The metis of responsible innovation

Helping society to get better at the conversation between today and tomorrow

Prof.dr Philip Macnaghten

Inaugural lecture upon taking the post of Personal Professor in Technology and International Development at the Knowledge, Technology and Innovation chair group at Wageningen University on 12 May 2016

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Esteemed Rector Magnificus, colleagues, family and friends

For most of my academic career I have been driven by the simple idea that the future could be otherwise (Irwin 2016). This is a shorthand for a complex set of arguments that seek to inject social agency into technological decision-making, the argument being that unless we find ways to shape science and innovation in tune with widely shared social values, future changes will occur without explicit societal shaping, commonly driven by the power of incumbent interests and the delegation of 'the good' to market forces. Thus, over the years, I have become engaged with a variety of technological domain areas – focusing predominantly on what my friend Richard Owen calls 'techno-visionary' science and innovation – exploring ways to understand the social and ethical issues associated with emerging science and technology at an upstream stage, and to develop novel frameworks of governance that can accommodate them. In pursuit of the latter I have become implicated in the development of frameworks of responsible innovation. In this inaugural lecture, using the ancient Greek idea of metis, defined as the practical skills and acquired knowledge required to respond to a constantly changing environment, I speak to the craft of doing responsible innovation, how it was put to use in devising a framework for the UK research councils and how in the context of particular technological innovations – using nanotechnology, climate geoengineering and agricultural biotechnology as cases – academic and policy understandings have to some extent been reconfigured and new directions opened up. I conclude with reflections on Wageningen as a site for collaboration on the crafting of responsible futures.

Introduction

Responsibility as a concept refers to the historical and largely 'modern' idea of people as possessing capacities for reflective action as moral agents. To act responsibly implies that to some extent we are answerable for our actions. This infers a *capacity* both to reflect upon our actions and to act upon our reflections, which implies a degree of free will or human agency (Hage and Eckersley 2012). One can act in a responsible manner either because we are acting on what we have done or failed to do in relation to the effects of our actions – what corresponds to a 'retrospective' or consequentialist framing of responsibility commonly associated with notions of accountability or liability – or where one can act with a view to the kinds of futures we collectively aspire towards – a future-oriented view of responsibility commonly characterized by notions of care and responsiveness (Pellizzoni 2004).

The governance and oversight of science has until recently been associated with a particular notion of responsibility. Since policy actors and scientists alike have invoked the project of science as emancipatory, the role responsibilities of scientists have been internally configured as that of producing reliable knowledge, typically through conforming to the so-called Mertonian norms. The beneficial impacts of science on society would be guaranteed, the argument went, through the institutional ordering of modern science according to the imperatives of communalism, universalism, disinterestedness and organized scepticism (the CUDOS principles). However, from the mid-20th century onwards, as the power of science and technology to produce both benefit and harm has become clearer – ranging from the agonising of physicists over their responsibilities towards the bomb (Weart 1976) to the increasing potential for novel technologies to generate unforeseen and potentially irreversible consequences (Beck 1992) – it has become apparent that debates concerning responsibility in science need to be broadened to extend both to their collective and to their external impacts (foreseen and unforeseen) on society.

Responsibility in science governance has historically been concerned with the 'products' of science and innovation, particularly impacts that are later found to be unacceptable or harmful to society or the environment. Recognition of the limitations of governance by market choice has led to the progressive introduction of post hoc, and often risk-based regulation, such as in the regulation of chemicals, nuclear power and genetically modified organisms. This has created a well-established division of labour where science-based regulation, framed as accountability or liability, determines the limits or boundaries of innovation, and where the articulation of socially desirable objectives – or what Rene von Schomberg describes as the 'right impacts' of science and innovation – is delegated to the market (von Schomberg 2013). For example, with genetically modified foods, the regulatory framework is concerned with an assessment of potential risks to human health and the environment rather that with whether this is the model of agriculture we collectively desire.

This consequentialist framing of responsibility is limited, because the past and present do not provide a reasonable guide to the future and because such a framework has little to offer to the social shaping of science towards socially desired futures (Adam and Groves 2011; Grinbaum and Groves 2013). With innovation, we face a dilemma of control (Collingridge 1980), in that we lack the evidence on which to govern technologies before pathologies of path dependency, technological lock-in, 'entrenchment' and closure set in. Dissatisfaction with a governance framework dependent on risk-based regulation and with the market as the core mediator has moved attention away from accountability, liability and evidence towards more future-oriented dimensions of responsibility – encapsulated by concepts of care and responsiveness – that offer greater potential for reflection on uncertainties, purposes and values that underpin scientific innovation and thus for the co-creation of responsible futures.

Such a move is deeply challenging for at least three reasons: first, because there exists few rules or guidelines to define how science and technology should be governed in relation to forward-looking and socially desirable objectives (see Hajer 2003, on the concept of the institutional void); second, because the (positive and negative) implications of science and technology are commonly a product of complex and coupled systems of innovation that rarely can be attributed to the characteristics of individual scientists (see Beck 1992, on the concept of 'organised irresponsibility'); and third, because of a still-pervasive division of labour in which scientists are held responsible for the integrity of scientific knowledge and in which society is held responsible for future impacts (Douglas 2003).

A framework of responsible innovation

it is this broad context that guided our attempt to develop a framework of responsible innovation for the UK research councils (see Owen et al. 2012; Stilgoe et al. 2013). In collaboration with my colleagues Richard Owen and Jack Stilgoe, and building on insights and an emerging literature largely drawn from Science and Technology Studies (STS), we started by offering a broad definition of responsible innovation, derived from the prospective notion of responsibility described above:

> *"Responsible innovation means taking care of the future through collective stewardship of science and innovation in the present."*
> *(Stilgoe et al. 2013: 1570)*

Our framework originates from a set of questions that public groups typically ask of scientists, or would like to see scientists ask of themselves. Based on a meta-analysis of cross-cutting public concerns articulated in 17 UK government-funded public dialogues on science and technology undertaken in an earlier project, we identified five broad thematic concerns that structured public responses: these were concerns with the purposes of emerging technology, with the trustworthiness of those involved, with whether people feel a sense of inclusion and agency, with the speed and direction of innovation, and with equity: i.e. whether it would produce fair distribution of social benefit (Macnaghten and Chilvers 2014). This typology, which appears to be broadly reflective of public concerns across a decade or so of research and across diverse domains of emerging technology (amongst our own, see Grove-White et al. 1997; Macnaghten 2004; Macnaghten and Szerszynski 2013; Macnaghten et al. 2015; Williams et al. 2015), can be seen as a general approximation of the factors that mediate concern and that surface in fairly predictable ways when people discuss the social and ethical aspects of an emerging technology. If we take these questions to represent aspects of societal concern in research and innovation, responsible innovation can be seen as a way of embedding deliberation on these within the innovation process. From this typology we derived four dimensions of responsible innovation – anticipation, inclusion, reflexivity, and responsiveness (the AIRR framework) – that provide a framework for raising, discussing and responding to such questions. The dimensions are important characteristics of a more responsible vision of innovation, which can, we argue, be heuristically helpful for decision-making on how to shape science and technology in line with societal values.

Anticipation is our first dimension. Anticipation prompts researchers and organisations to develop capacities to ask 'what if. . .?' questions , to consider contingency, what is known, what is likely, what are possible and plausible impacts. Inclusion is the second dimension, associated with the historical decline in the authority of expert, top-down policy-making and the deliberative inclusion of new voices in the governance of science and technology. Reflexivity is the third dimension defined, at the level of institutional practice, as holding a mirror up to one's own activities, commitments and assumptions, being aware of the limits of knowledge and being mindful that a particular framing of an issue may not be universally held. Responsiveness is the fourth dimension, requiring science policy institutions to develop capacities to focus questioning on the three dimensions listed above and to change shape or direction in response to them. This demands openness and leadership within policy cultures of science and innovation such that social agency in technological decision-making is empowered.

To summarise, our framework for responsible innovation starts with a prospective model of responsibility, works through four dimensions, and makes explicit the need to connect with cultures and practices of science and innovation. Since its inception our framework is being put to use by research funders and research organisations alike. Indeed, since we developed the framework in 2012, one of the UK research councils, the Engineering and Physical Science Research Council (EPSRC) has made an explicit policy commitment to it (EPSRC 2013; Owen 2014). Starting in 2013, using the alternative 'anticipate-reflect-engage-act' (AREA) formulation (see Murphy et al. 2016), EPSRC have developed policies that set out their commitments to develop and promote responsible innovation, and their expectations both for the researchers they fund and for their research organisations.

In the next part of this lecture I focus on the practice of doing responsible innovation, using previous research projects on nanotechnology, climate geoengineering and agricultural biotechnology as cases. I argue that the successful accomplishment of responsible innovation requires practical craft skills alongside formal epistemic skills, which I refer to using the ancient Greek concept of metis, following Marcel Detienne and Jean-Pierre Vernant's majestic treatment of the term in *Cunning Intelligence in Greek Culture and Society* (Detienne and Vernant 1978). According to Detienne and Vernant, metis was a permanent mental category in ancient and classical Greek thought that has been systematically marginalised by classical scholars due to the dominant legacy of the Platonic metaphysical tradition. Mythologically, Metis – the wise councillor – was Zeus' first wife who Zeus ingested so to avoid the prophesy that Metis would give birth to powerful children who would eventually overpower him. Culturally, metis came to represent the combination of wisdom, deep thought and magical cunning; an informed prudence that involves close observation, flexibility and the ability to seize the moment; an ability to foresee the unforeseeable, to be present in the world of becoming and to dominate a situation by becoming "even more supple, even more shifting, more polymorphic than the flow of time" (Detienne and Vernant 1978: 20). It is this capacity that makes possible a reversal of power and that enables the poor and the weak to dominate the big and the powerful. In his classic book *Seeing like a State*, James Scott (1998) appeals to metis as the necessary antidote to the logos and 'imperial' rationalist knowledge taken to their logical extreme in high modernist authoritarian plans that attempt to impose administrative order on nature and society, and that believe that scientific intervention can improve every aspect of human life. Metis is the practical skills and acquired intelligence that enables Odysseus to outwit the Cyclops, the fox to outwit the crow, Mark Twain's riverboat pilot to navigate the Mississippi. Metis is the skills that are needed to respond to "a constantly changing natural and human environment", "to which no formula can apply", and "which is most valuable in settings that are mutable, indeterminant (some facts are unknown), and particular" (Scott 1998: 313–316).[1]

Responsible innovation requires the cultivation of practical skills – metis – given the indeterminacies of foreseeing the future impacts of early stage science and technology, of undertaking such work with and for society, and of using such understanding to reverse existing trajectories, commonly reinforced by the power of incumbent interests. Indeed, what codified knowledge that does exist – in the form of codes of practice, indicative techniques and approaches – will need critically to be translated, extended and at times reversed if they are to be locally successful. I now turn to the metis that was enacted in each of my three research cases, focusing on the practical skills and judgement that led to the reconfiguration of academic and policy understandings and to the opening up of new research directions.

Case 1: Nanotechnology and the crafting of 'upstream' public dialogue[2]

Nanotechnology is my first case and stems from research aimed at crafting an 'upstream' public engagement methodology for emerging nanotechnologies. Following the political controversies associated with agricultural biotechnologies and their failure to command societal acceptance, the policy context for the research was to explore whether new deliberative mechanisms for interaction with the public could lead to better representation of the potential social and ethical implications of the technology, at a stage early enough to guide (or even restrict) their further development. Yet, is this possible? Are social science methodologies and conceptual approaches up to the task?

Crafting a methodology

Working with colleagues Sarah Davies and Matthew Kearnes, and building on earlier collaboration at Lancaster's Centre for the Study of Environmental Change especially with Robin Grove-White and Brian Wynne, we responded to this challenge through crafting a methodology aimed at a contextual understanding of how people develop their attitudes under conditions of unfamiliarity. For the European-funded Deepening Ethical Participation and Engagement in Emerging Nanotechnologies (DEEPEN) research project we developed a three-part methodology: an initial focus group where participants discussed their views on technology and where different

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1 *Unlike the concept – or what Aristotle calls the intellectual virtue – of phronesis, which similarly is associated with practical wisdom and experiential knowledge, metis cannot be understood in rational terms but must be approached by subtlety, indirection, even cunning.*

2 *Detailed accounts of our research on nanotechnology and narrative can be found in Davies et al. 2009; Davies and Macnaghten 2010; Macnaghten 2010; Macnaghten et al. 2010; Macnaghten et al. 2015.*

frames of nanotechnology were introduced, a reconvened focus group a few days later where people discussed what they considered to be the key issues at stake and where they worked on the presentation of these issues in the form of a sketch, and later that day a theatre session in which one focus group presented their sketch to another.

The focus groups were designed to encourage discussion of potential issues arising for nanotechnology, where the analytical task was one of examining the cultural forms and processes through which the unfamiliar was rendered familiar. Narrative was a key concept in the research, defined for our purposes as a spoken or written account of connected events that depicts the world at a level of generality that is applicable across a range of contexts, and that operates as a resource that people draw upon in everyday social interaction and discourse. Our research questions included the following: What substantially concerns people about emerging nanotechnology? What factors underpin and mediate these concerns? What narrative resources do people draw upon to make novel innovation readily sensible and meaningful? How do these emerge and solidify in guided social interaction? How and at what level and with what epistemological and ontological significance can these be codified? Can these be considered in some manner or form 'arche' or master narratives (for a more detailed account of the research design principles and of the metis deployed, see Macnaghten et al. 2015)?

Listening to the focus group dialogues, we were struck by the dilemmatic qualities of public concerns and hopes. Rarely were people either 'pro' or 'anti' a particular technology. Nor, were people responding in simple distributional terms, of evaluating the apparent benefits of the technology pitted against its harms. Rather, the way people constructed their responses, in conversation, spoke to the moral meanings of the technology, its purposes, its transformative and transgressive potential. Strikingly, as the discussions progressed, we witnessed a 'tragic' mood to inflect the ways in which participants imagined the technology to fold into the future. Variously, nanotechnology innovation, driven by capital and neoliberal logics, was seen as likely to exacerbate, inter alia, individualism and conspicuous consumption, sloth and insularity, local and global inequalities, danger and at times catastrophe, and ultimately free-will and what it means to be human. Collectively, our participants appeared to reject the key modernist Enlightenment narrative of science that imagines technology to drive inexorably forward and to bring, with appropriate governance and steering, inevitable social benefits (Davies et al. 2009).

This is not to imply that our participants did not tell positive stories about science. They did. Our focus group discussions were replete with stories about the power of scientific breakthrough, the virtues of scientific curiosity and the potential for science to ameliorate human ills. Nevertheless, people rarely expressed confidence that scientific innovation under real-world conditions and under current structures of regulation and oversight would overcome seen and unforeseen harms and ills[3]. Which begs the question: if people are not drawing on this standard modernist narrative of science, what counter-narratives are being drawn upon to structure public responses (Bamberg and Andrews 2004)? In exploring this question, the DEEPEN research identified five underpinning cultural narratives, each familiar in Western culture, which were continually enacted and re-performed in the focus group discussions (Macnaghten et al. 2015). The use of age-old narratives does not mean that these narratives are somehow static or that our participants can be represented somehow as representatives of the past. Rather, what we are saying is that past stories can be very useful in explaining an unfamiliar present and in developing a vocabulary for an imagined future, including why people feel impoverished agency in shaping technological choices and trajectories. I now describe each of these narratives in turn.

The five DEEPEN counter-narratives

The 'be careful what you wish for' narrative is the first of the DEEPEN narratives. As Dupuy recounts in his narratology of the five DEEPEN narratives, the idea that getting exactly what you wish for may lead to unforeseen disaster and catastrophe "is one of the most ancient wisdoms of the Western world and, probably, of humankind in general, as soon as it begins to reflect on the relationship between human desire and the human good" (Dupuy 2010: 155): a familiar and staple theme embedded in philosophy, folklore, literature (both adult and children), song, poetry and film. In our focus groups, participants were concerned by the ethically troubling nature of the seductive promises nanotechnology holds out. Nanotechnology-derived products and innovations may be desirable and even offer the promise of perfection, but there was a sense that getting exactly what you want may not ultimately be good for you. In the theatre sessions where participants developed theatre scripts to play out the issues associated with nanotechnologically-generated futures, each of the improvised plays presented by our focus group participants could be regarded as a modern-day morality tale, where nanotechnology came to represent a particular kind of seduction (e.g. of eternal youth, control over nature, cures for all illness, perfect bodies and other forms of 'boundless desire') and where the quest to realize these

3 *Interestingly this 'tragic' mood is not particular to nanotechnologies but is replicated in parallel research on agricultural biotechnologies (Grove-White et al. 1997; Macnaghten 2004; Macnaghten and Carro-Ripalda 2015), fracking technologies (Williams et al. 2015) and solar radiation management geoengineering technologies (Macnaghten and Szerszynski 2013).*

(false) pleasures and desires were seen to lead to unforeseen consequences and at times disaster.

Pandora's Box is the second of the DEEPEN narratives. The story of Pandora's box is a familiar one: a temptingly closed box or jar that, when opened, releases the gamut of human evils. The story has its origins in ancient Greek mythology: Pandora, the first woman, was given a huge jar that she was instructed not to open. Out of sheer curiosity, Pandora opened the lid and all the evils, miseries, diseases and illnesses that mankind previously had been spared from flew out and infected the world. In the DEEPEN dialogues, in response to especially radical and utopian claims for nanotechnology, even though such innovations were not born of evil intent, people used this narrative to explain why such intervention was likely to release unforeseen perils.

A close variant was the 'messing with nature' narrative. The idea that emerging (nano)technology has the potential to 'mess with nature' relies on the ancient idea of nature as having sacred qualities that establishes norms or order to the human world that should not be transgressed. Again, this is an ancient Greek story, linked to the Greeks' conception of the sacred: the Gods, proving to be jealous of men, sent after them the goddess of vengeance, Nemesis, who unleashed revenge upon those who succumbed to the vice of hubris: arrogance before the Gods. The 'messing with nature' narrative was used in focus group talk to help explain the potential pitfalls of a technoscientific endeavour that was seen as disruptive of natural orders and boundaries and that did not respect preordained limits or basic human values. With nanotechnology, the 'messing with nature' narrative was commonly deployed in response to the technology's promissory ambitions to extend control over the human and natural world.

The 'kept in the dark' narrative is a different kind of story. It was deployed in contexts where people feel powerlessness in the face of an emerging technology and, in particular, where they feel they have been left unaware of the technology's existence and potential. It speaks to the concept of alienation, in the modern sense of being disenfranchised from the research and development (R&D) innovation process. There exist two variants: either that emerging technology is being controlled by elite actors (governments, corporations and the media) and where lay people are intentionally being 'kept in the dark' or, alternatively, that emerging technology has its own internal dynamics and logics that influence society in ways that are largely beyond cultural or political influence. This broad narrative was used to underpin people's sensed lack of agency to emerging nanotechnology. Participants felt dependent and thus compelled to trust 'expert systems' (governments, regulators, scientists, corporate R&D and media reporting) responsible for the development and governance of nanotechnology but deeply powerless over their conduct.

Our final narrative is the 'rich get richer'. Again largely a modern story, in so far as it is premised on the ideal of social equality as a foundational element in modernity, it speaks to the potential of emerging technology to engender further injustice and inequality, both globally and locally. Ultimately, the narrative goes, promises of environmental or inclusive technology will meet the inevitable logics of neoliberal political economy, resulting only in the rich—big business and the already powerful—benefitting, while the poor or excluded are further marginalized. At a global level, this draws together concerns about a wealthy, consumer product-focused North enjoying both emerging technology and its benefits, while the global South is left behind; on a more local level, it is linked to concerns about the practicalities of ordinary people securing access to advances or consumer goods enabled by emerging technology.

Reflections on progress, policymaking and post-Enlightenment social imaginaries
So far we have explored the stories that people draw upon in responding to emerging nanotechnology. Although there were other narrative resources available for people to draw upon, the five narratives highlighted above have emerged repeatedly and consistently in public dialogues not simply on nanotechnology but also across a diversity of technological arenas – from fracking (Williams et al. 2015) to agricultural biotechnologies (Grove-White et al. 1997; Macnaghten 2004), synthetic biology (TNS-BMRB 2010) to climate engineering (Corner et al. 2013; Macnaghten and Szerszynski 2013) – suggesting they are a reasonably robust means of understanding how public attitudes to emerging technology are formed in guided social interaction.

The obvious question is why these particular narratives seem to be so central to the articulation of public responses. Why these stories, and not others and why now? Partially this can be explained by their absence from formal processes of technological appraisal, which continually limits public involvement in societal agenda setting to the role of the consumer. These narratives are called forth, in other words, by neoliberal policy logics that emphasize inevitable technological progress and associated social gains, with little public space for questioning the purposes, nature and reality of either the progress or the social effects. It is this that brings forth a set of counter-narratives which highlight the precariousness of positive social impacts from rapid technological change, and which almost inevitably end in reinforcing the tragic (inequality in 'the rich get richer'; or ecological or social disaster in 'opening Pandora's box' or 'messing with nature').

For Dupuy (2010), the five DEEPEN narratives are not independent of each other but should be grouped together into two metanarratives: one ancient, the other modern. The ancient metanarrative draws together the 'be careful what you wish for', 'Pandora's Box' and 'messing with nature' narratives. It is ancient because it explains the potential of ills and harms as the product of the transgression of norms and orders that hold a sacred or ontological quality, and where the standards of good and bad conduct transcend human affairs. By contrast, the 'kept in the dark' and the 'rich get richer' narratives are modern in that the fruits of science and technology are not put under scrutiny: it is simply that people are being excluded from decision-making processes ('kept in the dark') or that the benefits are unfairly distributed ('rich get richer'). Thus, we could suggest that the formation of public attitudes to emerging technology depends on the interplay of three master narratives: a dominant master narrative of scientific breakthroughs linked to social progress and the triumph of pure knowledge ultimately derived from the Enlightenment (Lyotard 1984); an ancient counter-narrative where the transgression of natural orders and boundaries (hubris) lead to ills and harms (nemesis); and a modern counter-narrative where publics are exploited and alienated through technology. Our analysis of the 'tragic' quality of public narratives points to a collective rejection of this master narrative of science in guaranteeing social progress, and a failure of imagination of tractable alternatives in navigating science and technology in more environmentally and socially beneficial directions.

So, how did the story end? In the European context our research findings has contributed to a greater emphasis on the value of public deliberation in the governance of new technologies, to an articulation of public concerns and hopes as being situated in the long durée of historical thought, to the institutional challenges of engaging with enduring public narratives and, possibly, to an informed prudence that may have mitigated some of the excesses associated with early utopian visions of nanotechnology's promise (for one such example, see Roco and Bainbridge 2003). Whether this narrative archaeological approach will extend to other cultures and technologies will depend, in large extent, on the collaborative intent of my friends and colleagues here at Wageningen.

Case 2: Good governance for geoengineering[4]

In this section I reflect on two encounters where craft knowledge and a degree of creative adaptability was required to help guide the responsible innovation of geoengineering research: first, to steer the discussion on whether and under what conditions, if any, field trials on solar radiation management (SRM) should proceed;

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4 Detailed accounts of our research on geoengineering, public engagement and governance can be found in Macnaghten and Owen 2011; Macnaghten and Szerszynski 2013; Stilgoe et al. 2013; Szerszynski et al. 2013.

the second, to articulate the nature and quality of public perceptions of geoengineering technologies through a reconfigured role for the social sciences.

The SPICE project

While Richard Owen, Jack Stilgoe and I were working with the UK research councils to develop the responsible innovation framework described earlier, we were presented with an opportunity to work alongside a particular science and engineering project to explore how the framework could be developed and refined through practice. The case was the Stratospheric Particle Injection for Climate Engineering (SPICE) project, devised to investigate whether the purposeful injection of large quantities of sub-micron particles into the stratosphere could mimic the cooling effects of volcanic eruptions as a possible means to mitigate global warming (SPICE 2010). The SPICE project was set up to answer three broad questions: first, what quantity of which type(s) of particle would need to be injected into the atmosphere (and where), to effectively manage the climate system? Second, how might we deliver it there? Third, what are the likely impacts associated with deployment? In response to the second question, a test was proposed of a scaled down delivery system, a 1-km high hose attached to a tethered balloon. Although the testbed would not be a geoengineering test per se – the trial would spray only a small amount of water – the testbed nevertheless constituted the UK's first field trial of a technology with geoengineering potential (Macnaghten and Owen 2011), and was as such deeply symbolic, even though this symbolism was not initially apparent to many of those involved.

Following the publication of the Royal Society's landmark geoengineering report in July 2009 (Royal Society 2009), the UK Research Councils convened a scoping workshop in October 2009 aimed at informing a programme of geoengineering research. The SPICE project was one of two projects funded from this workshop and did not include ethics or social science competency. Aware of at least some of the wider ethical and socio-political dimensions of solar radiation management, the UK research councils were sensitive to the potential for the SPICE project to be the subject of external scrutiny, particularly given that its proposed testbed moved beyond laboratory tests or simulations and thus could be defined as a "small field trial" (see SRMGI 2011, p. 26). Perhaps unsurprisingly, the SPICE project passed through the ethics procedures at the Universities concerned with little or no comment: the research did not involve human volunteers or animals and the research was unlikely to have a direct effect on the environment. Ethical codes for research tend to be based on a retrospective framing of responsibility (e.g. avoidance of harm and respect for human and animal rights) with little guidance on how research may be perceived as a symbolic act, a potential signifier of intent (in this case, the intent of using geoengineering as a plausible response to the problem of climate change). Nevertheless, given the evident sensitivities involved, the research councils decided upon an oversight review process, to help determine whether the proposed testbed should proceed.

It was at this stage that I became involved. As a member of the UK's Engineering and Physical Science Research Council's (EPSRC) Societal Issues Panel (SIP) my role was to provide advice and guidance to the executive on up-and-coming issues that had societal import. The terms of reference for the panel were loose: we were a small group of approximately eight members—made up of science and technology scholars, ethicists, governance specialists, journalists alongside societally-oriented physicists and engineers—that met three to four times a year to deliberate on matters on societal importance, with minimal formal responsibilities but with the ear of the executive. In many respects we were appointed for our skills in metis, our practical experience in both understanding and responding to societal issues and on crafting expert advice.

Following a presentation on the SPICE project in mid-2010, members of SIP voiced the opinion that the project posed a significant issue and responsibility for the Council and that they should proceed with caution. I was particularly vocal and subsequently was asked by the panel chair, Lord Robert Winston, if I would chair the oversight panel which was being set up to provide guidance on whether the proposed SPICE testbed should proceed as planned. At the same time my colleague Richard Owen and I were leading our project on responsible innovation for the research councils and we agreed to use our (at the time emerging) framework to help both the SPICE researchers and the research councils to characterise better the depth of the issues they were dealing with. More prosaically, Richard Owen became the architect — instigating a 'stage gate' review (a governance process in which funding for each phase of research and development is preceded by a decision point) and a set of criteria against which the SPICE team were asked to respond — while I ran the oversight review panel (Macnaghten and Owen 2011). Other members of the stage gate panel included a social scientist, a representative of a civil society organisation, an atmospheric scientist and an aerospace engineer.

The criteria and their implementation are described elsewhere (Owen 2014; Stilgoe et al. 2013) but are briefly summarised as follows. Criteria 1 and 2 involved consideration of direct risks, safety and regulatory compliance (e.g. for flying tethered balloons) associated with the testbed itself, for which the SPICE team were asked to submit a risk register and statement of regulatory compliance. The third criterion required the SPICE team to reflect on the project's framing and communication, asking them to develop a communication plan to allow dissemination about the nature and purpose of the testbed, and for this plan to be informed by dialogue with stakeholders. Criterion 4 asked the SPICE team to anticipate, reflect on and describe the envisaged applications of their research and the impacts (intended or otherwise) these applications may have, and to embed mechanisms to review these as more information became available in the future. It asked them to broaden their visions of application and impact, to think through other pathways to other impacts, to contextualise their work within a review of the known or potential risks and uncertainties of SRM and the questions (social, political, ethical) that might arise as the testbed is projected through to deployment. The final criterion asked the SPICE team to identify mechanisms to understand public and stakeholder views around the project and its envisaged applications and potential impacts, and the understandings, assumptions, uncertainties, framings and commitments associated with these. These criteria thus aligned to the framework for responsible innovation I have discussed earlier, asking the SPICE researchers to be anticipative, reflexive, inclusively deliberative and (ultimately) responsive.

Having defined the criteria around a framework of responsible innovation and agreed how the SPICE team, working with others, needed to respond, the oversight stage gate panel convened in June 2011 to undertake the evaluation. The panel was charged with providing a recommendation for each of the five criteria (pass, pass pending further information, fail) to the research councils who would make the final decision concerning the future of the testbed (Macnaghten and Owen 2011). The panel decided, after considerable discussion, rebuttal and debate, that the first two criteria, concerning safety, risks and regulatory compliance associated with the testbed itself, were convincingly passed, but that the other three criteria would only be passed pending further work and provision of further information. There were particular concerns regarding the quality of the communications strategy and the extent to which it had been informed by stakeholder engagement and substantive pubic dialogue, the quality of the SPICE team's reflective capacity on the testbed and whether they had sufficiently anticipated the future issues for SRM as it moved from the testbed projected through to deployment and, finally, the lack of substantive engagement with stakeholders concerning the project and its intended application(s). This was a challenging experience for all concerned that raised questions about the way the project had been set up largely as one investigating technical feasibility and environmental impacts, but not the wider social, ethical and political dimensions. Amongst these was the question of whether the project should have been funded at all.

On September 26th 2011, following a meeting with myself, Richard Owen and members of the SPICE team, the research councils decided to postpone the testbed until the pending actions had been addressed, with the intention of convening the stage gate panel again to review this six months later. On that very same day the research councils received a letter, copied to the then UK Secretary of State for Energy and Climate Change and signed by more than 50 NGOs, demanding that the project be cancelled. The NGOs saw the testbed as symbolic, sending the wrong signal to the international community, deflecting political and scientific attention from the need to curb greenhouse gas emissions (HOME 2011). There was concern that its "sole purpose is to engineer the hardware that would later allow chemicals to be injected into the stratosphere to reflect sunlight" as "a dangerous distraction from the real need: immediate and deep emissions cuts" that would "condemn future generations to continue a high-risk, planetary-scale technological intervention that is also likely to increase the risk of climate-related international conflict".

With mounting interest in the media and beyond the SPICE team began to address the outstanding criteria. It was as part of the subsequent discussions that the projects' principal investigator became aware of the existence of a patent application for the balloon-tethered hose delivery system (Davidson et al. 2011), submitted by one of the sandpit mentors just prior to the sandpit itself and including two of the SPICE project scientists as named inventors. Although an internal review conducted later by EPSRC found no evidence that research council policies on conflicts of interest had been broken, it was clear that the patent posed a significant issue for the project in terms of the nature of at least some of the participants' motivations, as well demonstrating a lack of disclosure. In May 2012, following a series of further discussions, the principal investigator of the SPICE team decided to cancel the testbed, instigating a more formal process of stakeholder engagement (Stilgoe 2015).

The role of the social sciences in public engagement research

By late 2011 (a couple of months subsequent to the initial decision to postpone the SPICE testbed but prior to the eventual cancelation) my colleague Bronislaw Szerszynski and I were becoming concerned with how the social sciences were being enrolled in public engagement research on geoengineering. In particular, we questioned the framings that underpinned the dialogue designs and whether the methodologies were sufficiently flexible to capture the full range of social dynamics likely to be associated with the deployment of the technology. To respond to this gap we requested independent funding (unrelated to my EPSRC role and involvement) directly from Durham University (where I was then employed), and within a period of six weeks were embarking on a deliberative focus group public engagement project, guided by the principles of 'upstream' public engagement (see Macnaghten et al. 2015). Seven focus groups were carried out in three UK cities (Durham, Newcastle and London) in December 2011, each with six to eight participants and lasting three hours.

Perhaps not surprisingly, notwithstanding the complexity of the topic, across all the groups, participants were able to learn about the issues, to consider and reflect on them, to become engaged, hear different perspectives, change their minds and develop their points of view. The early stages of deliberation were characterised by a complexity of positions. For some, geoengineering should be opposed completely; for others, it was an option to be explored. However, as the discussions progressed and as they were exposed to multiple frames—geoengineering as a policy response to anthropogenic climate change (the dominant policy discourse), geoengineering as a retrospective technofix (the NGO discourse), geoengineering set within the geopolitical history of weather and climate modification—people developed a clearer sense of their views and attitudes. In line with current research findings there was general concern about the uncertainties involved, about unintended effects and about the 'unnaturalness' particularly of solar radiation management techniques (such as what was being proposed in the SPICE research) and of whether the technology constituted a short-term fix rather than a genuine solution to climate change. In addition to these findings, our research highlighted the *conditionality* of people's responses since even for those who were initially supportive in principle of the technology, such support was at best reluctant and then, if only certain conditions were made.

The five conditions were: confidence in climate science as a reliable guide to policy and action; confidence in the ability of research to anticipate the side effects of solar radiation management; confidence in the ability of research to demonstrate the efficacy of solar radiation management; confidence in the political organisation and effective governance of solar radiation management; and confidence in the capacity of existing political systems to accommodate solar radiation management. Having articulated the key conditions, we then explored how realistic, tenable, feasible, likely, probable, believable the conditions were perceived to be under real world conditions. Importantly, these conditions were seen by and large as highly implausible in terms of their potential to be met. Even those participants who started from a position of conditional acceptance grew to perceive the conditions for successful and acceptable deployment as being unfeasible and implausible i.e. the more people learned about SRM technology the more sceptical they became.

So how did the story end? The SPICE testbed was postponed and later cancelled. The responsible innovation framework had provided a decision support tool that arguably helped the research councils avoid what was fast becoming a major science policy incident. The research councils learnt that in potentially controversial research there is an imperative for embedded social science and ethics competence and that there are occasions when social science research needs to prefigure technical and engineering research. The public engagement research introduced a perspective that focused on the conditionality of public acceptance and the plausibility of these conditions being realised in practice; and, perhaps most profoundly, the research introduced the question as to whether SRM is a governable object, at least within democratic political systems.

Case 3: Global lessons from GM crops[5]

My third and final case concerns the governance of agricultural biotechnology. It begins will a call issued in 2011 by the John Templeton Foundation, a US philanthropist trust dedicated to asking the 'big questions', in this case asking for innovative responses to the question as to whether 'GM crops can feed the world'. This is a timely question. With world population expected to exceed 9 billion by 2050, with hunger and chronic malnutrition still afflicting over 800 million people, with a growing demand for food globally including meat and dairy products, with the need to protect land for biodiversity and ecosystem services, and with the mounting threats associated with climate change and the likely increased scarcity of water and land, it is unsurprising that developments in the life sciences are being called upon to respond to this global challenge.

At Durham University where I was then working, I led a broad-based interdisciplinary group that decided that the question that structured the call was not the most profitable way to structure a debate around agricultural sustainability. Our inversion ran as follows: "Unless we examine why GM crops have not been universally accepted as a public good, we will fail to understand the conditions under which GM crops can help to feed the world". Our starting point thus began with local experience rather than with global imperative, with the dynamics of GM crops as understood and embedded in local practices rather than with a technology that requires optimal practices and policies to be successfully implemented. This attempt to reconfigure the debate was not merely academic. It was highly necessary given that agricultural GM crop technologies have been controversial not just in the UK and Europe but internationally.

Our second inversion was our choice of setting. The majority of scholarship on GM crops has focused on the Global North. Yet it will be in countries in the Global South more where agricultural innovation is most needed, where the bulk of food provision is expected to come from and where debates over GM technologies are likely to be

5 *Detailed accounts of our research on agricultural biotechnology and governance can be seen in Grove-White et al. 1997; and in various chapters in the edited collection, Macnaghten and Carro-Ripalda 2015: see in particular Carro-Ripalda et al. 2015; Egorava et al. 2015; Guivant and Macnaghten 2015; Macnaghten 2015a; Macnaghten 2015b.*

most intense. For this reason we choose to conduct detailed ethnographic qualitative work on farmers, scientists and publics, undertaken in collaboration with local partners—in Brazil on GM soya, in India on GM cotton and in Mexico on GM maize—engaging with the dynamics through which GM crops have been promoted, implemented and at times resisted across different scales and contexts by an inclusive array of actors.

Across the three case studies, we found that current approaches to the regulation and governance of GM crops have been dominated by risk-based assessment methodologies, the assumption being that the key criterion mediating their release should be an independent case-by-case risk assessment of their impacts on human health and the environment. One consequence of this framing is that the public debate surrounding GM crops has all too often been boiled down to one of safety: are they safe to eat, and are they safe to the environment? In relation to these questions we remain agnostic. Our argument was that we need, in addition, to ask different questions. If we are to govern GM crops in a socially and scientifically robust fashion, we need to engage with the issue within the terms of the debate as it is considered by an inclusive array of actors.

In our research Suzanna Carro-Ripalda and her team found that maize in Mexico is highly culturally resonant, deeply engrained in Mexican identity and history as well as in everyday food practices (Carro-Ripalda and Astier 2014; Carro-Ripalda et al. 2015). In such a context, protests against GM maize have come to signify the defence of Mexican culture in the face of an unwanted form of imposed neoliberal globalization. In Brazil, Julia Guivant and her team found that even though the coverage of GM crops had risen rapidly since 2005 (mostly GM soya and maize), the issue is far from settled, with little evidence of public acceptability or inclusive governance (Guivant and Macnaghten 2015). In India, Yulia Egorava and her team found that GM cotton has become a provocative symbol of foreign control and imposition, where regulatory bodies have been routinely criticized for using inadequate procedures for the approval of GM crops (Egorava et al. 2015). Overall, across each of the research sites we found that the factors responsible for the controversy over GM crops were social, cultural and institutional in nature, in each case transcending questions of technical risk (Macnaghten 2015a). Thus, not surprisingly, the technical regulatory bodies charged with approving the release of GMOs had not provided 'authoritative governance' (Hajer 2009): that is, they had not lead to decisions, developed through reasoned, open and transparent deliberation, that were seen as trustworthy and as worthy of acceptance by the broader community.

Responding to this 'institutional void' – namely, the lack of agreed structures or rules as to how technology should be governed in its 'beyond risk' dimensions – we examined whether frameworks of responsible innovation have traction in opening up new and more responsive governance options. Using the 'anticipation-inclusion-reflexivity-responsiveness' (AIRR) responsible innovation framework we examined what responsible and inclusive governance could mean in practice: what new institutional capacities are required to anticipate better the wider driving forces as well as the impacts of agricultural technologies, how to open up an inclusive debate with stakeholders and wider publics, how to develop more reflexive scientific cultures and what kinds of new governance architectures are needed that are responsive to these processes (Macnaghten 2015b). This is a new application of the framework. While frameworks of responsible innovation have been developed and deployed in relation to novel and potentially transformative technologies, inquiry has yet to address whether they offer potential to open up governance arrangements on technologies that are already relatively mature, that already hold a certain degree of path dependency, and that have already proved to be socially and politically controversial. GM crops thus represent a 'hard case'. If frameworks of responsible innovation are to prove successful in aligning innovation dynamics with societal values, they will have to demonstrate their capacities to shape existing technological trajectories, alongside those that remain 'in-the-making'.

So how does the story end? It is too early to report a definitive policy impact. How this story unfolds, particularly in relation to the need for new governance arrangements in Europe for agricultural technologies, will depend not least on future collaboration across the Wageningen nexus – equipped par excellence to lead such innovations in governance.

Helping society to improve the conversation between today and tomorrow

So does the metis of responsible innovation offer new pathways to help society to improve the conversation between today and tomorrow. I believe it does. Whether – as in the nanotechnology – it is through the articulation not just of the reasonableness of public concerns but of how they are part of the grand durée of human thought, in this case stretching all the way back to the ancient Greeks; or – as in the geoengineering case – it is as a decision support tool that can help governing institutions make important decisions in the context of high complexity and uncertainty; or – as in the GMO case – it is in opening up governance discussions with the promise of innovations that are designed to become better embedded in society. In each case the aim is not simply to characterize societal values in all their complexity but to feed such understanding back into scientific and governance processes.

There is much more that needs to be done. How can we ensure that the lessons of previous technological failures – such as GMOs – are properly learnt? How can we ensure that scientists and innovators develop capacities to enable them to anticipate future impacts and embed societal values into their research? Or perhaps more ambitiously – as demonstrated in the nanotechnology case and its insights on the pervasiveness of 'the tragic' – how can we excavate a new set of cultural resources out of which to build a positive narrative of science?

Future directions at Wageningen

I am relatively new to Wageningen. But I feel extraordinarily happy and privileged to be here as I can think of no better place, and no better institution, to develop my research and to co-construct with all of you more responsible, more inclusive, more socially just futures. In education, I have taught a course on environmental communication and responsible innovation, where students develop an communication strategy which they have to test through a focus group project, thus learning the metis of how to embed innovation in society. Next year, my colleague Sietze Vellema and I develop a new masters' level course in which we teach methods aimed at enabling innovation to become responsive to the needs of social actors. More long term, I plan to develop a minors in responsible innovation, with broad Communication, Philosophy and Technology (CPT) section-wide collaboration. Across the institution, my ambition is for responsible innovation to become a formal element of PhD training with additional bespoke courses for faculty. In all my vision is for Wageningen to become the go-to place in Europe to develop the craft skills for doing responsible innovation, particularly but not exclusively in life science applications.

There have also been already interesting developments in research. The Responsible Life-Sciences Innovations for Development in the Digital Age: Environmental Virtual Observatories for Connective Action (EVOCA) project, led out of CPT, has responsible innovation as a core underpinning conceptual framework. Indeed, a few weeks ago I had the privilege of running a 1 week course with the 11 EVOCA African PhD students, examining what responsible innovation could and should mean in relation to five cases: (1) a crop and disease management expert system in potato production in Ethiopia; (2) water monitoring and irrigation management for food production in Ghana; (3) a malaria mosquito radar as a digital citizen science platform in Rwanda; (4) tick-born disease and livestock-wildlife management in

Kenya; (5) sustainable intensification of cocoa and food crop farming systems in Ghana. The conversations were rich and insightful as the students reflected on how to embed their innovations in very particular and contingent societal contexts. To my knowledge this is the largest and most systematic attempt to apply responsible innovation in an international development context – a first for Wageningen.

I am also part of a new NWO investment, led by my colleague Vincent Blok and with Tom Long as research associate, which aims to explore the potential for integrating responsible innovation into sustainable entrepreneurship processes, with climate smart agriculture as a particular case. At the European level, I am part of a new Horizon 2020 consortium, leading the Wageningen team alongside Barbara van Mierlo and Vincent Blok, examining Wageningen University's internal responsible innovation policies and practices alongside a workpackage addressing how to develop a global conversation on responsible innovation with Brazil as a particular case. While, more locally, I am coordinating the social science (SSG) contribution of the synthetic biology strategic theme investment, working with colleagues on the project of embedding social science (and ethics) into scientific research on synthetic biology, and of crafting approaches aimed at articulating the co-evolution of the technology and ethics.

What I want to finish with goes back to the theme of metis and the imperative of helping society to get better at the conversation between today and tomorrow. The future is a troubling category not least because we live in turbulent times. With rising and apparently intractable problems of war, migration and assorted nationalisms; with the rising peril of climate change; with the growing disconnect between citizens and the political class currently leading to unpredictable outcomes; with mounting mistrust in the capacity (and motivations) of governing institutions to provide enduring solutions; and with a lack of belief in current political philosophies, including neoliberalism, and a lack of plausible alternatives; it is not surprising that people find if increasingly difficult to maintain a belief in a better future. Science is inevitably caught up in these trends. In a modest way this is the context in which responsible innovation – and with a judicious application of metis – offers a way of structuring a conversation between today and tomorrow.

Some words of thanks

I would like to give profound thanks and gratitude to Cees Leeuwis for his powers of facilitation, his wise council and his friendship. It was Cees who effectively brought not just me but my family over and without whom none of this would be possible. I would like to thank Noelle Aarts for her part in this story, her hospitality, passion and introductions. I would like to thank my colleagues in the KTI group, but also in the Philosophy and Strategic Communication group: I have enjoyed my conversations with many of you. This is a rich Section – with a creative and inspiring dynamic fast emerging – and I look forward to fruitful collaboration in the coming years.

I would also like to thank those who were particularly formative at an earlier stage: Robin Grove-White for showing me the way; the late John Urry who taught me how to be an academic; Brian Wynne who has in effect been my mentor for well over two decades. But I would also like to thank more recent friends and collaborative partners. Good ideas have always emerged out of conversations and friendship and I have been extremely fortunate in having such inspiring friends and collaborators as Richard Owen, Jack Stilgoe, Tom McLeish, Matthew Kearnes, Sarah Davies, James Wilsdon, Jason Chilvers, Alan Irwin and Barbara Adam.

But my real thanks goes to my family, to my sisters and brother including Antony who has joined me today – but especially my wife Simone, to our daughters Melina and Sophia as well as to Caio – who have uprooted their life and come to a new country, a new culture, a new (and rather odd) language. I would like to thank all of you – including our new friends in Wageningen and beyond – for making us feel at home.

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Ik heb gezegd

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Prof.dr Philip Macnaghten

'In this inaugural lecture, using the ancient Greek idea of metis, defined as the practical skills and acquired knowledge required to respond to a constantly changing environment, I speak to the craft of doing responsible innovation, how it was put to use in devising a framework for the UK research councils and how in the context of particular technological innovations – using nanotechnology, climate geoengineering and agricultural biotechnology as cases – academic and policy understandings have to some extent been reconfigured and new directions opened up.'

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