Chapter 19

Nanotechnology and Public Engagement: A New Kind of (Social) Science?

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Nanotechnology is often framed as revolutionary, both within science and in the effects it will have on our lives. Increasingly, the relationship between nanotechnology and society is cast as a hallmark of this distinctiveness. In current debates concerning its governance and regulation nanotechnology is cast as an opportunity to 'get things right' and 'avoid the mistakes of the past'. Recent emphasis on the responsible development of nanotechnology, for example, demonstrates the increasing incorporation of both ethics and public participation initiatives into nanotechnology research programmes. In this chapter we examine this trend, reviewing current research on the relations between laypeople and nanotechnology. We reflect on both quantitative and qualitative literatures as well as the broader difficulties of engaging with an emergent technology such as nano, ending by suggesting issues, problematics and challenges that future social science on public engagement with nanotechnology should engage with. Not least of these is the question of how to research public concerns about a technology that is 'in-the-making'.

Nano Meets Macro - Social Perspectives on Nanoscale Sciences and Technologies
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www.panstanford.com
978-981-4267-05-2

1. Introduction

Nanotechnology, we are told, will change all of our lives. Enthusiasts argue that the technology will usher in a 'new industrial revolution' that will include breakthroughs in computer efficiency, pharmaceuticals, nerve and tissue repair, catalysts, sensors, telecommunications and pollution control. The US's National Nanotechnology Initiative envisions a future "in which the ability to understand and control matter on the nanoscale leads to a revolution in technology and industry",[1] while a 2007 report by the insurers Lloyds suggests that "current and potential areas of application include transport, manufacturing, biomedicine, sensors, environmental management, food technology, information and communications technology, materials, textiles, sports equipment, cosmetics, skin care and defence" (Lloyds 2007, p.1-2) – and notes that the list is not exhaustive. For some, these visions culminate in the suggestion that nanotechnology represents a new kind of science, one that is both substantively distinct from existing disciplinary approaches and that has the potential for radical transformation. Thus a number of commentators have suggested that part of what defines nanotechnology is a unique attempt to unify an otherwise disparate range of scientific and technical approaches and disciplines. Similarly, the philosopher Alfred Nordmann sees nanotechnology as paradigmatic of a new kind of 'noumenal technology' which exists beyond human perception and control (Nordmann 2006).

Increasingly, the relationship between nanotechnology and society is cast as a hallmark of this distinctiveness. In current debates concerning its governance and regulation, nanotechnology is commonly cast as an opportunity to 'get things right' and 'avoid the mistakes of the past' (Krupp & Holliday 2005; Rip 2006; Randles 2008). Nanotechnology is thus represented as a unique opportunity to learn from previous scientific controversies and mishaps, including that of genetically modified crops and foods (Thompson 2008) and to create a new, socially robust science

[1] See the 'Frequently asked questions' on the initiative's website, www.nano.gov/html/facts/faqs.html (accessed March 2009).

(Kearnes *et al.* 2006). Building on the model established by the ELSI programme of the Human Genome Project, in which a proportion of genetics research funding was reserved for identifying the ethical, legal and social implications of human genetics research, early nanotechnology policy documents spoke of nanotechnology as a "rare opportunity to integrate the societal studies and dialogues from the very beginning and to include societal studies as a core part of the [nanotechnology] investment strategy" (Roco & Bainbridge 2001, p. 2). As a culmination of this now international consensus, a new discourse has emerged, speaking of the "responsible development of science and technology" (see for example: European Commission 2008; Meridian Institute and National Science Foundation 2004; NNI no date; Tomellini and Giordani 2008) and how this can be achieved – principally through the incorporation of social science and ethics into nanotechnology research programmes (Kearnes & Wynne 2007; Kearnes & Rip 2009). One practical effect of this discourse has been a proliferation of ethical codes on responsible practice in nanoscience and the increasingly strategic role of programmes of public engagement (Kearnes & Rip 2009).

Thus public engagement, through the incorporation of public participation and deliberation into nanotechnology research programmes, is seen as a key enabler of responsible development (Royal Society and Royal Academy of Engineering 2004), and as such operates as an epistemic definition of the field. This emphasis can be viewed as the endpoint of a distinct history. Macnaghten and colleagues (Macnaghten *et al.* 2005) trace the development of attitudes to science-public relations from the communication-focussed deficit model (Irwin & Wynne 1996), through a new emphasis on dialogue (House of Lords 2000), to the notion of upstream engagement (Wilsdon & Willis 2004). Beyond this, however, they call not only for a new mode of doing science but for a corresponding new role for the social sciences in becoming "an actor in these changes and [providing] insights that are simultaneous with scientific, technological, and social changes" (Macnaghten *et al.* 2005, p.269). Nanotechnology, they suggest, presents an opportunity for robust social insight to be built into scientific innovation at an early stage.

In this chapter we consider what this might mean for studies of nascent and emerging public responses to nanotechnology. In particular we focus on public engagement activities and processes, discussing the current state of the art before moving on to set out a future agenda. We begin by briefly reviewing what we know already about the relations between laypeople and nanotechnology. How visible is nanotechnology? What do people think of it? How do they think it should be developed? We start to answer these questions from both quantitative and qualitative literatures, and, in conclusion, point to the challenges for a future social science fit for researching the social dimensions of a technology that is 'in-the-making'.

2. Risks and Benefits: Governance, Trust, and Survey Research

The advent of interest in nanotechnology, then, has brought with it an intense debate about public participation and the nature of 'responsibility'. A number of scholars have responded to this debate by suggesting that we are, in fact, currently witnessing the emergence of a new set of governmental techniques[2]—principally public deliberation, ethics and foresight—which are increasingly being incorporated into the formal governance of nanotechnology (Kearnes & Wynne 2007; Kearnes *et al.* 2006; Kearnes & Rip 2009; Macnaghten *et al.* 2005). Though there is considerable debate about the precise role that these techniques might play in the governance of science, Macnaghten *et al.* (2005) suggest that these deliberative and anticipatory techniques are increasingly cast as central to the successful development of nanotechnology. For example, UK policy on nanotechnology now indicates an official commitment:

[2] This terminology is drawn from Rose and Miller's (1992) distinction between the 'problematics of government'—that is the rationalities that constitute the logic of government—and the technologies of government—defined as the 'the complex of mundane programmes, calculations, techniques, apparatuses, documents and procedures through which authorities seek to embody and give effect to governmental ambitions' (p. 175). Authors have explored the embodiment of governmental rationality in a range of different technical areas—for example in techniques of auditing and accounting (Porter 1995; Power 1997), in psychiatric practice (Rose 1991) and in techniques of public participation and consultation (Cruikshank 1999; Lezaun and Soneryd 2007).

> *to enable [public] debate to take place 'upstream' in the scientific and technological development process, and not 'downstream' where technologies are waiting to be exploited but may be held back by public scepticism brought about through poor engagement and dialogue on issues of concern* (Department of Trade and Industry/Department for Education and Skills/HM Treasury 2004, p.105).

Significantly, the initiation of forms of participatory and deliberative approaches is set in the context of what has been described as a deficit in public trust concerning science and technology (House of Lords Select Committee on Science and Technology 2000). Public engagement is here represented as a mechanism through which public trust can be restored by increasing the transparency and accountability of scientific governance and policy development. Though UK policy increasingly speaks of a commitment to forms of upstream public engagement, the rationale of this policy development tends to be framed as ensuring that technologies are not 'held back' by public scepticism (Kearnes & Wynne 2007). Public concern, set against a broad lack of public trust in regulatory institutions and a succession of well-known technological controversies, can therefore be identified as the assumed backdrop to the current proliferation of studies on public perceptions of nanotechnology: the implicit assumption is that by measuring public opinion and perceptions of nanotechnology, and by actively engaging the lay citizenry in the development of nanotechnology, public trust can be restored and nanotechnology 'successfully' developed. These aims appear explicitly, for example, in a recent UK government document (Department for Innovation Universities and Skills 2008) in which the Department for Innovation, Universities and Skills outlines the broad ambitions of its science and society policy as producing:

1. A society excited by and valuing science;
2. A society that is confident in the use of science; and
3. A society with a representative, well-qualified scientific workforce.

If current governmental techniques are fundamentally driven by a desire to measure and mould citizens who trust in and are excited by science, it is perhaps not surprising that this has been made manifest in a swathe of surveys of public opinion. Over the last six years there have been several key studies which have examined different aspects of public perceptions of nanotechnology, starting with an early, internet-based survey by William Bainbridge (2002) which suggested high levels of enthusiasm and expectation of future social benefit for nanotechnology and little concern about possible dangers. Two years later Michael Cobb and Jane Macoubrie conducted the first national phone survey of Americans' perceptions of nanotechnology, set up to measure public knowledge, levels of familiarity, sources of information, perceptions of risks and benefits, and levels of trust (Cobb & Macoubrie 2004). Critically, and as expected, the survey found that most citizens of the United States were unfamiliar with nanotechnology, with 80% of survey respondents reporting that they had heard 'little' or 'nothing' about nanotechnology, and with only one in three correctly answering questions designed to measure factual knowledge. Notwithstanding this low awareness, the respondents nevertheless anticipated the greater probability of benefits over risks, with 40% agreeing that benefits would outweigh risks, compared to 22% agreeing that risks would outweigh benefits. However, the survey found respondents expressing low levels of trust in the nanotechnology industry, with 60% of respondents stating that they had 'not much trust' in business leaders' ability or willingness to minimise the risks of nanotechnology to human health. The survey was interpreted to suggest that Americans are basically positive towards nanotechnology (even when it is presented within negative frames) but that trust in elites is low.

A more elaborate follow-up study in 2005 aimed at providing an in-depth look at 'informed public perceptions of nanotechnology and trust in government' (Macoubrie 2005; 2006). Funded as part of the Woodrow Wilson's 'Project on Emerging Nanotechnologies', this research differs from most other studies by focusing on informed lay publics and by incorporating qualitative aspects into its design. In many respects, though, its findings echo those of previous work. Awareness of nanotechnology was low (the media did not appear to be a significant

source of information); general attitudes towards nanotechnology were enthusiastic (50% being positive rather than neutral or negative); 71% thought that benefits would equal or exceed risks; and there was little support for any ban on the technology. Reported concerns included uncertainty as to effects, regulation and risks, and the effects on human health and the environment. As with previous studies, there was a deep distrust of government, industry and regulatory authorities – largely ascribed to prior experiences of these bodies. Finally, the study reports a widespread desire for more information and openness and to be included in decision-making processes.

These studies all focus on the United States. In contrast, a 2004 report commissioned by the Royal Society and the Royal Academy of Engineering's Nanotechnology Working Group (BMRB Social Research 2004) provides a UK perspective. The study found limited awareness of nanotechnology (just 29% of respondents said they were aware of the term), although awareness was higher among men (40%) than women (19%), and was slightly lower for older respondents. The majority (68%) of those who were able to give a definition of the word felt that it would improve life in the future, compared to only 4% who thought it would make things worse, depending on how it was used. Use of the Eurobarometer survey tool also provides a US-European comparison, revealing some key differences as well as similarities (Gaskell *et al.* 2004; 2005). When asked whether nanotechnology will improve our way of life, 50% of the US sample agreed against only 29% of Europeans. The authors suggest that "people in the US assimilate nanotechnology within a set of pro-technology cultural values" (2005, p. 81) and are thus more positive about science and technology generally. By contrast, in Europe there is "more concern about the impact of technology on the environment, less commitment to economic progress and less confidence in regulation" (Gaskell *et al.* 2005, p. 81).

The overall picture from these studies, then, is of low public awareness and a cautious enthusiasm. As our earlier discussion would suggest, however, these findings need to be understood in the context of their production. Given the performative nature of all social science, and the assumptions driving the desire to measure citizens, we should be aware of the limitations of the social science which has 'found' and

reported them. Significantly, surveys tend to utilise a framing in which risk is the assumed key point of interest for publics with regard to new technologies: public attitudes are thus understood to be focussed around issues of safety and to involve assessments of the possible risks of nanotechnologies (see Bowman & Hodge 2007; Peter D Hart Research Associates 2007). Benefits, similarly, tend to be either assumed or framed in economic terms with little effort devoted to examining how the promised benefits relate to social values. Broader framings, concerns and meanings are thus either ignored or under-represented, with minimal scope for meanings and understandings to be expressed in participants' own terms. This limitation has potentially profound implications in that surveys may be unwittingly imposing pre-defined categories, questions and issues that reflect the researcher's own assumptions, often in close alignment with regulators and corporate interests, and possibly at odds with wider public sentiment. Some recent work, for example, focuses on public knowledge of particular 'facts' relevant to nanotechnology under the explicit belief that public "understanding of nanotechnology will be an important challenge to avoid a backlash by a less than informed public" (Waldron *et al.* 2006; see also Castellini *et al.* 2007). Further limitations arising from the specific character of the technology include the highly questionable assumption that nanotechnology exists as a unified research programme to which it is possible to have a single, stable response or 'attitude'; the fact that most nanotechnologies remain at an early or pre-market stage of development, existing largely in terms of their promise; and the reality that most people are unfamiliar with the term, and so presumably do not have pre-existing attitudes as traditionally conceived. These challenges—which will apply to any engagements with a technology as emergent as nano—will be discussed further in the conclusion.

3. Beyond Risk: Findings from Qualitative Studies and Deliberative Processes

Survey research on public attitudes, then, runs the risk of slipping back into understanding how publics should relate to nanotechnology in terms of a deficit model, whether of knowledge or of trust (Wynne 2006): the tacit implication of this research is that the key challenge for public policy on nanotechnology is one of improving public knowledge about, and thereby trust in, nanotechnological development. In this section we turn to examine how findings from qualitative research and deliberative or dialogue processes might both broaden our understanding of public responses to nanotechnology and challenge this assumption.

The Royal Society and Royal Academy of Engineering working group commissioned the market research group BMRB to undertake both qualitative and quantitative research as part of its study activity (BMRB 2004). The qualitative aspects of this aimed to examine public awareness and attitudes and public views on potential environment, health and safety impacts, and social and ethical dimensions. Perhaps not surprisingly – given the scope this aspect of the research provided for more indepth discussion – the research found considerable ambivalence towards the technology. While enthusiasm and excitement was expressed towards prospective applications, notably in the medical domain, and in its potential to improve quality of life, concerns were also expressed as to its impending transformative impacts in restructuring social and economic life, coupled with unease on possible long-term and unforeseen effects. The report concluded that considerable 'public engagement' initiatives were required to ensure that constructive and proactive debate about the future of the technology developed before deeply entrenched or polarised positions appeared. Clearly influenced by their recent bruising experience of genetically modified foods, where public attitudes were seen to have played a formative role in the development of the controversy, the UK Government and associated funders launched a series of initiatives aimed at proactive or 'upstream' public engagement (Bowman & Hodge 2007).

A report by the Nanotechnology Engagement Group (NEG) has summarised the findings of key UK activities which resulted from this

funding emphasis, including the NanoJury UK (a citizen's jury); the Small Talk programme (which sought to coordinate science communication-based dialogue activities); Democs (a conversation game designed to enable small groups of people to engage with complex public policy issues); and the Nanodialogues project (a series of practical experiments in four different institutional contexts to explore how the public can meaningfully inform decision-making processes related to emerging technologies) (Gavelin *et al.* 2007). The NEG report discusses each project's findings in detail, as well as synthesising these in the form of recommendations for science policy and for public engagement, and including the suggestion that there are three key areas which are consistently raised by lay publics deliberating nanotechnology.

The first of these relates to the fact that public attitudes are not formed in relation only to the technical aspects of particular technologies. Rather, public responses to new technologies are embedded in what we might call the 'political economy' of technological innovation: the trajectory of scientific and technological development as it is shaped by a host of culturally embedded 'imaginaries' of possible social transformations. Such imaginaries often take the form of unquestioned assumptions that implicitly shape technoscientific goals and priorities (Kearnes, *et al.* 2006; Marcus 1995). Public responses to new technologies might therefore be considered as a reaction to these inbuilt values and assumptions together with the political and policy conditions that enable technological innovation. Qualitative studies of latent public concerns demonstrate that public participants are not only concerned with the potential benefits and risks of nanotechnologies, but also with broader questions concerning who these benefits and risks are most likely to affect, why this technology and not another, and what this will mean for questions of control.

The second observation concerns the institutional dimensions of risk perceptions. Public attitudes to risk, uncertainty, and regulation were found to be interconnected with the perceived ability of regulation and regulatory authorities to manage complex risks. Perceptions of risks were thus mediated by public perceptions of those institutions charged with oversight – their honesty, independence, competence and so on – all of which influenced people's reception of current claims (see also Wynne

1982; 1992). And, thirdly, there was a consistent demand for more open discussion and public involvement in policymaking relating to the management of nanotechnology policy, invoking the sense that such matters were too important to be left to 'experts' but needed instead to become part of public discourse and civic life.

The reports from the individual projects discussed in the NEG report flesh out these findings in more detail and with more specific emphases (see Kearnes *et al.* 2006; NanoJury UK 2005; Smallman & Nieman 2006; Stilgoe 2007). For example, the ESRC-funded *Nanotechnology, Risk and Sustainability* project[3] (Kearnes *et al.* 2006) incorporated a focus group phase where laypeople were introduced to and discussed nanotechnology in the context of their experience of other technologies. The authors identify key themes of enthusiasm and ambivalence and gradually evolving concerns around risks, but also questions of control, power, inequality and the kind of 'utopian' futures being promised. As with most other studies, participants had little knowledge of what nanotechnology was. The authors note that "when pressed, people tended to define it as something that was scientific, clever, small, possibly medical, futuristic and associated with science fiction" (Kearnes *et al.* 2006, p.47-8). Further analysis from this research suggests that there are, in fact, several broad areas of concern which are key in shaping lay responses to nanotechnology. These patterns of concern include: their potential for harm, mishap and potential irretrievability; the inevitability of technological innovation as being double-edged; the likelihood that the technology would reduce autonomy, choice and personal control; the ability of technology to transgress limits and to 'play God'; and, finally, the speed of technological innovation as beyond the control of governance (see Macnaghten 2009).

More recently, a number of deliberative initiatives have been commissioned concerning nanotechnology. The consumer organisation *Which?* funded a deliberative process similar to a citizen's jury (see Wakeford 2002), designed to look at how nanotechnology would "affect consumers" (Opinion Leader 2008). Again, the jury identified key opportunities: medical applications, increased consumer choice, the

[3] Phil Macnaghten and Matthew Kearnes were directly involved in this research.

potential to help the environment and developing countries. The process brought up safety as a key concern, along with the current lack of effective regulation and labelling and, accordingly, recommendations focussed around the need for better regulation and information. While this process might be considered problematic in its strong focus on participants as consumers and corresponding emphasis on risk (the report's introduction notes that the organisers were "keen that consumers should be able to make educated choices about the extent to which they use nanotechnologies … being aware of the areas in which uncertainty remains"; Opinion Leader 2008, p. 3), it is striking that despite these framings broader issues still emerged. The report notes, for example, that some participants were concerned about relying on 'high-tech' rather than currently available 'low-tech' solutions, or whether nanotechnology was simply a money-making opportunity for big business.

The Engineering and Physical Sciences Research Council (EPSRC) funded a process with a rather different emphasis, using deliberative workshops to help define priority areas for research in nanotechnology for healthcare (Bhattachary *et al.* 2008; see also Corbyn 2008). One striking finding from this process was a concern about nanotechnological devices removing control or agency; those developments which would empower people, rather than taking control of healthcare from them, were seen as more likely to be beneficial. Other concerns and enthusiasms were familiar from previous processes. Diagnostics and treating serious illnesses such as cancer were seen as priorities, while there were concerns about issues of privacy, surveillance, safety and personal autonomy.

Internationally, there are few divergences from the key findings the NEG reported (Gavelin *et al.* 2007), with engagement processes in France (Ile-de-France 2007) and Switzerland (Rey 2006) producing similar recommendations to UK processes. Indeed, a key finding of the Swiss *publifocus* process was simply a marked ambivalence towards nanotechnology (Burri & Belluci 2008). Public engagement activity in the United States has been more limited, although the investment of a NSF funded Centre for Nanotechnology in Society has created a context for deliberative research which is rapidly being translated into initiatives, the most notable of which is an integrated set of consensus conferences

on human enhancement set within a National Citizens' Technology Forum. Loosely based on the Danish Consensus Conference practice, and conducted across six sites in the United States, the research was set up to present the informed, deliberative opinions of ordinary, non-expert people for the consideration of policy makers who are responsible for managing these technologies before those technologies are deployed. The process itself was extensive, involving parallel panels of approximately 15 individuals undertaking a guided process of learning and deliberating in order to create a set of recommendations arrived upon by consensus. The final reports show common themes: the call for regulation, the need for a new and dedicated policy commission, concerns over access and equity, the need to prioritise remediation over enhancement, and the requirement for wise and judicious oversight (see National Citizens' Technology Forum 2008).

The literature we have examined so far—whether survey-based, drawn from qualitative research projects, or reporting deliberative processes—has focused on publics and their perceptions of nanotechnology. While this has—as we described above—been the emphasis of much research, social science studies have also examined more general public discourse on nanotechnology in the media, policy communities or fiction. There is, for example, a small literature examining media coverage of nanotechnology (for a brief review, see Kjølberg & Wickson 2007; also Anderson *et al.* 2005; Faber 2006; Gaskell *et al.* 2005; Kulinowski 2004; Stephens 2005). Scheufele *et al.* (2007) have, for example, demonstrated that public discourse concerning the risk of nanotechnology has tended to emanate from with the scientific community itself. Toumey's work explicitly relates media coverage to public perceptions. As well as tracking nanotechnology's 'creation myth' through the scientific and popular press (Toumey 2005), he has argued that the narratives surrounding nanotechnology will help anticipate public reactions to it (Toumey 2004). Drawing on the histories of recombinant DNA and cold fusion research, he suggests that if certain conditions are met—including polarised and hyperbolic discourse and exacerbated differences in power and wealth—then negative stories about nanotechnology may rapidly become dominant. As he notes, a "little bit of recklessness or disdain will easily be magnified and

transmuted into a compelling story about amoral scientists arrogantly producing terribly dangerous threats to our health and our environment" (Toumey 2004, p. 108). Similarly, Schummer (2005) attempts to understand public interactions with nanotechnology through examining patterns of book buying. Using a complex network analysis based on data from Amazon.com, he argues that there is high public interest in nanotechnology, with many purchasers of 'nanobooks' being new to science and technology literature, and that this interest is focused in books about forecasting and investment. He also suggests that interest in fiction and non-fiction about nanotechnology remains mostly separate, but that links between them are growing—as are connections to the business world—through 'border-crossing' authors.

A related literature has focused on the visions or imaginaries that are manifest in nanotechnology policy and discourse and their role in constructing future-oriented promises and expectations. Informed by wider social science interest on the role of expectations in constructing socio-technical futures (Brown & Michael 2003; Selin 2007; van Lente 1993), and on the master narratives of technoscience that drive and frame current science and technology policy (Felt & Wynne 2007), research has begun to explore the multiple ways in which scenarios, foresight or vision assessment techniques can be deployed to help anticipate the likely social and ethical implications of nanotechnology. For example, van Merkerk and van Lente explored the concept of 'emerging irreversibilities' underlying the dynamics of on-going technological development of nanotubes, with the aim of rendering the technology more socially accountable (van Merkerk & van Lente 2005); the European Framework 6 project Nanologue has developed three scenarios aimed at setting out three possible futures in the development of nanotechnology with the aim of structuring the debate around 'responsible innovation' (Nanologue 2007); while scenarios have been incorporated into research projects around upstream public engagement (Kearnes *et al.* 2006), and green technology foresight (Jørgensen *et al.* 2006). Other studies have examined the role of science fiction in the development of nanotechnology policy (Milburn 2004), and in shaping the moral imagination of practitioners (Nerlich 2008; Berne 2006).

4. Conclusion: Nanotechnology and Public Engagement

Qualitative research, and that derived from dialogic or deliberative processes, then, has certainly broadened our understanding of the ways in which lay publics relate to and negotiate nanotechnologies beyond a framing of 'risks and benefits'. There is in fact remarkable consistency across different studies: we find optimism—particularly about the social benefits of new technology—mingled with concern, particularly around the motivations and trustworthiness of those driving the technology, and combined with a desire for increased openness, information, and public deliberation. In addition, not only has this consistency been expressed as a research outcome, but also as a deliberative finding from engagement processes seeking to involve publics in nanotechnology's 'upstream' direction. Can we assume, then, that social science is doing its job, and innovating in a way which involves genuine intervention in nanotechnology's development, making it increasingly socially robust (cf. Rip 1986)?

Despite considerable advances in the sophistication of both research engagements and policy-oriented activities, we would suggest that there is more work to be done in building robust social research into the "complex and difficult terrain" (Macnaghten *et al.* 2005, p. 278) of emerging technologies. To celebrate not insignificant successes—not least in bringing the language of public participation into, in many countries, the policy mainstream—without acknowledging the limitations of these is to ignore at least two important challenges that continue to face public engagement with nanotechnology.

The first of these relates to nanotechnology's emergent nature. The difficulties of negotiating a technology which largely exists in promises and speculation create a number of problems not just for survey research —as discussed above—but for any kind of engagement (see Macnaghten 2009). At this stage, in other words, nanotechnology is effectively invisible to most people. In particular, we can point to two related aspects of this 'invisibility' which are key challenges for public engagement processes but which remain largely unresolved: *problem definition* and *stakeholder definition*. The first draws on an understanding of engagement and deliberation as the negotiation of difference around a

shared question or problem (Benhabib 1996); without a commonly acknowledged problematic issue, in other words, there is nothing on which to focus deliberation (see also Andersen & Jaeger 1999). With downstream or already-controversial technologies, the shared problem is frequently obvious (often coming down to the question: how can we mutually resolve this – problematic – situation?). But with nanotechnology, problem definition, and therefore the structure and outcomes of public engagement, is by no means clear. Its lack of a material presence in many people's lives, and the fact that the majority of people are unaware of the term's meaning, coupled with disjunctions between technically expert and lay concerns, can make identifying shared problems around which to engage deeply challenging and result in a lack of focus within engagement processes.

Stakeholder definition is, of course, related to this. Where there is a commonly acknowledged problem it is usually clear who is a stakeholder in resolving this; to use Collins and Evans' (2002) language, there are a range of different forms of interactive and contributory expertise which have relevance to the issue. In the case of nanotechnology, there are currently only relatively few groups who would consider themselves as stakeholders in the technology and its development (we might suggest: nanoscientists, those who make nano-related policy, representatives from nanotechnological industry, and a small number of NGOs). Most laypeople – as our review of public engagement literature has highlighted – are unaware of the technology and do not see themselves as having a stake in it; even when their awareness of it is raised, they often feel disempowered to the extent that they cannot view themselves as active participants in its coproduction (Kearnes, *et al.* 2006). At the very least, this raises the practical point that public engagement on nanotechnology inevitably must involve a phase of awareness or consciousness raising in which lay participants can develop their own concerns around the technology (similar, in fact, to the qualitative focus groups described above). At a more fundamental level, this and the question of problem definition highlight the essential performativity of public engagement on emerging technologies. While all engagement processes shape their participants into certain forms of citizens mobilised around certain kinds of issues (see, for example, Irwin 2001; Goven 2006), those focussed

around upstream technologies are exemplary in doing this in that they take what to many participants is an invisible issue—a non-issue—and create a problem, *ex nihilo*. In doing so they not only construct a problem to be solved but a group of citizens who are to perform their concerns in certain ways. This feature of public engagement with nanotechnology—and the impact that this creative process has on resulting public debate and wider discourses—remains, if not exactly a challenge to be overcome, a key aspect of the role of social science to be reflected upon.

A second challenge relates to the wider context into which the findings of public engagement are received. As a number of authors have pointed out, while the language of dialogue, public engagement and participation may have become a reality in policy, it is far less clear how such activities relate to the everyday practice of governing nanotechnology (Irwin 2006; Joly & Kaufman 2008; Rogers-Hayden & Pidgeon 2007; Wynne 2006). Assumptions about right relations between science, laypeople, and policy are often deeply embedded, and it has always been optimistic to assume that because language and, to some extent, practice have altered, such assumptions will also change automatically (Joly & Kaufman 2008; Jones & Irwin 2009). Direct and obvious outcomes such as those arising from the 2008 EPSRC deliberative process (see above), which clearly shaped research priorities, remain unusual. In addition it should be noted that understanding this wider policy context is not simply a matter of checking off whether policy commitments relating to public engagement have been put into practice; whether, in other words, public recommendations have been acted on (although this would certainly be a start). Rather, the imperative is also towards finding where it is possible to have an impact, where irreversabilities are already and are becoming fixed, and in what ways public engagement should be structured in order to best shape these (Joly & Kaufman 2008). Without greater analysis of these questions, and the development of more effective participation mechanisms and institutional structures, public engagement with nanotechnology runs the risk of becoming what Alfred Nordmann has called an unending buzz of conversation, acting merely as a soundtrack as, by design or default, decisions are made elsewhere (personal communication).

Public engagement with nanotechnology therefore remains a fertile field for analysis and for methodological innovation, offering the opportunity to develop thinking on deliberation in a way that enables it to cope better with the challenges of emerging technologies. As we conclude we wish to emphasise one concept which, we suggest, might help develop a social science that is equipped to do this. A key feature of our discussion has been that nanotechnology is distinctive in a number of ways (to the extent that it has been framed as a new kind of science). Not the least part of its uniqueness as an object for social science study is its emergence: it presents particular challenges due to its current upstream position and public invisibility. In order to deal with these challenges we might suggest that we need a social science which is also emergent; that is, in development, experimental, exploratory—and therefore also multidisiplinary and 'messy' (cf Law 2004). Taking this concept as a framework will allow methods—of both engagement practice and analysis—that are flexible, growing with the technology and with lay agency, and open to shaping by a range of actors (cf Rip 1986). It justifies innovation and experimentation, enabling us to retreat, if necessary, from a range of tried and tested practices that may no longer be appropriate. It will allow us to reflect on and acknowledge the work being done by our own methods and processes, and the citizens, sciences, and futures being performed by them. Finally, we would hope that as these new methods of social science unfold alongside nanotechnology's own development, they would enable this development to be more robust, socially valid, and resilient.[4]

[4] This work has been supported by the DEEPEN (Deepening Ethical Engagement and Participation with Emerging Nanotechnologies) project, an EU Sixth Framework Programme funded project and Europe's leading partnership for integrated understanding of the ethical challenges posed by nanotechnologies (see www.geography.dur.ac.uk/projects/deepen). We would like to acknowledge productive discussions around this topic with the other DEEPEN partners.

Questions for Reflection:

1. What visions and imaginaries are shaping developments in nanotechnology?

2. How can the development of nanotechnology become the subject of greater public discussion?

3. What do you think the role of social science should be in the development of new technologies?