myths, earlier events are shaped to *explain* actual ones, in the case of SF stories, future events are shaped to *question* actual ones. Science Fiction stories are narratives that use a future, fictive reality to help us reconsider our present situation. They link this future with a distorted present (Delaney, cited in (López 2004)). These distortions serve to defamiliarize the present and open up the exploration of alternative social, cultural, and political arrangements (Jameson cited in (López 2004)). Science Fiction is neither about forecasting nor is it about describing possible future societies. It is less concerned with actual factors that can give rise to a specific future, than with presenting a specific future and discovering what it means to act in specific ways - if one believes that those ways of acting are necessary for accepting, rejecting, or doubting the principles upon which this particular future social order rests (Elkins cited in (López 2004)).

To conclude, if we conceive of visions/imaginaries as myths, we can learn something about possible future actions, events, or situations that participants to the first phase of NanoSoc's action research section find frightening or disturbing, and we can learn which present issues – issues that, according to the participants, explain these frightening or disturbing results - the participants deem unavoidable, fixed, not susceptible to change. If we conceive of visions/imaginaries as SF stories, we can learn from participants' descriptions and comments which actual issues they deem open to reconsideration.

Visions and imaginaries as communication platforms and strategic instruments

Narratives in general and futuristic visions or techno-scientific imaginaries in particular are both a means of communication and a means of strategy. Visions and imaginaries are a customary form of communication in the science community as well as between the science community and wider society (Grunwald 2005). They are hybrids between various forms of knowledge (e.g. natural science, industry and business, popular culture, etc.) and, as such, function as mediators between the various functional systems of society and as common platforms of understanding among the actors participating in the development and utilization of new technologies (Lösch 2006).

Visions/imaginaries have, moreover, both normative and predictive value, as the author of a particular vision assumes that the developments proposed *shall* come into reality, and the developments proposed *will* come into reality (Grunwald 2005). They also have a performative quality to them (Lösch 2006). They produce the conditions for attracting attention and gaining acceptance and, thus, frame the selection of preferences and evidences for specific research questions, investment decisions, and staged scenarios by the mass media. They are, hence, a strategic instrument. They influence processes of development and the socio-technological acceptance of innovations. They influence, in short, how nanotechnology finds its way into society.

Visions'/imaginaries' capability of influencing our future does not so much relate to their "truth" as to their "effectiveness" (Lösch 2006). Visions are tools for normative decisions to accept or reject specific nanotechnological products. 'The crucial significance of the visions is not, however, that they show what is possible technologically, rather they can show

where technological innovations can sensibly be applied in society. In this sense, analyses of sociotechnological visions can be relevant by the very reason of their normative character' (Lösch 2006).

The effectiveness of visions can be derived from the frequency with which they are communicated and with which they can be found at the interfaces of crucial functional systems – between politics, science, business, and the mass media. According to Lösch, this effectiveness relates to the spatial dimension of visions. Visions arrange nanotechnological products and uses in spaces that are simultaneously *imaginary* and *real.* The spaces are imaginary, such that they assume potential societal implications of future nanotechnologies. They are real, such that the effects of nanotechnology are described by means of spatial semantics and discursive orders that have already proven their value in describing the effects of current technologies. These “spaces of possibilities” connect the uncertain future of nanotechnology back to the already observed sociotechnological effects of established technologies. According to Lösch, if one wants to study the effectiveness of nanotechnological visions, it is advisable to inspect the connections between the certainties of today and the uncertainties of tomorrow.

These connections can be made with different forms or ‘space constitutive strategies’: demarcation (inclusion and exclusion), ordering (localization and modification) and distribution (Lösch 2006). The strategy of demarcation determines the external boundaries of the spectrum of possibilities. To this type of strategy belong definitions of what nanotechnology is today and what it can be in the future. Definitions establish differences and, consequently, lead to the inclusion and exclusion of, for instance, specific scientific disciplines or economic production sectors. Strategies of ordering define the inner spatial order of the spectrum of possibilities. They localize the means of use at specific sites with the help of portrayals of local functions. Bio-on-chip technologies are, for instance, situated in contexts of medical treatments of neurological disorders (brain implants) or of environmental monitoring (bio-sensors). The strategy of distribution describes the inner distributions of the means of use in social spaces. Questions regarding social opportunities and risks, the distribution of advantages and disadvantages, winners and losers are answered here.

To conclude, visions or imaginaries are appropriate tools to communicate with a wide variety of members of society, because they represent hybrid forms of knowledge. The kinds of nano-technological applications (cfr. Lösch’s ‘strategy of ordering’) and the kinds of ethical, legal, and social issues (cfr. Lösch’s ‘strategy of distribution’) that participants to the first phase of NanoSoc’s action research section deem worthwhile to mention, provide us with an indication of the effectiveness – the extent to which visions regarding applications and issues find their way to the specific group of participants to this first phase - of the different applications and issues that can be found in scientific, policy and media documents.

Visions and imaginaries as political resources

Many – not necessarily consistent or compatible - visions/imaginaries co-exist and compete with each other. Although they often profess ‘accuracy’, they are never neutral or unbiased (Dawson and Buchanan 2005). Irrespective of their author, they both reflect political positions and they are political resources that serve to maintain or to advance the positions of individuals and groups, while delegitimizing the accounts and positions of others.

A confrontation of different perspectives helps, according to Hannah Arendt, to strengthen our sense of reality of intangible worldly matters (Arendt cited in (Vasterling 2007)). Interaction with other people exposes us directly and uncontrollably to the contingency of human affairs, even to 'the shock of the new'. It prevents us to fit events and affairs all too easily into the subjectivity of our own viewpoint. Interaction with real others invites us to come to terms with conflicting and, sometimes, incompatible perspectives. It urges us not only to extend, but also to transform our personal frame of reference. A transformed frame of reference allows us to see and understand new things that we did not see and understand before, because what we saw was not consistent with our former frame of reference and unintelligible from our former point of view.

To conclude, competing visions can be appropriate instruments to make participants aware of differing frames of reference. Awareness raising is a necessary condition to transform enactors' frames of reference in order to allow for an integration of the expectations and concerns of the wider public.

Implications for methodology and analysis

Futuristic visions or techno-scientific imaginaries are suitable tools to explore, communicate about, and debate possible futures with nanotechnologies. Situated between guiding technological visions and Science Fiction stories, they guarantee continuity between the present and possible futures. As a narrative form, they are rather comprehensive, i.e., they illustrate both technological and societal dimensions of possible futures. From a societal perspective they are considered richer than technological or industry roadmaps, which focus on the development trajectories of technologies to provide new products or might be "function-oriented" as to make the linkage between technology developments and subsequent uses of technology. As hybrids of various forms of knowledge, they can mediate between various knowledge systems. As strategic instruments, they have an influence on the selection of nano-technological applications that are deemed sensible and, consequently, on the definition of research policies and R&D activities. Since visions and imaginaries are also political instruments, competing visions testify of differences in societal and normative positions.

For the first phase of NanoSoc's action research section, the methodological implications of this theoretical description of visions and imaginaries are that

a) in order to guarantee that the final nano-imaginaries that will function as an input to the second phase of NanoSoc's action research section are appropriate communication tools, participants to the first phase – in which these nano-imaginaries will be jointly constructed - should represent various societal knowledge systems;

b) participants should be summoned to imagine fictive stories that contain both technological and societal elements and that build further on the information they dispose of with regard to actual nano-technological research;

c) the research consortium should strive for as wide a variety of visions and imaginaries as is practically feasible in an experimental setup in order to reflect a variety of political positions;

d) participants should be confronted with each others' visions and imaginaries.

The analytical implications are that, from NanoSoc's first phase, we can learn

a) from the variety of visions and imaginaries presented in the three Delphi-rounds, which applications are more or less effective in the group of participants to this phase;

b) which issues in their actual societal context participants experience as questionable and which possibly distressing issues they descry in the future;

c) from visions or imaginaries that are the result of joint construction processes, which elements in the frames of reference of respective participants are called into question.

Method

A Delphi-exercise

In order to explore possible futures with new nanotechnologies, the social scientists of the NanoSoc-consortium considered the Delphi-methodology to be a suitable approach. The Delphi-method was first developed at the beginning of the Cold War within the Rand Corporation to forecast the impact of technology on warfare[5]. The objective of the method was to combine expert opinions on the likelihood and expected development time of the particular technology in a single indicator. Later the Delphi method was applied in other areas, especially those related to public policy issues, such as economic trends, health and education. The traditional Delphi method aims at a consensus of the most probable future through a process of iteration. The Policy Delphi, launched by Murray Turoff, is instead a decision support method aimed at structuring and discussing the diverse views of a preferred future.

The Delphi-method is a structured interaction between various participants. Many variants of the Delphi-method exist. Some recurrent characteristics are:

- the participants are considered experts with respect to the topic under debate;
- interactions happen anonymously;
- there is an iteration of discussion rounds;
- at the beginning of each round the organisers provide the participants with controlled feedback;
- participants are confronted with and react to the opinions and visions of the other participants.

Many variants of Delphi-exercises exist because of differences with regard to the answers asked for (quantitative or qualitative), the questions posed (estimation of probability or desirability), the ambition (reaching consensus or making a diversity of arguments and motivations explicit), the degree of anonymity (full or relative), the type of feedback procedures. The NanoSoc-team took Linstone's advice to 'suit the method to the problem, not the problem to the method' to heart when it discussed, round by round, what input to give and what output to ask for (Linstone 1978, cited in (Kenis 1995)). The resulting choices and considerations are presented in the next paragraphs.

[5] See, for instance, http://en.wikipedia.org/wiki/Delphi_method, and Turoff, M. & Linstone, H.A. (Eds.), (2002). "The Delphi Method: Techniques and Applications", http://is.njit.edu/pubs/delphibook.

Participants

The original intention of the social-scientific team of the NanoSoc-consortium was to 'visit' possible futures by making the visions of nano-researchers explicit. The team amended this original intention based on the idea that a confrontation with visions from actors other than nano-researchers would be helpful to become aware of the peculiarities of nano-researchers' own visions. Moreover, in order to comply with the criterion of 'maximal diversity' and in order to create suitable – i.e., hybrid – communication platforms, the team needed to gain insight in visions and imaginaries resonating in various societal contexts. It therefore appealed to actors with different types of expertise in relation to the topic of nanotechnologies. On the one hand, it invited 'enactors', on the other it made an appeal to 'comparative selectors' (Rip and Schot 2002). Enactors are actively involved in developing and introducing new technological options. Their perspective is characterised by a concentric bias in the way it starts with novelty creation and follows its journey over time and across space. Comparative selectors, on the contrary, have a non-concentric view. They are not biased towards success of a technological innovation. For them the new technological option is only one option and, possibly even, an unwanted intruder.

The NanoSoc-team distinguished between three types of participants. The first group of participants consisted of nano-researchers. This group is considered to belong to the category of enactors of nanotechnologies. The second group consisted of 'societal experts': civil servants, journalists, politicians, social scientists, artists who are some way or another confronted with or inspired by nanotechnologies in their professions. These societal experts can either belong to the category of enactors – for instance, when involved in science and innovation policy – or to the category of comparative selectors – for instance, when involved in regulation regarding risk and authorisation. The third group of participants consisted, of 'primary involved citizens': individuals who are not professionally engaged with new technologies, but have a strong interest in technology innovation or development. The team tried to find these citizens among visitors of science museums and science theatres and readers of popular science journals and of science supplements of newspapers. Members of this group are most likely to belong to the category of comparative selectors.

First round: Personal visions

In the first round of the Delphi-exercise, the research team wanted to get an idea of participants' visions with regard to future nanotechnologies. Therefore, participants were asked – via an on-line questionnaire - to write two or three short stories with a maximum of two paragraphs per story. As an input to the first round, the team provided the participants with a short description, written by the nano-researchers within the consortium, of the technological challenges that characterise each case and with two or three examples of short stories. These examples were meant to illustrate the type of contributions the consortium expected from the participants, namely, short stories that are both an illustration of technological and societal dimensions of a future situation (admittedly with the risk of influencing participants' own conceptions and visions of the future). These stories resulted from a close co-operation between social- and natural-scientific members of the research consortium. For each of the three cases, different stories tailored to each case were created.

	Round 1 Number of participants			Round 1 Number of stories
	NE	C	SE	
Bio-on-Chip	10	12	7	63
New Materials	12	5	3	37
Smart Environment	7	10	5	38
Total	29	27	15	138

Table 1: Number of participants and stories per case in the 1st Delphi-round (NE = nano-researchers; C = citizens; SE = societal experts)

Second round: Links between the present and possible futures

Inspired by the stories gathered in the first round, the NanoSoc-team derived a list of statements per case. These statements express ideas with regard to situations that will or will not be the case in a future world. An example of a statement out of the list of the Bio-on-Chip case is 'Bio-on-Chip technologies used for identification objectives will not be able to rule out misuse of personal data'.

This list was offered as an input to the second round of the Delphi-exercise. The participants were asked to indicate to what extent they agree with the statements on a Likert scale, with categories ranging from "strongly agree", "agree", over "neutral", to "disagree" and "strongly disagree"; and with an additional category, "no opinion". They were also asked to motivate their answers.

From the output thus generated, key drivers, understood as those forces that drive or impel a situation or scenario (such as economic imperatives or the individual and/or social wish for privacy or security, for instance), and the major issues (such as privacy, security and autonomy) which were raised in statements and/or in the responses to those statements were derived. Both the driving forces for nanotechnology research and development and issues were passed on to participants in the third round.

	Round 2 Number of participants			Round 2 Number of statements
	NE	C	SE	
Bio-on-Chip	10	8	5	37
New Materials	12	7	4	54
Smart Environment	6	9	5	43
Total	28	24	14	

Table 2: Number of participants and statements in the 2nd Delphi-round

Third round: Co-constructed imaginaries

In the third and concluding Delphi phase, participants – most of whom had participated in the two previous rounds – convened for one day and a half in March 2007 in a hotel in

Antwerp to interactively construct and consider possible nanotechnology-driven imaginaries of the future.

	Round 3 Number of participants			Round 3 Issues
	NE	C	SE	
Bio-on-Chip	6	11	7	16
New Materials	7	6	4	14
Smart Environment	5	7	6	16
Total	**18**	**24**	**17**	

Table 3: Number of participants and issues in the 3rd Delphi-round

As in the previous two rounds, participants were explicitly instructed not to dream up a desirable future, but to come up with potential futures with nanotechnologies in consideration of technological and social possibilities. In addition, their contributions had to be based on a distinctive combination of three driving forces selected from the list of forces and issues drawn up in the second round. After holding a group discussion, the participants chose the three factors they deemed most significant in the development and design of a future with nanotechnologies.

On the basis of this prioritization of three determining factors, each factor was then varied from low to high, and three groups of six participants each set out to construct one unique imaginary of a nano-future, resulting in a total of three diverging 'nano-imaginaries' at the end of the second day.

To enhance creativity and as a means to communicate their ideas to one another, participants were instructed to draw and sketch their views of ingredients of the future on paper. Throughout the process participants from each group also visited each other's sketches. At the end of the workshop, the resultant sketches were presented to all and appraised by the other participants in terms of possibility and internal consistency. A science journalist eventually translated each sketch into a full fledged nano-imaginary.

	Nano-imaginaries		
Bio-on-Chip	***Chip Chip Hooray!!?*** Anticipatory government Low reliability Low social equity	***Every Chip under control*** Reactive government Low reliability High social equity	***From bio-chip towards dictator-chip*** Reactive government High reliability Low social equity 7
New Materials	***An Inc. Convenient Truth*** High economic attractiveness Negative impact on human health and	***Oops, the air got polluted*** High economic attractiveness Negative impact on human health and	***No more sales*** Low economic attractiveness Positive impact on

	environment Exploration of uncertainties	environment Neglect of uncertainties	human health and environment Exploration of uncertainties
Smart Environment	***Nano-adolescent*** High security Low privacy Low autonomy	***Grandpa home, grandma at home*** High security High privacy High autonomy	***Win for Life*** Low security Low privacy High autonomy

Table 4: Nano-imaginaries, with their titles and combinations of extremes constituting them

Analysis

In the following sections the variety of the visions described in the short stories of the first Delphi-round and in the imaginaries that were collectively constructed in the third Delphi-round is considered. This analysis offers an overview of the effectiveness of visions. Further, the comprehensiveness of the visions and imaginaries is paid attention to, keeping in mind the question to what extent the visions and imaginaries show us possible future societies in both their technological and societal dimensions. Finally, some differences noticed in participants' frames of reference are reflected on.

The stories received in the first Delphi-round expressed participants' 'personal' visions, visions that individual participants deem intriguing and interesting enough to express in short stories. A hypothesis of the NanoSoc-team is that, for the most part, participants' 'personal' visions are not unique - in the sense that Feynman's vision of self-replicating nano-machines arguably was (Glimell 2004) -, but came to their minds via a variety of communication sources. It is interesting to consider whether participants belonging to different groups – nano-experts, societal experts or citizens - are confronted with, or select certain visions or elements of visions out of the many that are circulating. In order to evaluate the effectiveness of visions, we compare the visions received during the Delphi-exercise with the visions as outlined in the literature summary provided by the UK Economic and Social Research Council (Wood, et al. 2007).

Visions contain both descriptions of 'applications' – Lösch's 'strategies of ordering' - and of 'issues' – Lösch's 'strategies of distribution' -[6].

[6] Strategies of demarcation – Lösch's third kind of strategies – could not be observed in the material obtained from the Delphi-rounds. However, during two 'reflection workshops' – workshops with nanotechnologists, held at the research institutes of the NanoSoc partners IMEC and EMAT on April 27, 2007 and May 4, 2007, respectively – discussion arouse whether some of the technologies mentioned in the nano-imaginaries really deserve to be labelled 'nano'. Such discussions, though, mainly seemed to emerge for defensive reasons. The researchers rather doubted whether the nano-dimension was a *necessary* aspect of these technologies. They did not doubt that the nano-dimension *could be* an aspect of the technology.

Applications

The application domains mentioned in the 2007 ESRC report are: generic products (nanobots, improved materials, computing devices, electronics, optoelectronics), ICT products, production processes (nanofactories, production processes using less natural resources), medical products and devices, food and agricultural products, cosmetics, construction products, clothes, automotive products, sports articles, environmental remediation products, defence products, nanometrology, space travel (space elevator). These application domains are so diverse, that one can hardly imagine an application not belonging to one of them.

Applications that receive much attention from the participants to the **New Materials case** are medical devices or systems and products for environmental remediation. In the **Smart Environment case** ICT products and devices are, obviously, prominent; they are conceived in function of home automation, household organisation (for instance, automatic ordering of food via a smart fridge), health care and care-taking, identification, transportation, tourism, public security, environmental remediation, social networking, and marketing and sales. In the **Bio-on-Chip case** applications are mainly imagined for health care and care-taking of, for instance, elderly people, young people or persons with a chronic illness. The main challenges for Bio-on-Chip applications are, successively, prevention, therapy and (hardly) enhancement. All examples related to therapy refer to the health sector. Prevention is mainly associated with applications in the health sector, but also with public security, environment, sports, agriculture, tourism and travelling. The challenge of enhancement is associated with war, office work and sports.

In the first Delphi-round no systematic differences are observable between the visions of the three groups of participants. Nanotechnologists do not necessarily provide more technological scope or detail than other respondents do, nor do societal experts and citizens necessarily focus more on societal dimensions than do nano-experts. Neither do nanotechnologists appear to envisage markedly different types of applications than citizens and societal experts do. However, in the New Materials case only nano-experts mention applications that will change production processes (for instance, hydrogen cars of which the components can be made instantaneously in decentralised facilities or catalytic agents for the reaction between NaCl and PVC) or applications in the transport sector, while only citizens think of applications in the food and agricultural sector. In the Smart Environment case, only one nanotechnologist elaborates specifically on how nanotechnology can act as an “enabler” for the smart environment and on other major boundary conditions that have to be resolved to create and maintain “intelligence” in such an environment (notably energy generation, transmission, storage and consumption)[7]. In the Bio-on-Chip case, citizens and societal experts appear to be less reluctant than nano-experts to mention Bio-on-Chip applications for psychological or psychiatric problems such as addiction or depression. According to one nano-researcher, the most important contribution of Bio-on-Chip technology to neurological problems will be that it generates insights in the way neurons in the brain work. This increased scientific knowledge - and not so much the Bio-on-Chip applications themselves - will imply a dramatic improvement of the way we will be able to treat brain disorders and neuropathies.

[7] In fact, when technology at all is mentioned, respondents frequently make use of vague terms and concepts such as “smart device”, “ambiware”, “ambient technology”, and “domotics” to substantiate their claims.

In the third Delphi-round the participants conceived of mainly the same applications as in the first Delphi-round. The only additional domain is defence (bombs with smart viruses, smart magnetic dust) in the New Materials case. Overall, applications that remain unmentioned are space products; applications that receive little attention are devices for human enhancement, self-replicating nanobots and sports articles.

To summarize, the participants introduced a wide variety of possible applications. It is, however, interesting, to notice that visions regarding products and devices for human enhancement are not very effective – in the sense that they did not succeed in gaining much attention - within the group of participants, though such visions are a topic of debate among EU and US policy makers[8]. It is, moreover, interesting to notice that visions in the context of defence are almost lacking[9]. Further, only one application based on the idea of nanobots – an apparatus that instantaneously produces party snacks – is mentioned, though this idea is central in what Roco calls 'The Original Nanotechnology Vision' and is the stumbling block in a fierce dispute between Smalley and Drexler (Roco 1999) (Glimell 2004)[10].

Questionable and distressing issues

The stories of the first Delphi-round, the statements provided to the participants as an input to the second Delphi-round and the judgements and comments received from them as a result, and the nano-imaginaries can be analysed using Lösch's concept of 'strategies of distribution'. Which issues in the future do participants conceive of as distressing but as resulting from unavoidable actual issues (mythic interpretation) and which issues in the present do they consider questionable and susceptible to change (Science Fiction interpretation)?

In accordance with the authors of the ESRC report, the term 'issue' rather than 'impact' or 'implication' is used to indicate social, economic and/or ethical topics which, according to the Delphi-participants, link present certainties with future uncertainties. The terms 'impact' and 'implication' imply that science and technology come first and that the social must always be downstream of the science (Wood, Jones and Geldart 2007, 12). We assume, on the contrary, that social, economic and/or ethical topics accompany innovation processes from the very beginning. Lewenstein (cited in Wood, Jones and Geldart 2007, 12) stresses, moreover, that any attempt to set boundaries as to what can be included as an issue is 'necessarily an exercise of power' by those defining the boundaries. Setting the agenda in terms of issues rather than implications is, according to Wilsdon & Willis,

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[8] Compare, for instance, **Nordmann, A.** 2002 'Converging Technologies, Shaping the future of European Societies', Brussels: European Commission. and **Roco, M. C. and Bainbridge, W. S.** 2002 'Converging Technologies for Improving Human Performance', Arlington, Virginia: National Science Foundation..

[9] A citizen who participated at the second step of NanoSoc's action research was quite upset when, confronted with this topic at the NanoNow festival organised by the TA-institute of the Flemish parliament (www.nanonu.be), he noticed this lacuna.

[10] According to Glimell, '"the Feynman legacy" – with its key thesis of the feasibility of human-controlled molecular assembling – provided the basis upon which extensive public promotion of nanotechnology was erected' **Glimell, H.** 2004 'Grand Visions and Lilliput Politics: Staging the Exploration of the 'Endless Frontier'', in D. Baird, A. Nordmann and J. Schummer (eds) *Discovering the Nanoscale*, Amsterdam: IOS Press..

Macnaghten, and Lewenstein, more in spirit with an inclusive approach to policy-making than one centred on the government agencies.

Compared with the issues mentioned in the literature summary provided in the ESRC report, the participants to the first phase of our NanoSoc project refer to a wide variety of issues, though the variety in the New Materials case is larger than in the Smart Environment and Bio-on-Chip case. Risks, the price of new technological products, concentration of economic corporations, environmental and health issues, the possibility of a nano-divide and of a divide between people that either accept or reject new technologies, the relevance of public perception and acceptance, of science communication, and of risk management, and the meaning of being human are issues popping up in the three cases. A number of issues is, however, also lacking. To start with, grey/green goo risks are not an issue. This is not surprising, since the participants hardly considered the idea of self-replicating nanobots. Secondly, participants do not refer to R&D activities in the nano-domain in terms of maintaining or ameliorating their country's or region's market position within the context of international economic competition. This is perhaps more surprising, since this idea is prevalent in several policy documents[11]. Thirdly, since participants hardly conceived of nano-technological applications to do away with ageing or enhance human performance or for purposes of warfare, discrimination between improved and unimproved people and misuse of weapons systems or an arms race are no issues either. Fourthly, it is remarkable that participants only consider a very restricted form of governance of the science – society relationship. They only conceive of public awareness, perception and acceptance, of science communication, and of a particular form of public engagement, namely direct action (boycotts, demonstrations, …), as possible ways to influence nanotechnological developments. They do not refer to other possibilities such as the proactive consultation of stakeholders and the wider public.

In the **New Materials case**, environmental remediation and better medical diagnostics and treatment are the most important issues. Health issues are, moreover, often linked to environmental issues and interest in the environment is mainly channelled by health concerns. Also the topic of social justice (elimination of hunger and poverty, nano-divide) receives considerable attention. The participants further question to the responsibilities of public authorities – and of enterprises and researchers - to develop suitable risk assessment and management initiatives and to manage innovation (via a deliberate definition of intellectual property rights, protection of academic freedom and of the public mission of public research institutions, selective co-operation between various research institutes) in the direction of a socially more just society. Sustainable production processes and relationships between academia, industry and government are other issues questioned; they only receive attention in this case.

Both societal experts and citizens express doubt with regard to the safety of present market introductions of new technologies and products. Enterprises are perceived as being in a hurry to market their products; economic and geo-political interests are deemed to prevent them to be open regarding known risks (and these issues are rather presented as

[11] See, for instance, **Commission, E.** 2004 'Towards a European Strategy for Nanotechnology '., **Roco, M. C. and Bainbridge, W. S.** 2002 'Converging Technologies for Improving Human Performance', Arlington, Virginia: National Science Foundation., or have a look at the strategic research agendas or roadmaps of the various European Technology Platforms (http://cordis.europa.eu/technology-platforms, consulted November 27, 2007).

facts). Issues that some respondents question are the meaning of 'pioneering' research – does this concept necessarily refer to high tech research or can it also refer to research with a particular contribution to pressing human needs? -, nanotechnologies as the most appropriate responses to environmental problems and to wealth creation, and human health as measure for a 'healthy' environment.

The most recurrent theme in the **Smart Environment case** regards life style and has to do with user convenience. Participants seemingly consent with a need for more comfort as the underlying rationale for the development of smart applications. They are concerned with making efficient use of their time and budget, improving their daily routines, and personalising leisure activities. The emphasis on systems which adapt themselves to the user and even anticipate on user needs, is reflected in the repeated mention of "personal devices" which assist users to organize their lives, all be it under different guises[12]. A second recurring theme is prevention, which links to convenience, though arguably on a more basal level of human needs (preventive control of diseases, prevention of too excessive exercise and/or injuries, stress prevention, preventing that babies go hungry or feel cold, prevention of accidents, crime prevention).

Both themes (convenience and prevention) are ultimately concerned with the issue of control. The first in terms of establishing our autonomy through assistive technology, the second in terms of gaining more control over our biological and social destiny. The extent to which they succeed in establishing control is prone to some criticism however. Two respondents mention explicitly that adding "smart machines" everywhere will not help overcome our dependency on technology. On the contrary, smart technology may increase the efficiency of time-consuming and laborious tasks, but at the cost of surrendering our autonomy to machines, which is conceived as a severe setback. A few respondents stress that living longer lives does not amount to living more happy lives per se. Age is but one (rather poor) measure which serves to assess the quality of one's life.

Most discussion in this case focuses on the issue of privacy regulation. To what extent can and should regulatory action on privacy be undertaken prior to technology issuance or in response to socio-technical developments? Will existent privacy legislation be sufficient, given new technologies (e.g. biometrical identification) and social developments (e.g. blurring of private and public spheres) in a future world? How can governments and public authorities provide consumers with information and raise awareness on the (privacy) risks involved with smart technologies? The issue of access to relevant information is, moreover, an issue that receives particular attention in this case. Finally, respondents stress individuals' own responsibility for not becoming too dependent and not relying too heavily on technology; for the information they surrender to product and service providers. In short, consumers are summoned to maintain control at all times.

Several issues – those relating to privacy, security, safety and comfort - in the **Bio-on-Chip case** are similar to the ones in the Smart Environment case. The possibility of a nano-divide and the more fundamental question of what it means to be human are, however, relatively more prominent here. Regulation of liabilities – who will be accountable in case no clear cause-effect relationships of implanted chips can be provided? – only receives attention in this case.

[12] "Personal Artificial Advisor", "Personal Digital Assistant", "Personal Mobile Assistant", "Personal Weather Forecaster", "Personal Digital Network Manager", or even "Adaptive Tex" (clothes considerate of the needs and demands of the user).

An issue questioned in the Bio-on-Chip case is whether the human body is the most suitable point of application to treat health problems relating to deteriorating environmental circumstances. Participants wonder, further, whether current efforts to decrease environmental pollution and increase food processing quality will disappear as advanced screening and monitoring techniques to detect a variety of diseases (e.g. cancer) in an early stage will become standard. The assumption that doctors and medical experts will control the medical system is also questioned. Doubts are raised that Bio-on-Chip technology and the according data-system will be free from harmful attempts of malicious persons or organisations to possess, abuse or disclose personal information. Moreover, multiple bio-on-chip implants might cause unforeseen interactions; scientists might not be able to provide evidence about cause-effect relations, and they will never be able to guarantee 100% reliability. Participants seem to acknowledge that complexity is becoming the norm in modern research and that society's acceptance of failure is a necessary precondition for the quest for medical solutions. Other questions relate to health policy: who will determine the priorities for research and innovation (insurance companies, pharmaceutical companies, medical profession, or parliament?); will they aspire to a socially fair innovation and commercialisation system?; will a centralisation or decentralisation of tasks within the health system occur?

Both in the Bio-on-Chip case and in the Smart Environment case, respondents from all categories make explicit mention of chips being implanted in the body, and this mainly for health purposes. The idea that chips and wireless technology will sooner or later be implanted in the human body is thus posited, but the idea is much less pervasive in the Smart Environment case than in the Bio-on-Chip case. Most respondents in the Smart Environment case foresee chips being used outside the body (in clothing, wristwatch, glasses or through PDA) and in the environment (the immediate home surroundings, public buildings, roads, and over vast terrains), while most participants in the Bio-on-Chip case, which focuses mainly on medical uses, foresee implants in the body or mind. In the latter case implants in the body outnumber implants in the mind as most participants perceive brain interference with electronics as too risky or too much science fiction.

Comprehensiveness

Compared to the personal stories of the first Delphi-round, the nano-imaginaries resulting from the third round are much more comprehensive, i.e., they show a richer picture of both technological and societal aspects of future societies. Parallel with an increasing comprehensiveness of the visions, the tone of the visions grew more diverse, more controversial, and more ambiguous.

On the whole, the technological applications depicted in the initial stories in the first Delphi-round are far more positive than negative in tone. Participants take the effectiveness of new nanotechnologies – do they realise what they promise?, are they reliable? – for granted. Their intuitive perceptions of societal issues accompanying these applications vary between very positive and very negative. This variety can be observed in the three groups of participants, but all sound much more frequently positive than negative. In general, participant nano-researchers and societal experts appear to be somewhat more doubtful about whether future nanotechnologies will lead to technological and societal advances, whereas citizens appear to be relatively more optimistic. In the second Delphi-round, participants' evaluations of the technical and societal possibilities of new technologies turn out to be more ambiguous (less unequivocally positive), more varied (more societal issues come to the surface), and more controversial (disagreements

between members of different groups of participants or between members of the same group pop up).

Contrary to the stories received as an output to the first Delphi-round, the nano-imaginaries that resulted from the third Delphi-round are not personal visions of anonymous participants; they are collectively constructed following a specific method. They are longer stories that offer a more comprehensive ordering of events, values and persons than the short stories of the first round. The three imaginaries that the participants jointly constructed for each case illustrate that the potential of a technology can turn out differently depending on the societal context in which a technology develops. In each case, the three imaginaries vary with regard to their perceived attractiveness.

In the New Materials case, for instance, the three final imaginaries mention versions of nanofilters, photovoltaic cells, nano-textiles, nano-coatings, synthetic materials. From a societal viewpoint the three imaginaries differ considerably. While in one of the stories, the societal context is only a bit more extreme than is the case in actual Western societies, another story is, in some respects, a very extreme version of our own. Environmental problems are much worse. Contradictions between rich and poor are translated in contradictions between people living in a safe but virtual underground world and a dangerous but real world above the ground. Without nano-technological applications, the world above the ground is hardly habitable. Short-sighted economic interests of a few very rich people and passive public authorities are at the origin of this world. Though apocalyptic, this world is, considered from a societal perspective, not revolutionary at all. The third imaginary confronts us with a different society. Environmental problems do not exist any longer; consumer society belongs to the past. It looks, however, as if the inhabitants of this nice, new world are struggling to find a new identity. This imaginary suggests that, in order to realise an environmentally benign world, a societal – rather than technological - revolution is needed.

But also the particular characteristics of the various technological applications in the three stories are different. While, in one story, the idea of a nano-filter is, for instance, made concrete in a cocoon to protect people against air pollution as a consequence of accidents with (nanotechnological) industrial processes, it is specified, in another story, as part of fuel cells that should prevent air pollution. Though in both cases the basic technological idea – nano-filter – is the same, the specific characteristics of the filters are different.

To conclude, the nano-imaginaries illustrate the idea of a co-evolution of science and society: specific features of the societal context and specific features of technological applications are, via a complex set of very different factors, mutually linked with each other.

Competing frames of reference

While the first two Delphi-rounds took place anonymously, NanoSoc-participants met each other face-to-face in the third round in an interactive workshop. Participants' task was to construct three nano-imaginaries interactively in various phases. The imaginaries should therefore be taken as the result of a direct confrontation between different perspectives. Both in the process of their construction and afterwards, when they were communicated to various individuals, they incited different reactions with different participants and their colleagues and supporters. As a final element in our analysis of the Delphi-exercise, we consider the reactions from nanotechnologists during and after the collective construction

of the nano-imaginaries and advance some hypotheses as to why these reactions were brought forward. We focus on a discussion of reactions of nanotechnologists, because they constitute the focal group of participants in our research endeavour in the sense that they are engaged throughout the entire NanoSoc project and in the sense that raising their – rather than citizens' – reflexiveness is basic to NanoSoc's rationale.

It should be noted however that these hypotheses rest on fairly tentative explorations of nanotechnologists' utterances which were gathered in informal conversation, group discussions, and/or in two ensuing 'reflection workshops' held at the two respective nanotechnology institutions that are both partners to the NanoSoc project. They were not gathered and analyzed consistently and should therefore not be taken as representative of the participant category or nanotechnology community as a whole, but as expressions of individuals' opinions in a particular situation and context. Nonetheless, we feel they deserve mention and merit our attention as they relate to recurring issues in literature (MacMillan 2004; Rip 2006; Sandler 2007)

In the New Materials and Bio-on-Chip workshops a few participating nano-experts questioned the link between possible nanotechnologies and the constructed imaginaries. They asked: "What does nanotechnology have to do with this?" These nano-experts appeared to expect a clear causal link between the nanotechnologies playing their part in an imaginary and the ethical and social issues of the broader societal context sketched in this imaginary. They asked: "if such a society is also possible without this technology, why should we question the technology?" Citizens or societal experts did not voice such concerns in the workshop. It could be argued that while individuals all hold different frames of reference on the issues at hand, citizens and societal experts are generally more eager to know the characteristics of future societies and the way in which nanotechnologies will be embedded in or contribute to them, whereas nano-experts are more interested in characteristics of future technologies and the extent to which they will be considered to be socially robust.

Another tension relates to nanotechnologists' appreciation of the final results of the workshops, and more specifically of the tone of the imaginaries, which some of them perceived as negative or even extremely negative. This perceived negative tone is a cause of concern to some of them. A few of them therefore repeatedly urged the NanoSoc-team to make clear to the outside world that the imaginaries are completely fictive and have no predictive value at all.

Some nano-experts who participated in the third round signalled that they were rather reluctant to contribute substantially. The research team asked them to participate as nano-experts, who dispose of a specific – techno-scientific – knowledge, but not to overrule participating citizens with normative views that citizens are prone to accept as established fact. Consequently, some nano-researchers experienced the presence of non-nano-experts as an impediment. They said they felt less free to provide their personal opinions than they would have if the workshop was exclusively composed of nano-experts. One nano-expert, who was clearly not hampered by the presence of citizens and who actively contributed to the construction of a very dark imaginary, afterwards felt very sorry about her role during the workshop. She feared that the story could have a negative influence on public opinion.

Some of the nano-experts who attended the above mentioned 'reflection workshops' expressed that they experienced the participation of citizens to the Delphi-exercise as an interference with their research activities; which they could not fully appreciate. On the one

hand, they argued that, because they are citizens themselves, they know what citizens want and, hence, considered citizens' interference as redundant. At the same time, some nano-experts acknowledged a lack of opportunities within their own research community to communicate, debate and reflect on the links between their personal social, ethical, economic, cultural, and political considerations and their research activities. The intriguing observation is that we could not observe systematic differences between the substantive contributions of the three groups of participants during the first two Delphi-rounds. It remains an open question whether a similar exercise with a different composition would entail fundamentally different outcomes with respect to the variety in applications and issues, comprehensiveness, and tone of the visions presented and of the imaginaries jointly constructed. Some statements of nano-researchers and citizens, though, lead us to assume, that some nano-experts experience the involvement of citizens as a risk, while citizens see the involvement of nano-experts as an opportunity.

Research questions and reflections

Our analysis of the Delphi-exercise raised some questions and reflections within the NanoSoc-team.

Gaps

To start with, we asked ourselves what the possible reasons could be for the observed gaps in the variety of applications and issues that are mentioned by the Delphi participants. Do these gaps indicate that the group of participants was not sufficiently representative of the various social positions? Should persons belonging to strategic or management levels of research institutions or to innovation policy institutions, for instance, be better represented than they were in our experiment? Or do these gaps indicate that some participants have strategic reasons to remain silent about some applications or issues? Or do they indicate that some applications or issues are deemed so natural or, on the contrary, so unrealistic or unattractive that they do not deserve mentioning?

Social context issues

Secondly, the question "What does nanotechnology have to do with this?", voiced by some participating nano-experts, can mean a number of different things. Either those voicing this concern expect that nanotechnologies will raise issues that are specific to this technological domain only and are hence not linked to other technological domains, such as biotechnology or information technology. In this case, authors consider nano-specific rather than more general issues as the only relevant topics for debate and reflection. Or, the authors expect that characteristics that are *inherently linked* to nanotechnologies are the only topics worthwhile of debate and reflection.

A third possibility is that the question is not so much about, or not only about, the technology as such, but reflects underlying doubts or uncertainty on behalf of some participating nanoscientists as to the relevancy of constructing fictive 'nano-imaginaries' for their day-to-day research and development practices. These doubts are reflected in statements by nanoscientists derived in at least one workshop in which they were asked to reflect and comment on the nano-imaginaries after the Delphi-rounds had been completed: "How is this [Delphi exercise] relevant to us?"; "I don't see the relevance of creating scenarios for me"; and the following, rather defensive reaction of one nanotechnologist: "There are always unpredictables (…) [these] cannot be taken into account [in any nano-imaginary]". I.e., the question "What does nanotechnology have to do with this?", may also

reflect unease with some nanoscientists about the aim, relevancy, and desirability of constructing nano-imaginaries with technology 'outsiders' as such, and hence, with the very ideas of nano-imaginaries and public engagement; and/or it may be an indirect way of conveying their uneasiness about the manner in which the nano-imaginaries were constructed in NanoSoc, given their repeatedly voiced concerns that it was not always clear what was expected of them in the Delphi exercise.

With regard to the first interpretation, several documents indicate that promises and concerns raised until now with regard to developments in nanotechnologies are quite general and could apply to any new or emerging technology (NRC 2006), (Swierstra and Rip 2007)[13]. This has, according to Swierstra and Rip, led to critical comments by nanotechnology actors as well as analysts, because they question the relevance of performing public engagement exercises if nothing specific to nanotechnology comes out of the discussions and reflections. Sandler replies to such comments by questioning why the social and ethical issues needing attention should be limited to those specific to nanotechnologies. He states: 'It may be that nanotechnologies raise familiar social and ethical issues, perhaps in novel or complicated forms, either themselves or in interaction with other types of technologies, which need to be addressed because they are significant social and ethical issues, whether or not they are unique or specific to nanotechnology' (Sandler 2007).

With regard to the second interpretation, Sandler argues that issues accompanying new technological developments are often not inherently linked to the technologies themselves. For instance, '[J]ust as nanotechnologies and nanomanufacturing processes are not inherently environmentally unjust, neither are they inherently environmentally just. Whether they are likely to exacerbate or alleviate environmental injustice in the obtaining social context depends on, for example, which nanotechnologies and nanomanufacturing processes are realized; how they are implemented, disseminated, and situated (and who or what factors determine these); who controls them; and what sorts of oversight and regulations pertain to them (and how effectively these are enforced)' (Sandler 2007). Nanotechnologies, like all technologies, are not separable from their social context. In order to identify and respond to the social and ethical issues associated with developments in the nano-domain, it is of no use to contemplate these developments as such, in the abstract, without situating them in their social context. Issues rather emerge from nanotechnology's interaction with problematic features of the social, ethical, cultural, and institutional contexts into which it is emerging.

This implies that a responsible governance of R&D activities cannot remain restricted to solving problems of technology-design or risk management and requires much more than maintaining open lines of communication and engaging in public outreach. Sandler concludes: 'Because the social and ethical dimensions of nanotechnology are determined by the characteristic features of nanotechnology and the social contexts into which it is emerging, addressing them includes thinking about product design and production processes, but that is not enough. To fully address the social and ethical issues associated

[13] Dupuy argues, on the contrary, that, since the unifying idea at the base of nano-research – remaking nature from an atomic level – entails complexity and, hence, irremediable uncertainty, nano-research brings with it really new ethical challenges (Dupuy in **Nanoforum** 2005 'Benefits, Risks, Ethical, Legal and Social Aspects of Nanotechnology'.).

with nanotechnology requires addressing the socially and ethically problematic features of the social contexts into which nanotechnology is emerging' (Sandler 2007).

To summarize, Sandler claims that the social and ethical challenges of nanotechnology can be fully identified only if both the characteristic features of nanotechnologies and the social contexts in which they emerge are considered. Our conclusion – derived from the varying tones of the nano-imaginaries that were jointly constructed in the third Delphi-round - that the potential of technologies can turn out very differently depending on the societal context in which they develop and get embedded, goes into the same direction. When performing foresight exercises, the construction of a fictive, but coherent societal context is apparently needed to let a more complete picture of possible issues relating to particular technologies become manifest.

Another claim of Sandler is that, once the issues are identified, they can only be addressed by remedying the problematic features of the social contexts, which cannot be accomplished by technology design or risk management alone. This argument indicates that responsible government of new technologies is a matter of collective co-responsibility (von Schomberg 2007). It is a responsibility that cannot be born by enactors of new technologies alone. Responsible governance involves the whole society. And this is, in our view, another good reason for "early public engagement".

It is conceivable that the magnitude of this task – looking for a new distribution of responsibilities and for new definitions of responsibilities with regard to problematic features of our societies that are perhaps ubiquitous, solidly institutionally and culturally entrenched, and multifaceted – induces defensive reactions (as we noticed with some nano-researchers). However, 'the point of considering and responding to social and ethical considerations is to make progress, not realize perfection' (Jamieson, quoted in (Sandler 2007)).

Dark scenarios

In both the New Materials and Bio-on-Chip case, one of the three imaginaries is utterly dark. The interpretation of the other imaginaries is, moreover, often ambiguous, depending on who is interpreting them. Some participating nano-experts experienced the perceived negativity of nano-imaginaries as rather inconvenient. Their fear is that negative scenarios can influence public opinion negatively, which, in turn, can negatively influence their R&D activities. Rip calls this fear of nano-researchers a 'folk theory'. Though empirical evidence suggests that even apocalyptic Science Fiction stories do not necessarily cause people to refute nanotech[14], Rip argues that scientists and technologists (and other promoters of nanotechnology) generally presume that publics are passive and susceptible to fearful interpretations. They are, in Rip's words, prone to project nanophobia and 'this projection can become a phobia in itself, a nanophobia-phobia' (Rip 2006). Rip's argument suggests that nano-researchers' discomfort with negative imaginaries is not founded.

If Rip is correct, this means that fear for influencing public opinion in a negative sense is no valid argument to withhold from using these imaginaries in further research steps of the

[14] Results of opinion surveys show that reading Crichton's novel Prey– which introduced the grey goo threat - makes people more interested and positive about nanotech, rather than more negative (Cobb and Macoubrie, 2004; Hanssen and Van Est, 2004, cited in **Rip, A.** 2006 'Folk Theories of Nanotechnologists', *Science as Culture* 15(4): 349-365.).

NanoSoc project. Other authors even provide arguments in favour of using dark, as well as attractive, imaginaries. Punie *et al.* stress that dark scenarios are not anti-technology or neo-luddite, but are intended to be constructive (Punie, et al. 2006). Their objective is twofold. Firstly, they are meant to identify potential threats and vulnerabilities that need to be mitigated in order to make a particular technological concept a future success story. Secondly, they should help to identify and propose safeguards that can address the identified threats and vulnerabilities[15]. Dupuy's line of reasoning is similar, but more radical (Nanoforum 2005). He argues, that, since the future of nanotechnology depends on the way society is going to react to the anticipations that are being made of this future and since nano-research will introduce a kind of uncertainty that is radically novel[16], we have to apply a method of 'ongoing normative assessment'. This method is, on the one hand, 'a matter of obtaining through research, public deliberation, and all other means, an image of the future sufficiently optimistic to be desirable and sufficiently credible to trigger the actions that will bring about its own realization'. It is, on the other, a matter of 'enlightened doomsaying', i.e., of obtaining 'an image of the future sufficiently catastrophic to be repulsive and sufficiently credible to trigger the actions that would block its realization, barring an accident'.

Rip's reference to the structural difference between the action perspectives of nano-researchers and citizens can contribute to an explanation of some nano-researchers hesitation to let negative imaginaries circulate in civil society. Rip argues that messages from the enactors to other actors will be framed in their enactment perspective, and not take the comparative-selection perspective into account. 'Nanoscientists and technologists want to realize what they think is important, starting with their own ongoing work and the financial and moral support for it. Thus, they become concerned about every signal that indicates concern about, let alone resistance, to their mission. They will see roadblocks, even when these are not there, and sometimes they create communication problems by their actions responding to actual or projected roadblocks' (Rip 2006).

Conclusion

Originally, the NanoSoc-consortium started the Delphi-exercise with the intention to explore possible futures with nanotechnologies. Gradually, it found that, via participants' visions and arguments, it was exploring the present as much as the future. This exploration of the present is far from complete: an analysis was, for instance, not made of

[15] Punie and colleagues argue that the need for dark scenarios stems from the fact that most foresight scenarios have an inherent bias towards presenting mostly optimistic visions of the future. In their view, this bias should be counterbalanced. Though at the end of their paper they mitigate this argument by questioning whether the scenarios they developed for the technological concept of Ambient Intelligence – or Smart Environment, in our terminology - really deserve to be called 'dark'. The organisers of the scenario-exercise express their concern to strike an acceptable balance between threats and vulnerabilities on the one hand and potentials and strengths on the other. 'The scenarios could certainly not be too negative'. Do these authors fear researchers' nano-phobia-phobia?

[16] Dupuy explains that it will be an inevitable temptation, not to say a task or a duty, for nanotechnologists of the future to set off complex processes. Complex processes are processes for which the simplest model is the process itself. 'The only way to determine the future of the system is to run it: there are no shortcuts'. The unpredictability of such processes is irremediable; and, therefore, complex processes introduce radical uncertainties.

the political and economic motives of important players in the nano-domain and of their influence on actual research and development agendas. Participants seem to be aware of the existence and relevance of these motives. The consortium noticed, moreover, that some gaps exist between these motives and those of participants, be they nano-experts, societal experts or interested citizens. On participants' side the motive of nano-research as a spearhead for international economic competition or for warfare is, for instance, nearly lacking.

The application domains and issues discussed in the New Materials case refer to actual societal problems such as environmental pollution and scarcities of energy resources and raw materials. Application domains and issues discussed in the Bio-on-Chip and Smart Environment case focus on specific actual problems of individuals such as an efficient and convenient organisation of daily life and prevention or treatment of human diseases. It is an open question whether the fact that applications in the Bio-on-Chip and Smart Environment domain are, in general, closer to market introduction than in the New Materials case – and that, consequently, in the former cases the trends are already set more clearly – has something to do with that.

It remains an open question whether the outcomes of the Delphi-exercise would have differed substantively if the composition of the participants would have been different. As for this Delphi exercise there appeared to be no systematic differences between the substantive contributions of the three groups of participants in the two first Delphi-rounds. Though it is quite possible that our methodological approach urged the participants to reflect as citizens rather than as researchers, the tensions that arose during and after the third Delphi rounds suggest that various participants consider the Delphi-exercise from different frames of reference. The value of a mixed composition seemingly does not relate so much to the substantive outcomes of the process, but rather to the reactions and reflections that this mixed process provokes. The mixed composition helped to incite – albeit perhaps in a modest way - participants' reflexivity. Some participating nano-experts expressed, for instance, a realization of the need to communicate with the wider public, of a need to learn what and how to communicate with the wider public, and of a structural lack of opportunities to debate the links between their research activities and their personal considerations - within their own research community to start with. For nano-researchers, as well as societal experts and citizens, constructing jointly nano-imaginaries is a first step: it incites them to imagine characteristics of attractive and unattractive future societies, it confronts them for a while with their own value systems, and it prompts them to reflect on the initiatives they are possibly prepared to take and the changes they are possibly willing to risk in order to join in on nano-futures.

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