Chapter 11
Nanotechnology, Risk and Public Perceptions

Philip Macnaghten

11.1 Introduction

In the past 10 years, a policy and media debate about nanoscience and nanotechnologies has emerged, characterised by competing visions of promise and threat (Selin 2007). For their advocates nanotechnologies are seen to have unprecedented economic and social potential, ushering in a 'new industrial revolution' that will include breakthroughs in computer efficiency, pharmaceuticals, nerve and tissue repair, surface coatings, catalysts, sensors, materials, telecommunications and pollution control (European Commission 2004; House of Commons Science and Technology Committee 2004; Lloyds 2007; Roco and Bainbridge 2003). Worldwide research funding for nanotechnologies has increased rapidly, with public investments in the US, Japan and the EU each topping $1 billion in 2005. Corresponding R&D investments by industry worldwide are around the same level, and increasing, with an average annual increase of approximately 25 %, year on year (Lux Research 2008; Renn and Roco 2007). The Project on Emerging Nanotechnologies as of August 2008 lists 620 consumer products on its inventory of nanotechnology-based consumer products, while Lux Research estimates that by 2015 the market for nanomaterials and processes will exceed $4.0 trillion (Lux Research 2008; Project on Emerging Nanotechnologies 2008).

At the same time, ethical, social and regulatory concerns which originated with dystopian fears of 'grey goo' and self-replicating nanobots running 'out of control' (Joy 2000; Drexler 1986), are rapidly taking on a sharper focus around a growing debate on the potential toxicity of nanoparticles and carbon nanotubes and their

P. Macnaghten (✉)
Department of Geography, Durham University, Durham, UK

Department of Science and Technology Policy, Institute of Geosciences,
University of Campinas – UNICAMP, Brazil
e-mail: p.m.macnaghten@durham.ac.uk

unknown and potentially hazardous impacts on the environment and human health (Nature 2003; The Economist 2007). Not surprisingly for such a novel technology, risk assessment remains at an early stage but mounting evidence appears to suggest the potential for significant harm. Such concerns are shared across learned societies, government departments, international bodies and industry as well as NGOs (see, amongst others, Council for Science and Technology 2007; Defra 2007; Friends of the Earth 2007; Lloyds 2007; Royal Society/Royal Academy of Engineering 2004), leading to various initiatives aimed at the 'responsible development' of nanotechnology (BASF 2007; Defra 2006; Dupont 2007; European Commission 2007). Given the novel properties that materialise at the nanoscale, not least the enhanced chemical reactivity arising from increased surface area (dissecting a 1 cm cube of any material into 1 nm cubes increases the total combined surface area some ten million times), it is perhaps not surprising that there might be unforeseen and unanticipated effects. Gold and silver are good examples. Normally inert and unreactive, at the nanoscale gold acts as a highly effective catalyst, and silver displays bioactive properties (Smith 2004).

   This brief account of the current policy and regulatory debate on both sides of the Atlantic provides a backdrop to review current understandings of public perceptions, to appraise diverse methodologies and approaches, and to evaluate their significance to current debates on governance. However, there is a further reason why questions of public perceptions have risen in prominence both in public policy and academia. Traditionally it has been assumed that technological innovation should proceed according to its own logic of assumed social benefit, relatively untainted by matters of ethics, democracy or social norms, and to find its eventual acceptance or rejection in the market place. It was assumed that any attempt to create 'barriers' to innovation, over and beyond matters of predictable harm, was anti-competitive and in breach of principles of free trade. The associated policy ambition was that of creating a society literate and confident in science, cognisant of its importance to social and economic well-being, and enabled by governmental and private sector educational programmes aimed at the so-called public understanding of science. However, of course, society has rarely accepted such claims of inevitable benefit without question, not least due to a range of contemporary experience of technological controversy and scientific mishap arising from unforeseen consequences of scientific advance, ranging from thalidomide to BSE to endocrine disruptors to chlorofluorocarbons. Part of the policy response to such critique, fuelled in part by the largely unanticipated political controversy surrounding GM foods and crops, has been to promote dialogue models of public engagement, starting with the prescient 2000 report from the UK House of Lords Select Committee on Science and Technology, and its call for more open, two way, exploratory and participatory forms of public engagement (House of Lords 2000). The appeal for more proactive involvement and deliberation in debates about the social and ethical dimensions of science and technology are now commonplace in policy papers and reports (see Department of Trade and Industry 2000; European Commission 2004; HM Treasury/DTI/DfES 2004; Royal Commission of Environment and Pollution 1998) with nanotechnology presented as the current focus (see Kearnes et al. 2006; Wilsdon and Willis 2004; Wood et al. 2003, 2007).

One of the implications that arise out of this 'anticipatory' turn in technological governance is that it reinforces the need to understand and characterise better the public, its perceptions of novel technology, and crucially, the factors that structure and underpin public attitudes and response. This is especially challenging for those analysts specialising in public perceptions since it is not clear precisely what constitutes the object of inquiry: i.e. nanotechnology. Indeed, the very definitions and constitutions of the term has been the subject of lively debate, within the scientific community and beyond (House of Commons Science and Technology Committee 2004). As conventionally understood, the term 'nanotechnology' refers to the design or manipulation of structures and devices at a scale of 1–100 nm (or billionths of a metre). Yet scale is but one characteristic that unites the diverse activities and applications commonly referred to in this way. Additional complexities flow from the convergence of nanoscale innovations in different domains: notably, the life sciences, cognitive sciences and information technology (Nordmann 2004; Wood et al. 2003; European Commission 2004). With these cautionary remarks to hand I now survey the current literature on public perceptions starting with survey data, paying particular attention to how nanotechnology has been framed in the research process.

11.2   Review of Survey Research

Analyses of public understanding to nanotechnology have been dominated by survey research. Over the last 6 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) sponsored by the National Geographic Society and the National Science Foundation. The survey suggested high levels of enthusiasm and expectation of future social benefit for nanotechnology and little concern about possible dangers. Over 57 % agreed that 'human beings will benefit greatly from nanotechnology' while only 9 % agreed that 'our most powerful twenty-first century technologies – robotics, genetic engineering, and nanotechnology – are threatening to make humans an endangered species, leading Bainbridge to interpret little public support for Bill Joy's prognosis of the likely future perils posed by nanotechnology and related fields. The respondents were seen also as more likely to associate mentally the future benefits of nano-technology with the future benefits of the space programme, nuclear power and cloning, as opposed to the 'pseudo-science' ideas of 'time travel machines' and instruments that can measure the 'human spirit', again leading Bainbridge to claim that association of nanotechnology as science fact rather than science fiction. While Bainbridge's non-random sample arguably was biased in favour of those who were already 'pro-science', the survey nevertheless found broadly equivalent 'pro-nanotechnology' views across age, educational and political orientation variables – the only significant difference being gender with 69 % of men agreeing with the pro nanotechnology statement compared with just 47 % of women.

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 and Macoubrie 2004). Critically, and as expected, the survey found that most citizens of the United States are 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 accurate factual knowledge. Notwithstanding this lack of factual knowledge, 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. The finding was coupled with strong correlations between the level of respondents' knowledge of nanotechnology, positive emotions and positive predictions of benefit versus risk. Drilling into the substance of risks and benefits, when asked to choose between alternatives, the survey found 'loss of personal privacy due to tiny surveillance devices' as the most important risk to avoid (31.9 %), while identifying 'new and better ways to detect and treat human diseases' as their most preferred potential benefit (57.2 %). Interestingly, and in contrast to corporate interest and investment in nanotechnology, only a small minority of respondents identified with 'cheaper, better consumer products' as of most potential benefit (3.8 %). 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 and follow-up study was conducted by Jane Macoubrie 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 work by focusing on informed lay publics and by incorporating more sophisticated qualitative aspects into its design: at this stage, at least, it appears to be definitive within this type of study (and given its limited geographical focus). In many respects its findings echo those of previous work. Awareness of nanotechnology was low (and 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 a ban. 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. Macoubrie notes that in the context of a lack of information (and trust) in the oversight processes designed to manage risks, the respondents drew on analogies drawn on 'experiential knowledge about past "breakthroughs" whose limitations and negative effects were poorly understood initially, and even when once known, were poorly managed' (2006, 221). While analogies to past

controversies – such as asbestos, dioxin, Agent Orange or nuclear power – may be misleading in strict scientific terms, they nevertheless may have resonance as social process, including, for example, latent concern in the ability of political and regulatory systems to keep pace with the commercial development and diffusion of scientific advance (see Grove-White et al. 2000). Finally, she reports a widespread desire for more information and openness and to be included in decision-making processes.

The studies above all focus on the United States. A 2004 report commissioned by the Royal Society and the Royal Academy of Engineering's Nanotechnology Working Group provides a UK perspective. The research aimed to assess awareness about nanotechnology, and also whether nanotechnology would have a positive or negative effect on quality of life (BMRB Social Research 2004). They found that there was limited awareness about nanotechnology (29 % of respondents said they were aware of the term). Awareness was higher among men (40 %) than women (19 %), and was slightly lower for older respondents. There was also a clear pattern by social grade, with awareness peaking at 42 % for ABs and falling to 16 % of DEs. 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 provided a 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, 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, 81).

Recent work has also sought to examine the mechanisms by which 'attitudes' towards nanotechnology are created. Thus Lee et al. (2005) look at the ways in which knowledge and affect interact to define attitude: they suggest both that knowledge about science is used to evaluate nanotechnology and that affective factors (such as trust or anxiety about science) provide important frameworks for those evaluations, while Kahan et al. (2007) explore the role of values in mediating expressed opinions to nanotechnology under conditions of unfamiliarity. Where there are strong emotions towards science, they argue, additional knowledge about nanotechnology may not change attitude. Schefuele and Lewenstein (2005), in a study based on data from a US phone survey, argue that 'cognitive shortcuts' (such as ideologies, religious beliefs or – particularly, they suggest – media portrayals) are used by laypeople to inform judgements rather than their using "all available information to make decisions" (p. 660; see also Scheufele and Lewenstein 2005). This, they suggest, means that understanding media coverage around nanotechnology will be vital for understanding likely public responses. A further study conducted in 2007 claimed that public concern over some risks of nanotechnology was actually less than that within nanoscience communities, possibly reflecting an increased sensitivity in the expert framing of risk and scientific uncertainty (Scheufele et al. 2007).

11.3 Underlying Frameworks

While illuminating in various guises it is important to note that much of this survey-based work is problematic in several regards. Perhaps most importantly, 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 understood to be focussed on issues of safety and to involve assessments of the 'risks and benefits' of nanotechnologies (see Bowman and Hodge 2007; Peter D Hart Research Associates 2007). Benefits, similarly, tend to be either assumed or framed in economic terms with little attempt devoted to examine how the promised benefits relate to social values. Broader framings, concerns and meanings are thus either ignored or under-represented with little scope provided 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. Recent work, for example, continues to operate 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) and therefore focuses on public knowledge of particular 'facts' relevant to nanotechnology. Indeed, in the related domain of GM foods and animals, a clear research finding was the inadequacy of such official framings in capturing the character of legitimate public concerns (Grove-White et al. 1997, 2000; Macnaghten 2004). 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;

More generic critiques of the limitations of survey research are well-rehearsed (see Hill and Michael 1998; Macnaghten and Urry 1998). One dynamic that seems especially important is how survey research addresses participants as citizens and/or consumers. Hill and Michael (1998) have shown that the Eurobarometer survey instrument is ambiguous as to whom it addresses: at times it seems to be concerned with the 'citizen', while at others it constructs the user as consumer and seeks to measure 'product recognition'. Similarly, much of the work discussed above assumes that the publics which they are interested in will exercise choice and control at the level of products. Publics are understood to be consumers (or not) of individual technologies rather than citizens with broader concerns: thus such work asks about "intentions…to purchase lamb or beef made using nanotechnology" (Cook and Fairweather 2007) or opinions on the safety of the food supply (Peter D Hart Research Associates 2007). Previous research (Grove-White et al. 1997) has indicated that people reflect in rather different ways when addressed as

citizens or consumers, bringing in particular framings, perspectives and rationalities to suit the context: the issue of exactly how participants are being framed is therefore an important one.

A further criticism concerns one of methodological individualism that resides within conventional survey research, and the embedded assumptions of human thinking, attitudes, values and opinions as internally coherent, reflecting as is presumed underlying cognitive processes. An alternative approach seeks to locate consistency not within the individual subject but rather in the cultural milieu out of which repertoires of understanding and argument emerge. Such 'discursive', 'narrative' or 'rhetorical' approaches to human thought and action develop a different mode of research praxis and analysis favouring qualitative and ethnographic methods where the analytical task is to observe the evolution and contestation of attitudes in context, and typically in conversation. Whether explicit or not, qualitative approaches offer the potential for understanding not simply what people think about nanotechnology, but the factors that underpin such thinking.

11.4   Review of Qualitative and Public Engagement Research

The Royal Society and Royal Society of Engineering working group commissioned the marketing group BMRB to undertake both qualitative and quantitative research as part of its study activity (BMRB 2004). The qualitative research aimed to examine public awareness and attitudes, public views on potential environment, health and safety impacts, as well as social and ethical dimensions. Perhaps not surprisingly, the research found considerable ambivalent attitudes towards the technology. While considerable 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 appear. Clearly influenced by recent and 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.

A report by the Nanotechnology Engagement Group (NEG) summarises the findings of UK research on public engagement on nanotechnology: these included the 2005 NanoJury UK (a citizen's jury); the 2004–2006 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 to explore whether the public can meaningfully inform

decision-making processes related to emerging technologies in four different institutional contexts (2005–2006) (Gavelin et al. 2007). The NEG report usefully discusses each project's findings in detail, as well as synthesising these in the form of recommendations for science policy and for public engagement. The authors suggest that there are three key areas which are consistently raised by lay publics deliberating nanotechnology:

First, public attitudes are formed not only in relation to particular technologies, but also to the policies and values that shape the direction of technological development, and to the social and political conditions in which they emerge. Public participants were not only concerned with the potential benefits and risks of nanotechnologies, but also with broader questions concerning who the benefits and risks are most likely to affect, why this technology and not another, and what this will mean for questions of control. This is an important finding and one that has important implications for traditional forms of technology assessment. 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 'rationally' influenced people's reception of current claims (see also Wynne 1980, 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; Smallman and Nieman 2006; Stilgoe 2007). For example, the ESRC-funded 'Nanotechnology, Risk and Sustainability' project (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 with 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" (pp. 47–48). A further paper suggests, from the focus group data, that there are several broad areas of concern which are key in shaping lay responses to nanotechnology. These patterns of concern are as follows (see Macnaghten 2010): (1) Their potential for harm, mishap and potential irretrievability; (2) The inevitability of technological innovation as being double-edged; (3) The likelihood that the technology would reduce autonomy, choice and personal control; (4) The ability of technology to transgress limits and to 'play God'; and (5) The speed of technological innovation as beyond the control of governance.

The most recent UK-based deliberative process was a citizen's jury-style event funded by the consumer organisation "Which?" designed to look at how

nanotechnology would "affect consumers" (Opinion Leader 2008). Again, the jury identified key opportunities: medical applications, increased consumer choice, the 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. The dangers of military or surveillance applications and questions about inequality and impacts on the environment were also raised. 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, 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 about whether nanotechnology was simply a money-making opportunity for big business.

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 set within a National Citizens' Technology Forum. Loosely based on the Danish Consensus Conference practice, and conducted across six sites in the United States (in New Hampshire, Georgia, Wisconsin, Colorado, Arizona, and California), 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 generated by the individual Citizens' Technology Forums show common themes around: 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 http://www4.ncsu.edu/~pwhmds/final_reports.html).

11.5 Other Perspectives on the Public and Public Discourse

A final category of literature is related to the role of the media and other mediating sources in the public reception of nanotechnology. There is, for example, a small literature examining media coverage of nanotechnology (for a brief review, see Kjølberg and Wickson 2007; also Anderson et al. 2005; Faber 2006; Gaskell et al. 2005; Kulinowski 2004; Stephens 2005). Toumey's work more 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" (2004, 108). Somewhat 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 focussed 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 expectations in constructing socio-technical futures (Selin 2007; van Lente 1993; Brown and Michael 2003), and on the master narratives of technoscience that drive and frame current science and technology policy (Felt and 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' to help underlying the dynamics of on-going technological development in the case of nanotubes with the aim of rendering the technology more socially accountable (van Merkerk and 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), green technology foresight (Joergensen et al. 2006), a CNS-ASU project that used scenarios to frame debates about the societal implications of nanotechnology, and a project commissioned by the UK Economic and Social Research Council to create scenarios about converging technologies. Using more literary cultural studies are studies that have examined the role of science fiction in the development of nanotechnology policy (Milburn 2004) and a project based on conversations with scientists and engineers about the role of science fiction in shaping the moral imagination of practitioners (Berne 2006).

Finally, there are at least two agenda-setting papers which seek to shape the emerging field. Bainbridge (2004) discusses six methodologies which he believes will be useful for social scientists seeking to examine the "socio-cultural meaning of nanotechnology" (p. 285). The six include web-based questionnaires, vignette

experiments, and quantitative content analysis: of the six, only one – textual analysis of science fiction novels – is a qualitative method. Bainbridge writes with a concern for examining and setting right – through "remedial action such as educational reform or public information campaigns" (p. 285) – cultural perceptions of nano-technology. His agenda – driven by the assumption that the technology unproblem-atically has "vast potential" (p. 298) – may therefore be viewed as somewhat limited. Writing from a different perspective, Macnaghten et al. (2005) similarly seek to outline a research programme for real-time social science analysis of nanotechnology. They describe five areas (Imaginaries, Public Engagement, Governance, Globalisation, and Emergence) which social science could productively investigate: all touch upon public negotiations of nanotechnology in some way. This research agenda is, as Bainbridge's is, explicitly linked to action. In this case, however, the emphasis is not on educating publics but on "rendering scientific cultures more self-aware of their own taken-for-granted expectations, visions, and imaginations of the ultimate ends of knowledge, and rendering these more articulated, and thus more socially accountable and resilient" (p. 278). Within this programme it is therefore science and its governance which are seen as the focus for action. Social science is viewed as part of an interdisciplinary collaboration whereby nanotechnology is robustly managed and lay inputs are included 'upstream' in its development (Wilsdon and Willis 2004).

11.6   Conclusion

The problematic nature of studying public perceptions of technologies that frequently don't exist yet can perhaps explain the structure of this body of literature: it is split between (generally) crude survey research and descriptions of deliberative policy processes. While many of the studies I have discussed might be questioned in terms of their framing, it is possible to draw out some key points. In sum, the key points are as follows.

Firstly, both quantitative and qualitative studies indicate that there is considerable optimism for (certain) nanotechnologies, particularly those which will deliver social benefits such as helping poor people or delivering new medical technologies or helping the environment. The question of motivation is a key variable in structuring public responses. However, in this regard, most survey research and many deliberative processes uncover distrust and cynicism of industry, science and government moti-vations, not simply in terms of their sensed ability to manage nanotechnologies and provide reassuring forms of oversight, but also with regards to the forces that are seen to be driving nanotechnology R&D. When acquainted with considerations of political economy, including the sizeable budgets allocated to research by both private and public institutions, people tend to question the likelihood that such research will be devoted to good purposes such as improving the environment or helping the poor. The associated promise that nanotechnology will be the 'next industrial revolution' simply accentuates this dynamic.

Secondly, most studies indicate that there remain some areas of concern. Survey work tends to deliver findings on concerns about risks, regulation, and uncertainty. These also emerge in more deliberative processes, alongside broader questions about control, inequality, power, and whether we really need or want these technologies. What this means is that public perceptions of nanotechnology can not be dislocated from wider perceptions of technology and its role – both good and bad – in constituting the good life. Nanotechnology, including its promises to 'control the structure of matter' and associated claims for precision and intervention on nature 'at its core', thus acts as a symbol that both galvanises concern and excitement about advanced science and its relationship to society. Understanding this symbolic role is a topic for future research.

Thirdly, most research indicates that lay publics would like more information and openness about nanotechnology, and that they feel it's important that they have the opportunity to be involved in shaping science policy in this area. Again this points to the widespread aspiration for closer involvement in nanotechnology research and policy decisions at a stage when there remain real opportunities for influence and modulation. Understanding how to operationalise such 'upstream' engagement in ways that are both meaningful and resonant to both public and private actors is a final issue for future inquiry.

References

Anderson, A., S. Allan, A. Petersen, and C. Wilkinson. 2005. The framing of nanotechnologies in the British newspaper press. *Science Communication* 27(2): 200–220.

Bainbridge, W.S. 2002. Public attitudes toward nanotechnology. *Journal of Nanoparticle Research* 4(6): 561–570.

Bainbridge, W.S. 2004. Sociocultural meanings of nanotechnology: Research methodologies. *Journal of Nanoparticle Research* 6(2–3): 285–299.

BASF. 2007. *Code of conduct nanotechnology*. http://corporate.basf.com/en/sustainability/dialog/politik/nanotechnologie/verhaltenskodex.htm?id=VuGbDBwx*bcp.ce.

Berne, R. 2006. *Nanotalk: Conversations with scientists and engineers about ethics, meaning, and belief in the development of nanotechnology*. Mahwah: Lawrence Erlbaum.

BMRB Social Research. 2004. *Nanotechnology: Views of the general public. Quantitative and qualitative research carried out as part of the nanotechnology study*. London: The Royal Society and Royal Academy of Engineering Nanotechnology Working Group.

Bowman, D., and G. Hodge. 2007. Nanotechnology and public interest dialogue: Some international observations. *Bulletin of Science Technology Society* 27(2): 118–132.

Brown, N., and M. Michael. 2003. A sociology of expectations: Retrospecting prospects and prospecting retrospects. *Technology Analysis and Strategic Management* 15(1): 3–18.

Castellini, O., G. Walejko, C. Holladay, T. Theim, G. Zenner, and W. Crone. 2007. Nanotechnology and the public: Effectively communicating nanoscale science and engineering concepts. *Journal of Nanoparticle Research* 9(2): 183–189.

Cobb, Michael D., and Jane Macoubrie. 2004. Public perceptions about nanotechnology: Risks, benefits and trust. *Journal of Nanoparticle Research* 6(4): 395–405.

Cook, Andrew J., and John R. Fairweather. 2007. Intentions of New Zealanders to purchase lamb or beef made using nanotechnology. *British Food Journal* 109(9): 675–688.

Council for Science and Technology. 2007. *Nanosciences and nanotechnologies: A review of government's progress on its policy commitments*. London: Council for Science and Technology.

Defra. 2006. *UK voluntary reporting scheme for engineered nanoscale materials*. London: DEFRA.

Defra. 2007. *Characterising the risks posed by engineered nanoparticles*. London: DEFRA. http://www.defra.gov.uk/environment/nanotech/research/pdf/nanoparticles-riskreport07.pdf.

Department of Trade and Industry. 2000. *Excellence and opportunity – A science and innovation policy for the 21st century*. London: DTI.

Drexler, E. 1986. *The engines of creation: The coming era of nanotechnology*. New York: Doubleday.

Dupont. 2007. *Nano risk framework*. Washington, DC: Environmental Defense – Dupont Nano Partnership.

European Commission. 2004. *Towards a European strategy for nanotechnology*. Luxembourg: Commission of the European Communities. ftp://ftp.cordis.europa.eu/pub/nanotechnology/docs/nano_com_en_new.pdf.

European Commission. 2007. *Towards a code of conduct for responsible nanosciences and nano-technologies research*. Consultation Document: http://ec.europa.eu/research/consultations/pdf/nano-consultation_en.pdf.

Faber, Brenton. 2006. Popularizing nanoscience: The public rhetoric of nanotechnology. *Technical Communication Quarterly* 15(2): 141–169.

Felt, U., and B. Wynne. 2007. *Taking European knowledge society seriously*. Report of the expert Working Group on Science and Governance to the Science, Economy and Society Directorate, Directorate-General for Research, European Commission, Brussels, January 2007.

Friends of the Earth. 2007. *Nanotechnology and sunscreens: A consumer guide for avoiding nano sunscreens*. http://www.foe.org/nano_sunscreens_guide/Nano_Sunscreens.pdf. Accessed 8 Sept 2008.

Gaskell, G., T. Ten Eyck, J. Jackson, and G. Veltri. 2004. From our readers: Public attitudes to nanotech in Europe and the United States. *Nature Materials* 3(8): 496.

Gaskell, G., T. Ten Eyck, J. Jackson, and G. Veltri. 2005. Imagining nanotechnology: Cultural support for technological innovation in Europe and the United States. *Public Understanding of Science* 14(1): 81–90.

Gavelin, K., R. Wilson, and R. Doubleday. 2007. *Democratic technologies?* The final report of the Nanotechnology Engagement Group (NEG). London: Involve.

Grove-White, R., P. Macnaghten, S. Mayer, and B. Wynne. 1997. *Uncertain world: Genetically modified organisms, food and public attitudes in Britain*. Lancaster: CSEC, Lancaster University.

Grove-White, R., P. Macnaghten, and B. Wynne. 2000. *Wising up: The public and new technologies*. Lancaster: CSEC, Lancaster University.

Hill, Alison, and Mike Michael. 1998. Engineering acceptance: Representations of 'The Public' in debates on biotechnology. In *The social management of genetic engineering*, ed. P. Wheale, R.v. Schomberg, and P. Glasner. Aldershot: Ashgate.

HM Treasury/Department of Trade and Industry/Department of Education and Skills. 2004. *Science and innovation investment framework 2004–2014*. London: HM Treasury.

House of Commons Science and Technology Committee. 2004. *Too little too late? Government investment in nanotechnology*, Fifth Report of Session 2003–2004. London: House of Commons.

House of Lords Select Committee on Science and Technology. 2000. *Science and society*. London: HMSO.

Joy, B. 2000. Why the future doesn't need us. *Wired* 8(4): 238–262.

Kahan, D., P. Slovic, D. Braman, J. Gastil, and G. Cohen. 2007. *Nanotechnology risk perceptions: The influence of affect and values*. http://research.yale.edu/culturalcognition/. Accessed 8 Sept 2008.

Kearnes, Matthew B., Phil Macnaghten, and James Wilsdon. 2006. *Governing at the nanoscale: People, policies and emerging technologies*. London: Demos.

Kjølberg, K., and F. Wickson. 2007. Social and ethical interactions with nano: Mapping the early literature. *NanoEthics* 1(2): 89–104.

Kulinowski, K. 2004. Nanotechnology: From "Wow" to "Yuck"? *Bulletin of Science Technology Society* 24(1): 13–20.

Lee, C.J., D.A. Scheufele, and B.V. Lewenstein. 2005. Public attitudes toward emerging technologies – Examining the interactive effects of cognitions and affect on public attitudes toward nanotechnology. *Science Communication* 27(2): 240–267.

Lloyds of London. 2007. *Nanotechnology, recent developments, risks and opportunities.* London: Lloyds Emerging Risks Team Report.

Lux Research. 2008. *The nanotech report: Investment overview and market research for nanotechnology*, 5th ed. New York: Lux Research.

Macnaghten, P. 2004. Animals in their nature: A case study of public attitudes on animals, genetic modification and "nature". *Sociology* 38(3): 533–551.

Macnaghten, P. 2010. Researching technoscientific concerns in the making: Narrative structures, public responses and emerging nanotechnologies. *Environment and Planning A* 41: 23–37.

Macnaghten, P., M. Kearnes, and B. Wynne. 2005. Nanotechnology, governance and public deliberation: What role for the social sciences? *Science Communication* 27(2): 268–287.

Macnaghten, P., and J. Urry. 1998. *Contested natures*. London: Sage.

Macoubrie, J. 2005. *Informed public perceptions of nanotechnology and trust in government*. Washington, DC: Project on Emerging Nanotechnologies at the Woodrow Wilson International Center for Scholars.

Macoubrie, J. 2006. Nanotechnology: Public concerns, reasoning and trust in government. *Public Understanding of Science* 15(2): 221–241.

Milburn, C. 2004. Nanotechnology in the age of posthuman engineering: Science fiction as science. In *Nanoculture: Implications of the new technoscience*, ed. N. Hayles, 109–129. Bristol: Intellect Books.

Nanologue. 2007. *The future of nanotechnology: We need to talk.* ftp://ftp.cordis.europa.eu/pub/nanotechnology/docs/nanologue_scenarios_en.pdf. Accessed 9 Sept 2008.

Nature. 2003. Nanotechnology is not so scary. *Nature* 421(6921): 299.

Nordmann, A. 2004. *Converging technologies – Shaping the future of European Societies.* Report to the European Commission. http://www.ntnu.no/2020/final_report_en.pdf. Accessed 9 Sept 2008.

Opinion Leader. 2008. Report on the citizens' panel examining nanotechnologies. Opinion Leader Research: London.

Peter D Hart Research Associates. 2007. *Awareness of and attitudes toward nanotechnology and federal regulatory agencies: Project on Emerging Nanotechnologies*. Washington, DC: The Woodrow Wilson International Center for Scholars.

Project on Emerging Nanotechnologies. 2008. *An inventory of nanotechnology-based consumer products currently on the market.* http://www.nanotechproject.org/inventories/consumer/. Accessed 9 Sept 2008.

Renn, O., and M. Roco. 2007. *White paper on nanotechnology risk governance*. Geneva: International Risk Governance Council.

Roco, M.C., and W.S. Bainbridge. 2003. *Converging technologies for improving human performance: Nanotechnology, biotechnology, information technology and cognitive science*. Dordrecht: Kluwer.

Royal Commission of Environment and Pollution. 1998. *Setting environmental standards, 21st report of the royal commission on environmental pollution*. London: The Stationery Office.

Royal Society, and Royal Academy of Engineering. 2004. *Nanoscience and nanotechnologies: Opportunities and uncertainties*. London: Royal Society.

Scheufele, Dietram A., and Bruce V. Lewenstein. 2005. The public and nanotechnology: How citizens make sense of emerging technologies. *Journal of Nanoparticle Research* 7(6): 659–667.

Scheufele, Dietram A., Elizabeth A. Corley, Sharon Dunwoody, Tsung-Jen Shih, Elliott Hillback, and David H. Guston. 2007. Scientists worry about some risks more than the public. *Nature Nanotechnology* 2(12): 732–734.

Schummer, J. 2005. Reading nano: The public interest in nanotechnology as reflected in purchase patterns of books. *Public Understanding of Science* 14(2): 163–183.

Selin, C. 2007. Expectations and the emergence of nanotechnology. *Science, Technology and Human Values* 32(2): 1–25.

Smallman, Melanie, and Adam Nieman. 2006. *Discussing nanotechnologies*. London: Think-Lab.

Smith, G. 2004. Nanotechnology: Friend or foe? *Science in Parliament* 61(1): 10–11.

Stephens, Lowndes F. 2005. News narratives about nano S&T in major U.S. and non-U.S. newspapers. *Science Communication* 27(2): 175–199.

Stilgoe, J. 2007. *Nanodialogues: Experiments in public engagement with science*. London: Demos.

The Economist. 2007. A little risky business: The risk in nanotechnology. *The Economist Briefing*, November 22, 2007, 1–4.

Toumey, C. 2004. Narratives for nanotech: Anticipating public reactions to nanotechnology. *Techne* 8(2): 88–116.

Toumey, C. 2005. Apostolic succession. *Engineering and Science* 68: 16–23.

van Lente, H. 1993. *Promising technology: The dynamics of expectations in technological developments*. PhD Thesis, Twente: Universitet Twente.

van Merkerk, R., and H. van Lente. 2005. Tracing emerging irreversibilities in emerging nano-technologies: The case of nanotubes. *Technological Forecasting and Social Change* 72: 1094–1111.

Waldron, A., S. Douglas, and C. Batt. 2006. The current state of public understanding of nano-technology. *Journal of Nanoparticle Research* 8(5): 569–575.

Wilsdon, J., and R. Willis. 2004. *See-through science: Why public engagement needs to move upstream*. London: Demos.

Wood, S., R. Jones, and A. Geldart. 2003. *The social and economic challenges of nanotechnology*. Swindon: Economic and Social Research Council.

Wood, S., R. Jones, and A. Geldart. 2007. *Nanotechnology: From the science to the social*. Swindon: Economic and Social Research Council.

Wynne, B. 1980. Technology, risk, and participation: The social treatment of uncertainty. In *Society, technology and risk*, ed. J. Conrad. New York: Academic.

Wynne, B. 1992. Misunderstood misunderstandings: Social identities and the public uptake of science. *Public Understanding of Science* 1: 281–304.