University of the
West of England
BRISTOL

OPEN SCIENCE AND PUBLIC ENGAGEMENT

EXPLORING THE POTENTIAL OF THE OPEN PARADIGM TO SUPPORT PUBLIC ENGAGEMENT WITH SCIENCE

ANN GRAND

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Faculty of Environment and Technology, University of the West of England, Bristol

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Abstract

Open science and public engagement

Exploring the potential of the open paradigm to support public engagement with science

Open science, a practice in which the entirety of a research project is made available, via the Internet, using a variety of tools and techniques, is an emerging approach to the conduct of science. The hypothesis that open science therefore has the potential to support public engagement with science has been investigated through the research outlined in this thesis. The research has also sought to address the related issues of how, or if, the science thus made available therefore needs to be translated and narrated for public consumption and how, or if, open science can or should develop as a deep and bidirectional mode of engagement between members of the public and researchers.

The research employed two methods of qualitative enquiry (interviews and case studies) and one method of quantitative enquiry (a web-based questionnaire survey) to enable appropriate validation through methodological triangulation. The interview participants, recruited through purposive sampling, took part in semi-structured interviews, which were analysed using a grounded theory approach. Three exploratory case studies were selected using a descriptive decision matrix. The case studies were conducted using a mixture of ethnographic observations of events, meetings and other situations involving personal contact, documentary studies of project websites, available materials and so on, and interviews with project members. Finally, a web-based survey was carried out to establish baseline data on the scientific and cultural background, motivations and opinions of visitors to open science project websites.

The results suggest that although the principle of openness is widely accepted, there are a number of issues to be addressed as research is opened up to a wider public. These include the development of shared praxis between researchers and members of the public, for example understanding of data analysis techniques and how to support judgements of validity and trustworthiness of information. Problems of data ownership are also foreseen, both in terms of proprietary and intellectual property rights, the maintenance of reputation, precedence and priority and in how to value non-professional and non-traditional contributions to research.

The results also indicate that open science has the credentials to claim a place in the ranks of public engagement strategies. This research indicates that open science is not yet a tightly-defined practice; as a flexible, innovative methodology, it offers a variety of routes for engagement for both scientists and members of the public. For scientists, it could be a mode for communication in which the communicative activities are part of daily scientific work. For members of the public, it could enable them to follow a project in which they are interested, offering direct access to data, publications and other research outputs. For both communities, it could support the development and sustaining of public participation in research, and enable dialogue and collaboration throughout the scientific process, from defining the research question, to research design, to experiment, to analysis.

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Chapter 1. Introduction

In 2006, for ‘seizing the reins of the global media, for founding and framing the new digital democracy, for working for nothing and beating the pros at their own game’, *Time* magazine made ‘You’ its Person of the Year (Grossman, 2006). The year 2006, the citation read, had been about ‘community and collaboration on a scale never seen before’ and about a co-operation that would ‘change the way the world changes’. Community collaboration, with the concomitant demand for open access to information, is a highly-visible cultural trend of the early twenty-first century, in which we have seen the prefix ‘open’ attached to a range of activities: government, culture, archives, research, knowledge, source code, data, democracy, science and more.

Two of the most visible of *Time*’s ‘digital democracy’ projects are the collaboratively-collated encyclopædia, *Wikipedia* and the community-written computer operating system, Linux. The principal characteristics of these and other user-created projects, which normally exist through and depend on the Internet and via freely-accessible websites, are that they are emergent,[1] are not centrally controlled, are exposed to public scrutiny and community oversight and contain freely-available information. The impetus for openness has grown alongside increases in the number of people around the world who have Internet access. In particular, the growth in the number of people using social media (OFCOM, 2008; Alexa, n.d.) has led to expectations of openness which have affected science as much as any other social activity.

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[1] ‘Emergent’ describes complex systems that arise from the interplay of many relatively simple interactions, for example the flocking of birds or the behaviour of social ant colonies.

More scientific open projects include the Open Science Project[2] (despite its wide-ranging title, this project is largely made up of researchers working in molecular and theoretical chemistry) which is ‘dedicated to writing and releasing free and Open Source software’.[3] However, the scientists, mathematicians and engineers involved in the Open Science Project clearly envision a wider community and seek to ‘encourage a collaborative environment in which science can be pursued by anyone who is inspired to discover something new about the natural world’ (Open Science Project, 2010).

A further example, myExperiment,[4] is a research project from the universities of Southampton and Manchester. The approximately 1300 members of myExperiment largely work in the field of bioinformatics. myExperiment describes its design as a ‘collaborative environment where scientists can safely publish their workflows and experiment plans, share them with groups and find those of others’ and its purpose as being to ‘enable scientists to contribute to a pool of scientific workflows, build communities and form relationships’ (myExperiment, 2011). As well as building a community, members report they have been able to use myExperiment to advance their science: ‘People claim they have done a new piece of science by making use of [workflows] in myExperiment’ (Collinson & Corbyn, 2009).

‘Open science’, which Nielsen defines as the sharing of ‘everything – data, scientific opinions, questions, ideas, folk knowledge, workflows and everything else as it happens’ (Nielsen, 2009, p. 32) is an overall description of an emerging approach to

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[2] http://www.openscience.org/blog/?page_id=44

[3] Source code is the set of instructions written by programmers that is then turned into software. The source code behind commercial software remains proprietary; programs written under Open Source agreements are distributed with their source code, which is therefore available for public modification and collaboration.

[4] http://www.myexperiment.org/

the practice of science, rather than a specific project, such as those described above. Potentially, open science allows active scientific investigations to be open to anyone to follow, analyse and contribute to. Although it is still a relatively rare protocol for scientists (Research Information Network, 2010b), as increasing numbers of people become ‘digital residents’ – individuals and groups who see the Web as a place to express opinions, form relationships, develop an identity and belong to a community (White & Le Cornu, 2011) – then the expectation that the Web will be the place where information is created and communicated can only grow.

The projects above, and other initiatives that classify themselves as open science, are, largely, designed *by* scientists *for* scientists, as effective ways to share methods, information and results with each other within the context of existing research groups and organisations. However, science performed in the open is open to anyone: to members of the public as much as to the scientists working on it. In the context of the myExperiment website, de Roure and colleagues, (2008, p. 7) noted that ‘the number of unique visitors […] is much larger than the number of registered users. This suggests that the publicly visible content on the site is of value to a wider audience’. This wider audience, potentially, is anyone who can access the information via the Internet. The experience of myExperiment is by no means unique: the existence of such a hidden group of observers and readers has been noted across a variety of websites and projects (Nielsen, 2006).

The current demand for publicly-available information is well-illustrated by the hydra-headed nature of the broadcast and published media. It seems as if no self-respecting newspaper article, television or radio programme, book or magazine item can afford to be without accompanying website, blog and links to other material or biographical matter. Information flows from publishers or programme-makers, offering consumers the opportunity to explore the wider context of the published article or programme. For example, the website of the BBC Radio 4 programme, *The Life Scientific,* (BBC, 2011) whose format is a discussion between a scientist host and a leading scientist, links to another BBC site, *Science Explorer,* which in turn links to the scientists' home pages and university websites, which in their turn offer links to newspaper articles, published papers and more. Articles on the *Guardian* website (Harvey, 2011) routinely contain links to similar articles, relevant research groups and background material, offering interested readers direct access to the science behind the published text. However, while these and similar websites do facilitate access to full journal papers, complete data files and other information, those using such facilities also routinely encounter blocked access, pay walls, non-existent websites, subscription requirements, abstracts and summaries, which inevitably creates disappointment and lowers expectations.

Science has not been able to allow itself the luxury of locking itself away behind such ivory walls for some time. Members of the public increasingly demonstrate a willingness to engage with science and science is demonstrating a willingness to engage with the public. The strategies through which the philosophy and wisdom of science have been, and are, shared between professional scientists and members of the public have changed over time, appearing under a variety of labels, such as scientific literacy, public understanding of science, scientific culture, public awareness of science, science communication and public engagement with science (Burns, et al., 2003; Bauer, et al., 2007). In particular, the trend from expert homily to mutual engagement has, it is suggested, afforded 'people with varied backgrounds and scientific expertise [the means to] articulate and contribute their perspectives, ideas, knowledge, and values in response to scientific questions or science-related controversies' (McCallie, et al., 2009, p. 12). However, although the general trajectory of exchange between scientists and members of the public has, in the UK at least, been characterised as moving from a one-way transmission of information (the 'deficit' model (see Section 2.3 below) to a multi-way dialogue, some have suggested that this move is neither complete nor irreversible (Trench, 2008b) and that moments of deficit may be found in the midst of ostensible dialogue (Davies, 2009a; Wilkinson, et al., 2011b). The strategies of engagement are highly dependent on the time, culture and attitudes of the societies in which they are practised: both discourse and understanding have evolved (Bauer, 2009).

The concept of what constitutes 'science' is notoriously difficult to define (Burns, et al., 2003). In a constantly-evolving knowledge domain, the difficulties of including every discipline into which science may be divided, for example, chemistry, geology, psychology, statistics, technology and more, have led to a search for broader and more systematic definitions. The Science for All Expert Group, in the UK, has adopted a wide-ranging definition of science that encompasses 'research and practice in the physical, biological, engineering, mathematical, health and medical, natural and social disciplines, and research in the arts and humanities' (Science for All, 2010, p. 3). Other definitions have attempted to overcome the difficulties of newly-emerging disciplines by using a description that defines the scientific method, rather than scientific knowledge. For example, science has been defined as 'an activity requiring the systematic application of principles; a study that applies objective scientific method; organised knowledge or intellectual activity' (Oxford University Press, 1993, p. 2717). This is the method used by the Science Council in its definition, eschewing disciplines and concentrating on methodology: 'Science is the pursuit of knowledge and understanding of the natural and social world following a systematic methodology based on evidence' (The Science Council, 2010).

The concept of what or who constitutes the 'public' is equally shifting in its definition. At its simplest, every person in a society is a member of the public but within this assembly are many shifting and volatile sub-groups. This flexibility and movement can be seen in endeavours to describe categories of the public. Burns and colleagues (2003) identify six sub-groups of the public: scientists, communicators, policy-makers, the general public (which has sub-groups of its own), the well-informed [about science] public and the less well-informed public. McCallie and colleagues (2009, p. 27) defined publics as including 'everyone who chooses to participate: parents, artists, students, senior citizens, scientists, or youth'. Braun and Schultz (2010, p. 408) construct four groups: the general public, the pure public (conceptualised as bringing an individual sensibility to debate, rather than being members of, for example, an interest group), the affected public (for example people affected by a medical disorder) and the partisan public (for example members of an interest group). Thus, the public has been – and continues to be – constructed in different ways, to the extent that language use has shifted from one 'public' to multiple 'publics' that form, re-form and overlap, depending on their interests, backgrounds, experiences and preoccupations.

The nexus between members of the public and science has evolved over time from the need for increased public scientific literacy, to the need for public understanding of science (PUS), to the need for public engagement with science and technology (PEST). The initial diagnosis was of a deficit in the public's knowledge of science, evidenced by the symptoms of low levels of scientific literacy and a lack of public understanding of science, both of which needed to be remedied by scientists if they were to avoid the possibility of an ignorant public offering insufficient support for science (Bauer, 2009). Bringing together scientists and members of the public in a social space could, it was hoped, effect a transformation of public literacy and understanding. However, for many scientists this space became ‘notable, even notorious, for the apparently interminable series of science-based controversies and, more threatening still, public contestation of science’ (Nowotny, et al., 2001, p. 201) and the model was gradually undermined. In the UK, for example, this destabilisation was seen in a series of debates over the regulation of genetically-modified crops and concerns over the government’s handling of the BSE crisis, and became the subject of considerable criticism (Miller, 2001; Falk, et al., 2007; Davies, 2009b).

In response, the issue of the public’s relationship with science was identified as being not so much a deficit of public understanding as a deficit of public trust in science and scientists, which could be cured by greater openness and consultation (Irwin, 2006). Where PUS saw communication of scientific understanding as flowing in one direction from scientists to members of the public, PEST offered a vision of a symmetrical, two-way flow (Miller, 2001) as scientists and members of the public were encouraged to come together to discuss issues in science and technology.

Modes of public engagement with science have taken some time to approach such equality and symmetry, if indeed they truly have. For example, in 2006, the UK Higher Education Funding Council defined public engagement as ‘the involvement of specialists listening to, developing their understanding of, and interacting with, non-specialists’. This definition offers little sense of the mutuality which is emphasised by McCallie and colleagues (2009), for whom PEST includes mutual learning by publics and by scientists, civic empowerment, awareness of the cultural relevance of science and recognition of the importance of multiple perspectives and domains of knowledge. Supporting such mutual, multiple, sustained and continuing engagement throughout the process of science calls for ‘real openness and genuine open-mindedness’ (Stilgoe and Wilsdon, 2009, p.1). Allied to this is a ‘continuing demand for more information directly from scientists’ and an associated need to ‘look for innovative ways to provide people […] with access to scientific resources and information’ (DIUS, 2008, pp. 7-8).

As a transparent, innovative, medium, open science can thus potentially claim a place in the ranks of public engagement strategies. Its point of departure from existing modes is that it can enable people beyond the research community to engage directly and in an unmediated manner with science – its data, information and methodologies – as much as with mediated opinions and ideas. An investigation as to how members of the public can, or should, engage with science through the mechanisms of open science; how, or if, the science needs to be translated and narrated for public consumption; and how, or if, open science can or should develop as a deep and bidirectional mode of engagement between members of the public and researchers is at the core of the research outlined in this thesis.

1.1 Researcher's background

For any research, it is necessary to recognise that the existing interests of the researchers involved may well influence the choices, plans and decisions made during the research. Therefore, it is important to clarify the context in which this project was designed, so that the potential of such influences can be judged against the choices ultimately made.

The basic premise of this research – that it should focus on the interface between open science and public engagement – was first established by the supervisory team. The team comprised a researcher in mobile robotics with a personal commitment to public engagement and an existing interest in open science and two researchers with interests in public engagement with science across a variety of topics (including robotics), different media and formal and informal settings. However, the detailed aims and objectives for the project, and the research plan, were determined by the author.

The author came to the project with a background in school science education and a long-term personal involvement with the café scientifique[5] movement. In science cafés, researchers and members of the public meet in informal venues to talk about topics in current science and technology; over time, this has become a well-known model for public engagement with science, providing a medium for dialogue around current issues in science and technology. However, cafes have weaknesses; for example, the engagement tends to be with a fragment of a research programme and thus lacks context. Cafes offer little opportunity for long-term engagement and, widespread as they are, nevertheless reach relatively small audiences. While it seemed to the author that open science had the potential to be a new space for

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[5] www.cafescientifique.org

dialogue, in which some of these challenges could be met, none the less, the interface between open science and public engagement presented some interesting challenges.

The author's and supervisors' backgrounds may be considered likely to have predisposed the author to set a high value on the importance of science communication and perhaps to adopt an uncritical position towards the philosophy of public engagement. To counterbalance such potential prejudices, throughout the research process the author took care to select methodologies that would reliably reduce, if not eliminate, any potential distortions arising from the inevitable biasses caused by previous experience and partialities.

1.2 Research aim and objectives

1.2.1 Aim

The aim of this research is to explore the hypothesis that open science can support public and community engagement with science.

1.2.2 Objectives

i. Through interviews, determine the views of researchers and members of the public on open science's principles, methods, values, barriers and benefits and the implications and potential of open science practice for public engagement with science.

ii. Through case studies, explore how open science principles are thus far being implemented in practice.

iii. Through an online survey, establish baseline data on the scientific and cultural background, motivations and opinions of visitors to open science project websites.

1.3 Outline

Chapter 1: Introduction

Chapter 1 discusses the factors underpinning this research, that is, (i) the social influences that support the rise of emergent, collaboratively-created, distributed projects (such as Wikipedia) and the general cultural demand for open access to information; and (ii) changes in understandings of the public, science and the public's relationship with science, from which the place of open science as a medium for public engagement with science may be derived.

Chapter 2: Literature review

Chapter 2 reviews the theoretical background to the research, considering (i) the development of the concept of communication both within and beyond the scientific community; (ii) the evolution of the practice of open science, including consideration of related issues such as open access; and (iii) the development of the relationship between science and the public, including the development of models of public engagement with science and public participation in science.

Chapter 3: Research Methods

Chapter 3 considers the methodological basis of the research: how validity is addressed, the design of the research project, the selection of data collection methods, sampling strategies, analytical approach and data management and ethical issues.

Chapter 4: Results

Chapter 4 considers the results of the research generated by the interview, case study and survey components. First, ideas arising from the interview components are discussed and collected into themes related to (i) understandings of open science; (ii) novel practices that open science can support; (iii) motivations for practising open science; (iv) difficulties of practising open science; and (v) methods and tools for open science. Second, a descriptive analysis of three case studies illustrates how different research and engineering projects are currently managing open science in an applied situation. Finally, the results of a web-based survey of members of the public visiting four websites with varying elements of open science are discussed.

Chapter 5: Discussion

Chapter 5 draws together the results discussed in Chapter 4, identifying a number of themes (see Section 5.1 below) related to the implications of using open science's inherent accessibility to extend and enhance collaboration between professional scientists and members of the public. It also considers the limitations of the research and the possibilities for future work based on issues uncovered during this research.

Chapter 6: Conclusion

Chapter 6 closes the work, offering the conclusion that open science has the potential to be a mode for public engagement with science, offering public audiences a view of active research and the outputs of research and researchers a new mode for communicating about their work. Open science can build on emerging trends in researchers and members of the public's use of social media tools and increasing expectations of the open availability of information. It also has the potential to attract new audiences to the practice of science, supporting collaboration and dialogue. However, both researchers and members of the public express concerns about open practice. Engaging in open science will mean that both researchers and public audiences will have to adapt present practices and possibly develop new skills.

1.3.1 Précis of results

A number of themes have arisen in considering the results of this research:

1 Open science is not yet a tightly-defined practice

There is considerable diversity in understandings of what ‘open science’ means, with definitions including aspects of open publication, enabling open access to results and complete transparency throughout the research process. There is a similar diversity in practice, ranging from exploiting open science as medium for simple sender-receiver communication to supporting full professional-public collaboration.

2 Open practice supports flexibility in modes for engagement

Open science can support a range of engagement modes. This flexibility both arises from, and is a consequence of, the fact that the tools and practices of open science are found in the rapidly-changing, dynamic realm of Web 2.0. This situation allows those who practise open science to make use of new tools and models as they emerge and indeed, to create their own tools. However, the degree to which material is fully accessible is noted as a problem, for example where material is held in subscription-only journals or behind pay walls.

3 Open science offers support for public participation in research

Although the principle of public participation in research is currently strongly supported, both by members of the public and scientists, evidence of existing professional-public collaboration is limited. The development of mechanisms that could support meaningful engagement, dialogue and collaboration deserves further attention.

4 *Wider participation raises concerns over the quality and quantity of information*

Methods must be found to address respondents’ concerns that non-professional participants in open science might find it difficult to cope with the quantity of data likely to emerge from some projects. Ideally, professionally-produced data would be richly contextualised, mediated and framed for public participants but there were concerns that this might necessitate extra work on the part of the researchers involved. The participation of members of the public as data gatherers and/organisers also raises concerns about the quality of the information thus provided. Although publicly-provided data can meet rigorous professional standards, this may involve adherence to strict methodologies, which might preclude deep intellectual involvement in the full process of science.

5 *Practising open science underscores the need to develop shared practices*

Practising open science in multi-site research groups requires the instigation of shared practices, agreed and pursued by all members of the group. However, the strong shared praxis of science means that these shared practices are likely to come about through the evolution of existing mores of scientific behaviour. How to extend these social systems to collaboration between professional and non-professional participants deserves further attention.

6 Open practice raises issues of ownership

Issues surrounding data ownership need to be resolved. This will involve a range of actors, including for example funders, publishers and businesses, as well as researchers. First, there may be a conflict between free availability of information and the protection and exploitation of intellectual property. Second, scientists have personal concerns regarding priority and precedence when results and data are accessible ahead of formal publication. Third, there are issues arising from varying disciplinary perspectives on information-sharing.

7 Open science may require the development of new tools and techniques

Open science has considerable potential to reveal the workings of science and scientists, as it can offer a complete record of research activity. However, for this potential to be realised, researchers may need to spend time developing the skills needed, for example to maintain an archive, a website, a blog or an open notebook. Committing time to open science may be seen as time taken away from ‘real work’ and therefore the tools and techniques used should, ideally, integrate seamlessly with day-to-day research practice. Public participants may need to be supported in developing the interpretive and analytic skills that will enable them to make effective use of the information made available by open science.

1.3.2 Publications

Conference papers:

Grand, A., Wilkinson, C., Bultitude, K., and Winfield, A. (2010). On Open Science and Public Engagement with Engineering. In: European Association for the Study of Science and Technology: Engineering Practice; performing a profession, constructing society. Trento, Italy, September 1–4 2010 (http://eprints.uwe.ac.uk/13541/)

Grand, A., Bultitude, K., Wilkinson, C. and Winfield, A. (2010) Muddying the waters or clearing the stream? Open Science as a communication medium. In: Science Communication without Frontiers: 11th International Conference on Public Communication of Science and Technology (PCST-2010). New Delhi, India, December 6–10 2010. New Delhi: INPCST (http://eprints.uwe.ac.uk/13540/)

Forthcoming:

Grand, A., Wilkinson, C., Bultitude, K., and Winfield, A. (2012) 'It feels like the right thing to do': ethical perspectives of open science. In: *Quality, honesty and beauty in science and technology communication (PCST 2012) 12th International Conference on Public Communication of Science and Technology*. Florence, Italy, April 18–20, 2012.

Grand, A., Wilkinson, C., Bultitude, K., and Winfield, A. (2012) Seeing the strangeness of science. In: *Science in Public 2012*. UCL, London, 20–21 July 2012.

In press:

Grand, A., Bultitude, K., Wilkinson, C. and Winfield, A. *Open science: a new 'trust technology'?* Submitted to *Science Communication* (Commentary, 2012)

Chapter 2. Literature Review

> Openness is arguably the great strength of the scientific method. Through open examination and critical analysis, models can be refined, improved or rejected. (Neylon & Wu, 2009, p. 540)

2.1 Introduction

Science functions because of the social manners by which scientists share models, discuss ideas and re-analyse others' data (De Roure, et al., 2008). Since the seventeenth century, when within the space of a few months, the Royal Society's *Philosophical Transactions* was first published in the UK and the *Journal des sçavans* appeared in France, 'scientists have been concerned to discourage secrecy with respect to the content of science, at least on the part of other scientists' (Hull, 1985, p. 10).

From those modest beginnings, the opportunities afforded for communication – and thus for openness among researchers – have bourgeoned. The number of journals has proliferated; the *Genamics JournalSeek* database currently lists over 23,000 titles in the fields of science, technology, engineering and mathematics (Genamics, 2011). Opportunities for personal contact through symposia, conferences and workshops have likewise grown. For example, just one database, *NatureEvents,* held information on more than 1900 events planned around the world in 2011 (Nature, 2011).

However, journals, conferences and the like are primarily media for peer to peer communication; very few members of the public attend scientific conferences or have access to learned journals. The increase in use of the Internet as a source of information and dialogue about science (IpsosMORI, 2011; National Science Foundation, 2010) and the increase in discourse using web-based tools offer scientists new modes for communication (De Roure, et al., 2008). This extends the opportunity for openness; to reach new audiences ‘beyond the borders of the scientific community’ (Suleski & Ibaraki, 2010, p. 112) who are located outside specialised scientific fields. Hess (2010) described this unofficial or emergent public, which uses alternative pathways and can arise from any social arena, as a scientific counter-public. The Internet is a tool that supports the creation of such dynamic, self-organised, shifting networks of individuals, and therefore the emergence of new counter-publics. It is also possible to imagine the Internet could support the emergence of ‘counter-scientists’; as Hess (2010) further commented, it is no longer possible to assume that scientists will be located in a physical institution, be that a university or an industrial organisation. They may be part of a civil organisation, belong to no organisation or move within a variety of situations. They might also not be professional scientists at all but emerge from a community organisation or interest group.[6]

The aspiration to attract a public audience to science can be dated to the late eighteenth and early nineteenth centuries. The impetus came from the scientific institutions: the Royal Institution, dedicated to scientific education as well as research, was founded in the UK in 1799, the British Association for the Advancement of Science followed in 1831 and the American Association for the Advancement of Science in 1848. Throughout the twentieth and twenty-first centuries, governments, media and the public, as well as scientists and scientific institutions, became involved as actors in the process of public engagement with

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[6] After the close of this research, the Royal Society has produced its report *Science as an open enterprise*. This report explicitly acknowledges the increased demand from citizens, civic groups and non-governmental organisations for the evidence that will enable them to scrutinise conclusions and participate effectively in research. The report concludes this trend has the potential to blur the professional/amateur divide and shift the social dynamics of science (Royal Society, 2012).

science. From the perception of the need for remedial education of a public deficient in scientific knowledge, to a situation in which it is assumed that it is the responsibility of all members of society to ‘discuss the issues that science raises for society’ (Poliakoff & Webb, 2007, p. 242), a multiplicity of modes for supporting public engagement with science has developed.

Scientists and members of the public can now choose to take part in a wide range of communicative activities (Mesure, 2007; Rowe & Frewer, 2005; Wilsdon & Willis, 2004; New Economics Foundation, 1999). However, while Wynne’s description of public citizen engagement as ‘something of a mirage’ (Wynne, 2005, p. 68) is perhaps a little severe, all science communication or public engagement mechanisms have limitations. For example, many require both scientist and public participants to positively choose to take part and thus necessarily exclude some in both communities. Those activities which take place through traditional media such as books, newspapers, television and radio, while they can reach large numbers, are largely one-way transactions, offering limited opportunities for feedback from the public. Face-to-face activities, although they offer greater deliberative possibilities, can, even at their greatest extent, only reach much smaller numbers.

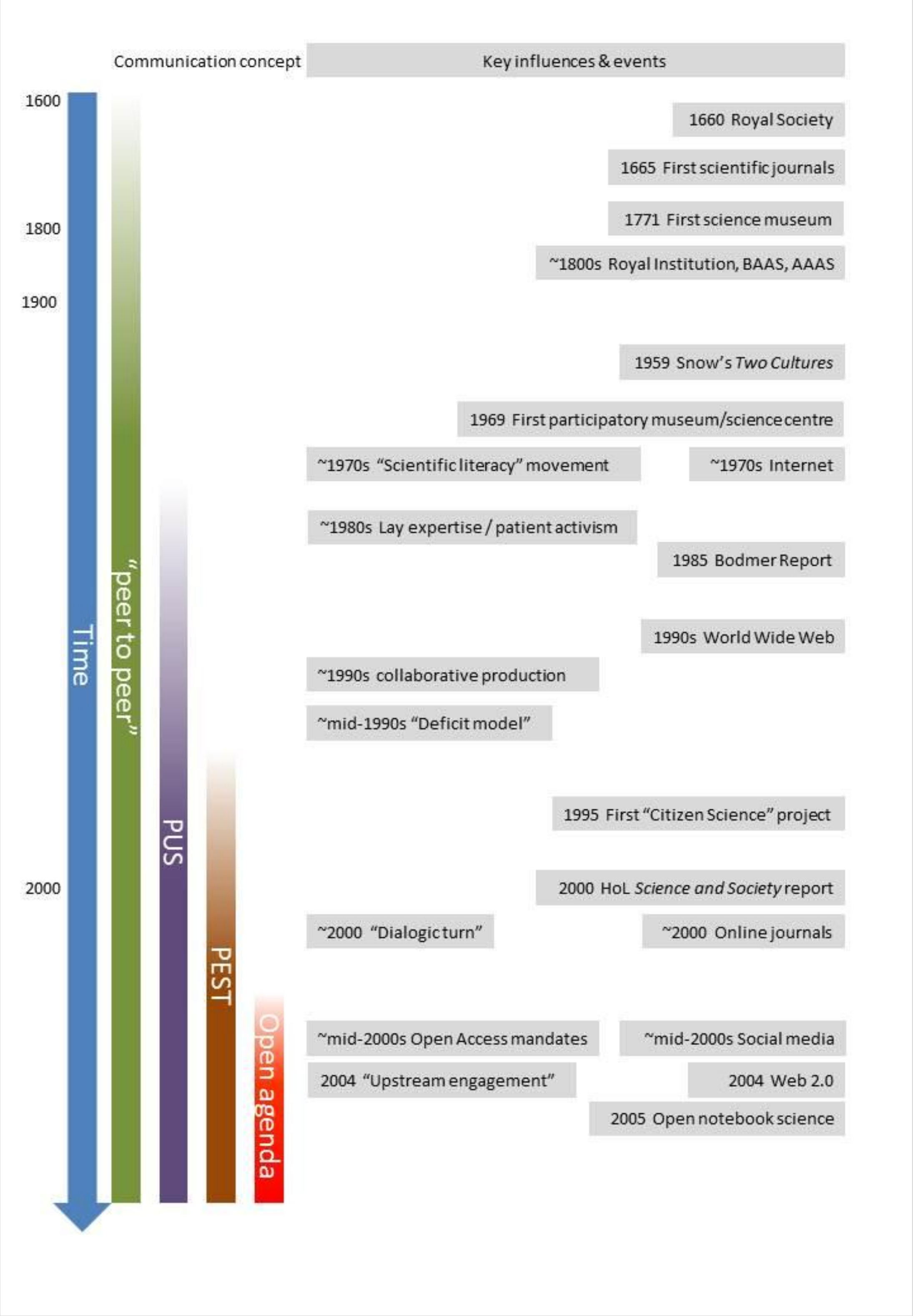
The Internet, however, has ‘made more completely porous the boundaries between professional and private communication, [facilitated] public access to previously private spaces and thus [turned] “science communication inside-out”’ (Trench, 2008a, p. 185). Open science projects exist through and depend on the Internet and are, normally, freely accessible websites, meaning they have both the potential to achieve broad access and personal exchange, not only at the end point but also throughout the scientific process. Since such research projects conducted under open science principles are predicated on direct, unmediated access, open science has the potential to reveal the previously private spaces of science, with few technological constraints to preclude members of the public from being among those who view and interact with what lies within.

2.2 The evolution of open science

> From the beginning, a tension existed between the need for scientists to cooperate and their desire to gain personal recognition for their achievements. Many scientists, Newton included, were loath to convey news of their discoveries to the Royal Society for fear that someone else would claim priority, a fear that was frequently realized. (Hull, 1985, p. 7).

The early practitioners of what we would now call science were certainly not renowned for openness (Hull, 1985; McMullin, 1985). Hooke encoded his eponymous law in an anagram that remained secret until he was ready to disclose his findings and Newton left a 38-year gap between his conception of calculus and full publication. Secrecy was held to be essential, whether for mystical reasons, to protect special knowledge from defilement, or to safeguard remunerative skills and information (McMullin, 1985). These notions were current from the Middle Ages until the seventeenth century, when Baconian ideas of the selfless pursuit of truth gave way to pragmatism, and academicians began to demand recognition for their work. From that time, changes in the nature of information sources and communication tools, and evolving constructions of the understanding of audiences and participants have formed the substrate in which open science has evolved. Some of the key influences in this evolution are shown in Figure 1.

Figure 1 Key influences and events in the evolution of open science



The dilemma between secrecy and promulgation was partially resolved when, beginning in the seventeenth century, the learned societies devised protective systems: deposition in temporary secrecy to establish priority, peer review, and corroboration, which allowed scientists to make a discovery privately but be recognised as the progenitor of the work as it was disseminated. These principles, in many ways, remain current in all academic disciplines, not just the sciences: submission of novel work to a journal, anonymous peer-review, validation by publication and dissemination by journal distribution. This system both allowed researchers to be recognised as originators of work contributed to the common store and other researchers to use and acknowledge that contribution. Thus, the protocols of modern science, its etiquette of priority, publication and citation, are based in the concepts of trust and civility current in seventeenth and eighteenth-century England (Shapin, 1994).

However, for all the community’s civility and shared understanding, until the 1990s, the costs of accessing science outputs (for example journal subscriptions) and the slowness of communication methods ensured science mostly remained the privilege of the few. With the development of the Internet, from about 1972, and particularly the mechanisms of the World Wide Web, from about 1990 (Liener, et al., 2011), new modes of co-operation and dissemination became available to scientists. Email, and easily-transmittable document formats such as PDF, replaced personal letters and offprints as a diffusion mode and medium of scholarly communication:

> Ten years ago [late 1990s] scholars and scientists did almost all their reading from paper journal issues, obtained as personal copies, circulating inside their organisations, or by retrieving the issues from library archives. Today the predominating mode is to download a digital copy and either read it directly off the screen or as a printout. (Björk, et al., 2010, p. 1)

The Internet also made new ways of working possible. Instead of the workroom of 'popular mythology [in which] science is a lonely activity, undertaken by eccentric boffins in dark laboratories late at night' (Leadbeater, 2009, p. 154), the laboratory could become a 'collabatory' in which researchers could work together, through the exploitation of software that enabled them to 'use remote libraries, collaborate with remote colleagues, interact with remote instruments, analyze data and test models' (Wulf, 1993, p. 854). However, Wulf made it clear that, at that time, scientists still had much to learn not only about how to use information technology to best effect but also about how to support such new methods of collaboration, not least in interdisciplinary work.

One of the first substantial mentions of 'open science' in the research literature occurred in a special edition of *Science, Technology and Human Values* in 1985. However, focussing on secrecy in university research and whether traditional concepts of openness are changing (La Follette, 1985), it is clear that the contributors are concerned with 'open' in the general sense of 'unrestricted, unconcealed or being in public knowledge' (Oxford University Press, 1993, p. 2003), rather than in the sense of a research protocol. Since the 1990s, web-based technologies have created tools that enable the researchers who choose to use them to move from a climate of secrecy and restriction and 'an obsessive focus on priority and publication, toward the kind of openness and community that were supposed to be the hallmark of science in the first place' (Waldrop, 2008a, p. 5). These changes of paradigm underpin scientists' characterisations of the value of openness.

However, the literature specifically relating to open science and its relationship with public engagement is limited. Nielsen's (2009) definition (see Chapter 1) was probably the first to consider open science as a process and even his definition chiefly concerns how and what information might be shared, not with whom it might be shared. Other early papers (see for example Willinsky, 2005) consider open science through an economic lens, as (largely) do Cribb and Sari (2010), while community authored reports and websites tend to concentrate on open access to data. For example, the Open Knowledge Foundation's *Panton Principles* began with the premise that:

> For science to effectively function, and for society to reap the full benefits from scientific endeavours, it is crucial that science data be made open [permitting] any user to download, copy, analyse, re-process, pass them to software or use them for any other purpose without financial, legal, or technical barriers (Murray-Rust, et al., n.d.)

The collaboratively-edited Science Commons' *Principles for open science* likewise stressed four elements as essential to open science: open access to research literature, open access to the research tools used, open access to the research data and an open cyber-infrastructure (Science Commons, n.d.). To these elements, Fry, Schroeder and den Besten (2009) add unrestricted access to tools and resources, free-of-charge tools and the adherence to non-exclusionary (open) standards.

For some scientists, however, the new techniques and tools made possible by the Internet force 'a tortured openness' (Lloyd, 2008, p. 1). It is clear that:

> … open science does not please everyone. Critics have argued that while it benefits those at either end of the scientific chain – the well-established or the outsiders who have nothing to lose – [...] it is throwing out some of the most important elements of science and making deep, long-term research more difficult (Johnson, 2011, p. 1).

Further, transparency brings its own difficulties: more information may create grounds for criticism and concern; increasing rather than lessening controversy; more discussion, through analysis of positions, may lead to the breaking down of debate rather than effective deliberation (Jasanoff, 2003; Irwin, 2006). There is evidence that some researchers ‘regard blogs, wikis and other novel forms of communication as a waste of time or even dangerous’ (Research Information Network, 2010b, p. 5). Further, some scientists see risks in placing unreviewed, unmediated data in public view and therefore open to speculation:

> [There are] dangers from […] mixing of contexts for discussions among experts and pedagogical discussions with lay people; weakening of the roles of accreditation, reputation and authorship in disciplining scientific discourse. (Smolin, 2008)

However, Internet-based tools have the potential to support greater co-operation and symbiosis in research by allowing the sharing of a much greater range of evidences, across more of the scientific process, than is possible via traditional publication. Data and methodology, as well as arguments and conclusions, can readily be made available online, with relatively low barriers to access. Using such tools can be an effective way for research groups – often sizeable and multi-national networks – to share methods, information and results and allow new ideas to emerge: ‘the traditional journal club can now span continents, and the smallest details of what is happening in a laboratory can be shared’ (Neylon & Wu, 2009, p. 540).

2.2.1 Open information

> Demands for openness and access to data are, like it or not, indicative of a transformation in the way science has to be conducted in the twenty-first century (Russell, 2010, p. 15).

In the late twentieth and early twenty-first centuries, both the tools used and the nature of the problems addressed by science require increasing levels of collaboration among participants. Leadbeater (2009, p. 155), demarcated the issue thus: ‘Karl Popper distinguished between problems that are like clocks – complicated but soluble – and problems that resemble clouds – diffuse and complex. Science is increasingly about clouds’. To see through the clouds, information-sharing among scientists has long been considered critical to scientific progress; indeed, to be a quality that distinguishes scientific effort from work in other areas (Lakhani, et al., 2007). Open science extends sharing to wider groups of collaborators. To further their work, researchers may choose not only to share information with their immediate colleagues but also with fellow-researchers beyond their research groups (Brumfiel, 2011). Taking sharing into a further community, scientists and their funders have recognised the importance of ensuring that the outputs of ‘publicly-funded science should flow into an open infrastructure that supports and encourages reconfiguration and integration and use by both professional researchers and the taxpaying public’ (Research Information Network, 2010b, p. 30).

As Overbye (2010) argued, the fate of such publicly-available data, ‘who owns it and who gets to see it, and when, has become one of the more contentious issues in science’. Open access to information and open collaboration challenge the creed that successful development requires control of ideas, knowledge and data and the asserting of intellectual property rights. This belief held current through most of the twentieth century and led to the creation of large government and private company research laboratories (Wilbanks & Wilbanks, 2010). In contrast, collaborative production, as Shirky (2008, p. 109) suggested, allows large, often widely-dispersed alliances to take ‘advantage of nonfinancial motivations [and] wildly differing levels of contribution’ (although it must be acknowledged that Shirky was not discussing scientific research). The open source (for example the Linux operating system) and collaborative creation movements (such as the online encyclopaedia, *Wikipedia*), are exemplars of co-operative innovation and product development, which use the unpaid labour of a multiplicity of producers. While there are unresolved questions around the use of unpaid contributions and thus the skewing of competition, Langlois and Elmer (2009) argued that it must be recognised that this user-produced content is an important component of the digital information economy, without which it would be unable to function; open source is not different from capitalism, rather, an evolution of it.

Cribb and Sari (2010, p. 13) argued that such democratisation of science, through open information-sharing and collaborative production, was as desirable from a scientific as from a societal viewpoint: ‘the community can bring to science many ideas and perspectives that will result in the science being more widely accepted, rapidly adopted or commercialised, and of greater value to more people’. However, achieving acceptable levels of openness and ‘outside’ engagement in scientific problem-solving may be a significant challenge. Organisations have understandable fears of revealing proprietary information and procedures, and institutions value their community norms, such as ‘priority, grants, prizes and tenure, which typically reward individual or small team accomplishments’ (Lakhani, et al., 2007, p. 13); systems which make no mention of non-traditional participants or contributions.

How to value non-traditional contributions to science is thus an emerging problem for universities and other organisations and for national assessment, recognition and reward systems. For example, funding bodies acknowledge there is a need to develop ways to recognise ‘the intellectual contributions of researchers who generate, preserve and share key research datasets’ (EPSRC, 2011, p. iii). Open source communities could help to provide a system of accreditation that could work alongside traditional academic systems (Bruns, 2009) to ‘remove disincentives and take proper account of the various new ways in which researchers can communicate and share the results of their work’ (Research Information Network, 2010b, p. 53).

At present, there is no generally-recognised method for measuring reputation or assessing the trustworthiness of information on websites. The anonymity and unregulated nature of most open systems means that traditional methods for assigning trust – such as knowing that the source of the information is controlled or that the information has been scrutinised by professional editors or similar filterers (Keen, 2008) – are not available. This, and the sheer quantity of information about science available on the web, can make it difficult for high-quality, rigorously-written sites to differentiate themselves from sites of lower quality and less thorough production.

Commercial systems, such as those implemented on shopping websites like eBay (www.ebay.co.uk) and Amazon (www.amazon.co.uk) ask buyers and sellers to rate the quality of a transaction from their point of view. Such collaborative filtering makes assessments of trustworthiness or reliability into a group task, as users pool their judgements and experiences (Metzger, 2007). The status thus built up can be referred to by subsequent users and may affect their willingness to carry on with a transaction with a particular buyer or seller.

Open and unregulated systems, such as Wikipedia, oblige their readers to make judgements of articles' quality. Adler and colleagues (2007) proposed a system, WikiTrust, to calculate quantitative values of trust for Wikipedia articles, combining the revision history of an article with information regarding the authors' reputation, to provide an indication of the text's reliability. The system codes the level of trust by using varying shades of background colouring of the text (WikiTrust, n.d.); the more intense the colour, the lower the reputation of the text. However, systems such as these both require positive action on the part of the user and may also affect the usability of the system being assessed. For example, Lucassen & Schragen (2011) noted that although WikiTrust influenced perceived trustworthiness, the effect of the colouring on readability considerably affected usability.

Reputation-based social notions of trust are an alternative paradigm. For example, i-Spot, a wildlife identification website, aims to recognise the developing reputation and expertise of its membership. It does this by combining 'social points', gained by using the website – for example posting comments and making observations – with 'identification points', gained for accurate identifications. Identification points are gradually weighted as users' accuracy increases, although accredited (through formal qualifications or positions) 'expert' users are granted high reputations. An expert's confirmation of an identification made by a user lower down the points hierarchy boosts that user's reputation (Clow & Makriyannis, 2011). MathOverflow, a community wiki on which members pose and answer high-level mathematics questions, operates a similar system, in which members earn reputation points if other members vote their questions or answers to be high-quality or helpful. Members can also lose points if their questions or answers are voted to be irrelevant or incorrect (MathOverflow, n.d.).

Such reputation management systems essentially replicate how trust relationships operate in real-world settings in which trust is ‘an emergent property of social relationships that are built up over time’ (Lipworth, et al., 2011, p. 804) and one’s opinion of a person’s (or a website’s) reputation may be based on a mix of informal, ‘friend of a friend’ information and the use of externally-validated qualifications (such as authors’ and publishers’ credentials, source references, funding information and organisational information) as cues to the credibility of a source and therefore the veracity of the messages (Metzger, 2007; Golbeck & Hendler, 2004; Treise, et al., 2003).

As Shulenburger (2009) noted, the outputs of publicly-funded research might be considered to be public goods and this may be the factor that ultimately ordains their public accessibility. Fortunately, this does not mean that their value is thereby reduced:

> Public goods have the characteristic that use of them by one individual does not diminish their value to others. In fact, the knowledge presented through scholarship generally becomes more valuable as it is shared more widely and becomes a building block upon which further scientific advances may occur. (Shulenburger, 2009, p. 5)

Such sharing – perhaps with limits to protect intellectual property or precedence – could both feed into the community norms that enhance the reputations of researchers and universities, and allow them to demonstrate their research productivity to tax-payers and other funders: ‘a great deal of our research is funded by public tax dollars ... although most taxpayers won’t have much interest in reading our papers or running our code, they ought to have the opportunity’ (Pedersen, 2008, p. 465). The increase in the numbers of university open access repositories is an example of this trend (see Section 2.2.2 below). There are also examples of scientific data sharing within restricted communities: for example, the Alzheimer’s Disease Neuroimaging Initiative[7] makes data available to the ‘general scientific community’ (Jack, et al., 2008, p. 685), although it requires users to register, so some boundaries remain.

2.2.2 Open access

> It is a sobering fact that some 90% of papers that have been published in academic journals are never cited. Indeed, as many as 50% of papers are never read by anyone other than their authors, referees and journal editors. (Meho, 2007, p. 32)

The mere existence of information cannot transform societies; for that, it must be accessed, shared and used (Gurstein, 2011). While Meho’s figures (above) are calculated in the context of citation studies, if they are realistic, and around half of papers are barely read, this constitutes a considerable waste of resources between the production and assembly and the dissemination, synthesis and exploitation of knowledge.

Improved access to scientific resources could serve many communities: researchers, educators, students, clinicians, patients, businesses and the public. For example, Houghton, Rasmussen and Sheehan (2010) judged that over a 30-year period following the implementation of an open access mandate, the potential economic benefits could be worth between four and 24 times the cost of the basic research, depending on the archiving model used. Researchers in low-income countries are among those who can find it especially difficult to gain access to information. This is recognised by the existence of programmes set up to facilitate such access. For

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[7] http://adni.loni.ucla.edu

example, the World Health Organization's HINARI programme offers funding to improve online access in low-income countries (WHO, 2011). While it may be impossible precisely to identify an absolute connection between lack of access to information and good-quality research, 'access to timely, relevant, high-quality scientific information represents a substantial gain for researchers, students, teachers and policy-makers in low-income countries' (Aronson, 2010, p. 968). Access to relevant research information can be just as problematic for commercial businesses, even in developed countries. Ware (2009) assessed information-use patterns and access to professional and academic information within large companies, small and medium-sized enterprises (SME), universities and colleges in the UK. Overall, only 28% of small and medium-sized enterprises described access to research articles as good or excellent, compared to 46% of large companies and 72% of universities, while 55% of SME respondents had experienced difficulty accessing research articles, compared to 34% in large companies and 24% in universities. Although enterprises made use of a wide range of access channels – including public libraries, subscriptions, open access journals and institutional repositories – the most-reported impediment to access was payment barriers. Access by paying for individual articles was infrequently used and unpopular; users perceived pay-per-view costs as high. This is likely to be an even greater consideration for researchers in low-income countries.

The move towards open access to research information began in the early 1990s (Laakso, et al., 2011). At present, around 120,000 articles are published each year in fully open access or hybrid (or delayed) model journals,[8] spread reasonably evenly

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[8] A hybrid-model journal may charge an author or their institution a supplementary fee, in return for which they make that paper open to all readers, regardless of whether or not they are subscribers (Weber, 2009). Alternatively, subscription journals may subject papers to a period of restricted

across disciplines (Dallmeier-Tiessen, et al., 2010). The Budapest Open Access Initiative (a multi-national project, despite its title) stated that although there are ‘many degrees and kinds of wider and easier access’, open access could broadly be understood as:

> ... permitting any users to read, download, copy, distribute, print, search, or link to the full texts of these articles, crawl them for indexing, pass them as data to software, or use them for any other lawful purpose, without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself (Suber, 2004).

Two commonly-described routes for open access exist: the ‘gold route’ and the ‘green route’ (Harnad, et al., 2008). On the gold route, articles are made freely available in an open-access journal. Publication costs are met by a mix of author-side fees, grants, membership fees and the use of volunteer labour (ALPSP, 2005). However, the free access sometimes has caveats: as noted above, availability may be partial or hybrid, or subject to varying lengths of embargo. Bjőrk and colleagues (2010) estimated that approximately 8.5% of all scholarly content for 2008 was available through some form of gold open access.

For researchers who wish, or are asked, to take the gold route, the number of open-access journals is increasing: Laakso and colleagues (2011) found that the number grew at about 15% per year between 1993 and 2009. This considerable growth should be compared with the general growth in journal numbers: Ware and Mabe (2009) calculated that the number of scientific and technological journals of all types grew by approximately 3.5% per year from the 1800s to the present day.

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availability then release them as open access after that time. This model constitutes approximately 14% of open access journals (Björk, et al., 2010).

Green open access relies on authors themselves archiving, in publicly-available repositories, work that they have already published by traditional means. Universities, with their ‘capacity for creating and transmitting knowledge’ (Hart, et al., 2009, p. 19) are well-placed to be gate-openers for public access to university-created knowledge, to the benefit of the universities’ research visibility, as well as improved access both for the wider research community and the public (Lawson, 2011). In 2010, there were 1640 institutional open access repositories world-wide: 195 are in the UK, 715 in other European countries and 451 in North America (OpenDOAR, 2010).[9] However, other methods for self-archiving are also used, such as subject repositories (for example the particle physics repository, ArXiv,[10] or the medical repository PubMedCentral[11]) and authors’ personal websites.

To meet the costs of publication, in the traditional, subscriber-pays, model, journals are paid for by readers, libraries and institutions, often through annual subscription or licence but occasionally through one-off payments or fees for specific articles (Wellcome Trust, 2004). This is costly: ‘in Britain, 65% of the money spent on content in academic libraries goes on journals, up from a little more than half ten years ago’ (The Economist, 2011, p. 70). In return for subscriptions, subscribers (or their employees in the case of institutions and businesses) receive unlimited access to the print and/or online editions of the journal. There are few extra publication fees levied on individual authors and peer-reviewers’ services are usually given gratis. Subscriptions can also cover the supply of offprints, the free provision of articles through (sometimes deferred) open access publication and additional ‘value-added’

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[9] For comparison, there are 280 universities or higher education institutions in the UK (Universities UK, 2012) and approximately 2235 in the USA (University of Texas, Austin, 2012)

[10] http://arxiv.org/

[11] http://www.ncbi.nlm.nih.gov/pmc/

editorial content, such as letters, reviews and editorials (Wellcome Trust, 2004). Non-subscribers can often only obtain articles by paying a per-article, often time-constrained fee, for example US$32 for an article in *Nature* (Nature, 2011), US$25 for one day's access to a paper in *Science Communication* (Sage, 2011) or US$15 for one day's access to a research report in *Science* (Science, 2011).

In contrast, payment for gold open access is 'author-side'; that is, authors (or their employer or funder) are charged a one-off fee for publication. Subsequent online access to the published journal is free to everyone, including members of the public. Author-side charges vary considerably among journals in when they are made, on what they are based and their absolute cost. In 2004, just over half of journals in the DOAJ 'did not charge author-side fees of any type, whereas more than 75% of ALPSP, AAMC, and HW[12] journals did' (ALPSP, 2005, p. 44). Even for DOAJ journals, only just over 30% of their income came from author-side fees (ALPSP, 2005). Where fees are charged, there seems to be a degree of convergence: for example, in 2011-12, PLoS ONE (n.d.) and Nature: Scientific Reports (2011b) both charged US$1350 per article, although they also offered discounts and fee waivers under certain circumstances.

The attitudes of research funders and governments to open access are changing rapidly. In the UK, the House of Commons Science and Technology Committee (2004) concluded that institutional repositories represented a low-cost way to enhance access to scientific publications. The report suggested that not only should all UK higher education institutions establish free, online, repositories but also that

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[12] DOAJ – Directory of Open Access Journals; ALPSP - The Association of Learned and Professional Society Publishers; AAMC – Association of American Medical Colleges; HW – High Wire Press (Stamford University Press).

publicly-funded researchers should be required to deposit a copy of all their publications in such a repository.

Funders took time to formulate their responses to this recommendation. In 2009, Corbyn noted that funders' policies varied; while the Medical Research Council compelled deposition of all papers in the PubMed repository, the Engineering and Physical Sciences Research Council (EPSRC) imposed no requirements (Corbyn, 2009). However in 2010, EPSRC resolved to mandate open access publication, requiring authors to ensure that 'all published research articles arising from EPSRC-sponsored research, and which are submitted for publication on or after 1st September 2011, must become available on an Open Access basis through any appropriate route' (EPSRC, n.d.). EPSRC's statement offered no comment on which routes it considered appropriate, although it included a commitment to the principles of an earlier statement from Research Councils UK, which likewise made no judgement as to the most appropriate model but affirmed that it was for authors to choose where to place their papers (Research Councils UK, 2006). The Wellcome Trust – a private charitable funder – has also mandated that all papers from work it funds should be made freely available on the Internet (Poynder, 2008). Similarly, the European Union mandated in 2008 that peer-reviewed research articles arising from projects funded by the Seventh Research Framework Programme (FP7) should be deposited in open access repositories (OpenAIRE, 2011).

Mandates such as these will increase the probability of more publications becoming readily available to scientific and public audiences. However, a number of difficulties remain. First, there is the issue of copyright: in the sciences, copyright in a published article is generally assigned to the publisher, which concerns some authors intending to self-archive, fearing they may infringe the publishers' conditions. This fear can be compounded for researchers who work in multi-national groups, where regulations may differ from one country to another. However, many journals permit self-archiving of ‘post-prints’,[13] which enables authors to deposit legally (Swan, 2008) and university repositories are beginning to provide help and support for researchers to negotiate the complexities of copyright (UWE, 2011; Open University, 2009).

Second, self-archiving can mean material lies in many places, in many formats, fragmented and variously recorded, making sustained and consistent searching difficult without prior knowledge. This is a problem likely only to increase as self-archiving is encouraged (see for example EPSRC, n.d.) and becomes more common.

Third, there are the difficulties of ensuring that researchers comply with the mandate: green open access is, by its nature, dependent on researchers’ willingness – and willingness to use their time – to populate the archives. Poynder (2008) suggested that researchers’ difficulties in depositing material were possibly the ‘greatest obstacle to filling institutional repositories […] even now, only 15% of the records in ORO [the Open University’s research repository] are full-text’. In 2009, only 43% of Wellcome Trust-funded researchers had deposited their work as required, and just 20% of the work funded by the EU Framework 7 programme was open access (Corbyn & Reisz, 2009), despite the existence of the mandate referred to above.

Researchers’ disinclination to self-archive may be philosophical as much as practical; they may simply not agree with the principle of open access (Lawson, 2011). Deposition is also more expected and encouraged in some disciplines than

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[13] The post-peer review but pre-publication version of a paper; that is, a product very close to the final published article.

others: some subject-specific archives in the physical sciences have high deposition rates, as do some medical archives, although some medical researchers have expressed concerns about how to retain patients' confidentiality in deposited datasets (Nelson, 2009).

Finally, there is impact: researchers want to 'publish their findings in order to ensure widespread dissemination of their work, primarily within a community of their peers, where it will be discussed, assessed and built upon' (House of Commons Science and Technology Committee, 2004, p. 9). For scientists, 'journal quality and impact factor is most important when deciding where to submit' (Vogel, 2011, p. 273).[14] However, scientists' perception of impact is almost as important as a journal's actual impact factor: the SOAP[15] project found that 30% of its respondents cited a lack of high-quality open access journals in their field as a reason not to publish in such journals (Dallmeier-Tiessen, et al., 2010), even though some open access journals have high impact factors (Kais, 2010).

It has been argued that open access affords researchers an impact advantage. Piwowar, Day and Fridsma (2007) showed that clinical cancer trials which shared their data were cited about 70% more frequently than trials which did not. However, this advantage is disputed: Eysenbach offered the alternative explanation that:

> ... important (high-citation) articles are more likely to be posted online by authors or users as a result of the articles' importance, or because authors post them on their homepages because they get so many requests from peers. (Eysenbach, 2006, p. 0692)

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[14] Impact factor is a calculation based on how many times the 'average article' in a journal is cited by other researchers within a given time (Thomson Reuters, 2012). It thus acts as a proxy for a journal's importance in its field.

[15] Study of Open Access Publishing (http://project-soap.eu/)

In other words, Eysenbach suggested, papers are found online because they are highly cited, rather than being highly cited because they are online.

2.2.3 Peer review and openness

While some open access journals are highly regarded by their community, and have high impact factors, only about two-thirds of open access journals are peer-reviewed (Kais, 2010). Most reputable journals (both open access and traditional) subject submitted texts to peer review; that is, the text is critically scrutinised (usually anonymously) by researchers working at a similar or higher level in the same research area, who are in a position to comment on, for example, the significance and originality of the research. Overall, authors are content with the peer review system, with the majority believing their work is improved by the process (Nature, 2006a). Similarly, peer review is trusted by both producers and consumers and considered as having practical utility as a means of selecting good-quality work: '[it is] a central aspect of scholarly communication [paving] the way towards the reproducibility that forms one of the foundations of modern science' (Morris & Mietchen, 2010, p. 3). However, it is acknowledged that the work involved in reading, reviewing, checking and commenting for peer review places burdens on researchers, even as this burden is also understood to be an 'integral part of the scientific and research process' (House of Commons Science and Technology Committee, 2011, p. 153).

Bornmann and Daniel (2010) conducted a utility analysis of peer review in one journal, *Angewandte Chemie International Edition*. Taking citation count in subsequent papers as their measure, they showed that between 65% and 78% of submissions were correctly accepted, returning higher citation counts than rejected texts that were subsequently published elsewhere. This analysis offered support for the system of peer review, although two points should be noted: first, citation counting as a measure of success is open to errors such as reciprocal citing by colleagues, double-counting of researchers with the same name, researchers changing their name, mis-spelling of names, deliberate self-citation and ceremonial citation[16] (Meho, 2007). Second, citation counting ignores the possibility that papers in reputable journals may have higher counts simply because they are in those journals; in other words, that researchers will tend to turn first to the leading journals in their field. Other measures of success, such as download counts and Hirsch's *h*-index, have been devised, to try to counteract the difficulties of citation-counting measures. Download counts, for example, mean the impact of an article can be measured immediately following publication, while the *h*-index quantifies a scientist's individual impact (Meho, 2007).

Whatever measure is used, peer review of journal articles enjoys the reputation of underpinning the trust among authors, editors and reviewers (Nature, 2006b) and users. For scientists, peer review acts as an 'invisible hand ... exerting [a] civilising influence to maintain quality' (Harnad, 2000) and is the 'key means to ensure that only high-quality research is funded, published and appropriately rewarded' (Research Information Network, 2010a, p. 4). Members of the public, especially when considering medical research, are encouraged to use peer review as a measure that the research can be:

> … considered valid, significant and original [...] statements made by scientists in scientific journals are critically different from other kinds of statements or claims, such as those made by politicians, newspaper columnists or campaign groups (Sense about Science, 2005, p. 1)

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[16] A citation purposely included to pay homage to pioneers or to noted authorities in the field.

This renders peer review a motive force behind public trust in science and scientists. The *Public Attitudes to Science 2011* (PAS) survey showed that approximately half of the respondents (51%) would be ‘more likely to trust scientific findings if they knew other scientists had formally reviewed them’ (IpsosMORI, 2011, p. 38) and that even respondents who did not normally think the information they heard about science was true were likely to trust peer-reviewed science. However, awareness of the information source, and the assumptions and partialities arising from that knowledge, may unwarrantedly influence users’ opinion of the quality of the information. Leggatt & McGuinness (2006) noted that, in some circumstances, users made more accurate judgements using anonymous sources, possibly because they then paid closer attention to the information itself.

Peer review is just one of the aspects that contribute to the unusual business mode in which scholarly publishing operates. In this system, as researchers seek the prestige of being published in, or otherwise involved with, scholarly publications, publishers get ‘their articles, their peer reviewing and even much of their editing for free’ (Monbiot, 2011). Further, universities, researchers and other readers must then ‘buy back that research in the form of increasingly expensive journal subscriptions’ (Poynder, 2008). However, while the studied disinterestedness made possible by such voluntary work may be one of the reasons why peer review is trusted, it is, none the less, not a perfect process. Writers and peer reviewers must both shoulder considerable responsibility; to err is human but to commit fraud is a crime. Despite all precautions, ‘cases of fraud demonstrably make it through the refereeing process’ (Nature, 2006b, p. 972) and standards are challenged by ‘highly-publicized cases of alleged fraud’ which allows those outside the system to question ‘underlying assumptions concerning the autonomy of science’ (Jasanoff, 2003, p. 229). Jasanoff does not cite particular cases but one example is that of the South Korean stem-cell researcher, Dr Woo Suk Hwang, whose 2004 and 2005 papers claiming success in creating human embryonic stem cells, published in the peer-reviewed journal *Science*, were later retracted, having been found to contain fabricated data (Vogel, 2006). There were other contentious issues in Hwang’s research, such his research students being allowed to donate their eggs to the project (Cyranoski & Check, 2005, p. 536) and Hwang was ultimately expelled from his university.

Even where there are no suspicions of fraud, and the work submitted for review is scientifically robust, other issues may arise. For example, high-quality work may be rejected during peer review because it clashes with reviewers’ own work and opinions or is too radical. Technical problems may be missed and cross-disciplinary work may be reviewed by someone who is familiar with only part of the field (Gura, 2002). In particular, the quality of work in ‘post-normal’ science, the ‘highly-uncertain, highly-contested knowledge needed for many health, safety, and environmental decisions, […] cannot be assured by standard review processes’ (Jasanoff, 2003, p. 232). Such cross-disciplinary work may need extended peer review, involving not only scientists in that field but also scientists in other areas and even stakeholders affected by the issues surrounding the science.

Publishers have therefore tested both alternatives to, and extensions of, peer review. For example, the journals *Atmospheric Chemistry and Physics* (ACP), *Cell*, *Nature* and *PLoS ONE* (the online edition of the Public Library of Science) have, at different times, experimented with open peer-review, in which papers were deposited on a website for free comment. The journals left some safeguards in place: for example, before deposition the papers were checked by an editorial board to ensure they were of acceptable quality and the discussions were normally moderated by an editor, who could remove inappropriate comments. The response rate was, however, low. Of two researchers who submitted papers to *ACP*, one received just two comments and the other three (Gura, 2002). Similarly to the results of *ACP*'s experiment, the editors of *Nature* concluded that, although there was 'a significant level of expressed interest in open peer-review […] there is a marked reluctance among researchers to offer open comments' (Nature, 2006a; Nature, 2006b).

In contrast, at around the same time, the *British Medical Journal* (BMJ) set up a 'rapid response' facility to allow the journal's readership to reply to and comment on published articles on-line, from the moment of publication. This facility was clearly welcomed by the journal's readers: the *BMJ* posted 30,000 rapid responses between 2002 and 2005; the editors judged the system to be a success, possibly even a pointer to new models of knowledge creation. However, eventually the editors acknowledged that the system had become a victim of its own popularity and they were forced to re-implement certain criteria for publication, for example that the comment be a substantial contribution and be below a specified word count (Davies & Delamothe, 2005).

It will be noticed that in the time since these experiments were conducted, the growth in the use of social media (see Section 2.2.4 below) has made online commenting and discussion a more commonplace phenomenon. The benefits of online commentary are not unmixed: for some the use of social media encourages timely and well-directed responses but for others, the 'pace and tone of online review can be intimidating – and can sometimes feel like an attack' (Mandavilli, 2011, p. 286), with criticism arriving from many directions at once. None the less, up to 45% of scientists are estimated to make occasional use, and up to 13% frequent use, of social media for 'purposes related to their research: for communicating their work;

for developing and sustaining networks and collaborations; or for finding out about what others are doing' (Research Information Network, 2010b, p. 19).

2.2.4 Science and social media

By their nature, published papers are 'effectively just [a] snapshot of what the authors have done and thought at [one] moment in time' (Waldrop, 2008b). Field and Powell (2001) argued that for 'established science', with demonstrable results and clear implications for the public, a single presentation – be that article, film, book, museum exhibit or other account – was generally sufficient. However, they also recognised that 'ongoing research is never static and new results are constantly changing the course of an investigation' (ibid. p.422), thus rendering a single presentation impracticable. This recognition of research as existing in a state of flux obliges all parties to 'revise and/or extend their routine practices of science communication to meet the requirements of a more demanding agenda' (Holliman, et al., 2009, p. 3). To paraphrase Irwin (2008), this could be characterised not just as the requirement to move from first-order (deficit-model, one-way, top-down, science-focused) thinking to second-order (two-way, bottom-up, dialogic, engaged) but to third-order (multiply-framed, contextual, contended) thinking.

The characteristics of Irwin's third-order grouping distinctly reflect the nature of research as a permanently evolving, dynamic, tentative and uncertain process, including controversies, detours and frequently-changing data, as well as new discoveries and new directions:

> In this situation, the public communication of science and technology both takes on new significance and faces substantial new challenges […] new possibilities emerge for forms of communication that […] open up fresh interconnections between public, scientific, institutional, political and ethical visions of change in all their heterogeneity, conditionality and disagreement. (Irwin, 2008, p.210)

It can readily be argued that the Internet has done much to make Irwin's 'fresh interconnections' possible. In 1998, it was already difficult for scientists to remember how they worked without the Internet (Rowland, cited in Trench, 2008a); now, more than ten years later, communication is the mainspring of science, takes up an increasing amount of researchers' time and indeed, 'scientists are socialised into a world in which communication via the Internet is "natural"' (Trench, 2008a, p. 185).

The concept of open science has advanced alongside the development of the group of innovative Internet technologies collectively termed 'Web 2.0'. Although often used as a descriptor, Web 2.0 is not a new technology in itself, rather, it is applied to a constantly-changing collection of technologies, including web sites based on certain presentation technologies, sites with strong social components and sites which encourage user-generated content (Cormode & Krishnamurthy, 2008). These technologies, often collectively described as social media or social networking tools, enable users to be co-developers and to share, participate and syndicate (O'Reilly, 2005), because they allow users to 'create, annotate, review, re-use and represent information in new ways' (Research Information Network, 2010b).

The concept of community is central to the value of Web 2.0 tools and the social aspects of the emergent community are as important as the quality of the technical material. This makes the roles of producer and consumer less easy to delineate;

indeed (to use a quote from a pre-Internet century), to render their separation to be ‘a distinction without a difference’ (Fenimore Cooper, 1871). As well as being as ready to produce as to consume, members of Web 2.0 communities are as able to socialise as to work (Bruns, 2009). As never before, ‘scattered groups of people unknown to one another, rarely living in contiguous areas, and sometimes never seeing another member, have nonetheless been able to form robust social worlds’ (Brown & Duguid, 1996, p. 3). However, even if they are also consumers, the producers’ perception of their audience is highly important, not just in simplistic terms of the vocabulary or linguistic style employed, but also in terms of their cognitive construction of the imagined audience, through which they articulate connexions and write their virtual community into being (Marwick & boyd, 2011).

Within their community, scientists recognise that ‘maintaining a prominent online presence can help researchers to network with colleagues, share resources, raise money and communicate their work’ (Reich, 2011a). Beyond using social media to create a digital persona, scientists make use of social media in their work in many ways. A small group of strong advocates (Research Information Network, 2010b) practise ‘open notebook science’, a research protocol in which ‘researchers post their laboratory notebooks on the Internet for public scrutiny […] in as close to real time as possible’ (Stafford, 2010, p. S21). Others make use of social citation websites, websites, blogs, wikis, electronic laboratory notebooks or deposit copies of their publications in institutional repositories or disciplinary archives. Even where repositories or archives do not enable direct links, such tools make it possible for information appearing in media reports to be tracked with reasonable ease, whether to proximate sources (such as press releases) or more remote locations (such as journal papers). Thus, what was previously confined to internal communication among scientists becomes public; and those who were formerly front-of-house observers become privy to some of the back-stage activity (Trench, 2008a).

More and more of the world is coming online: in 2009, the world average of Internet users was 27.1% of the population (World Bank, 2011). However, this average conceals considerable country-to-country differences: approximately 82% of people in the USA have access to the Internet (USC Annenburg, 2011), while in its southern neighbour, Mexico, the figure is closer to 32% (World Bank, 2011). In the UK, approximately 73% of the population has access to the Internet in their home (Dutton & Blank, 2011). Despite such differences, however, more and more people are unquestionably able, via a variety of access modes, to use social media to engage, create narratives and connect in new ways. As data, publications, models, methodologies and more of the scientific apparatus are embedded in online networks and communities, novel participants can both reach, access, use and create them.

These new participants are able to become actors as well as audiences in the play of science, interacting with the 'data traces left by others alongside direct interactions with those who created them' (Hogan, 2010, p. 377). Taking blogs[17] – an 'individualistic, sometimes anarchistic and convention-breaking form of communication' (Wilkins, 2008, p. 413) – as an example, Goldstein (2009) described how they can contribute to all stages of the research process: posing questions, identifying uncertainties, exploring new formulations, locating positions, presenting results and supporting discussion. In a blog, the writer writes but crucially, as the reader comments, the writer responds and the reader re-responds,

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[17] A blog (contraction formed from 'web log') is a type of website, usually written and maintained by one person, with diary-type entries of commentaries, descriptions of events and other material, usually published with the most recent entry at the top. They can be publicly accessible or private.

this series of comments can build into a chain of debate. Therefore, in the many 'societal debates that have much to gain from the uncensored voices of researchers [a] good blogging website […] can make a difference to the quality and integrity of public discussion' (Nature, 2009, p. 1058). Not all blogs are uncensored or written as the researchers' personal reflections. Some are institutionally-generated, for example the blog of Cancer Research UK,[18] which is written by a group of specialist science communicators within the charity. However, even though most blogs are personal, this does not mean they are devoid of scientific rigour; they can include links to other research websites or published papers.[19]

A similar mix between conversation and rigour is shown by scientists' use of the micro-blogging site, *Twitter*. The users of Twitter converse through short posts – 'tweets' – restricted to 140 characters in length, which enforces rapidly-moving, pithy conversations, with the ability to include links to more detailed information if required. As noted in Section 2.2.3 above, this rapidity is not universally welcomed; none the less, scientists were early adopters of Twitter. Many now send Twitter updates from conferences, pass on links to papers or pieces of interesting news, and old formats, such as the journal club, have adapted to this new medium (Reich, 2011b), for discussion and criticism of published papers.

Blogs, Twitter and other Web 2.0 tools enable users to mix, in greater or lesser degree, personal and professional communication and personal and professional competencies. Thus, they particularly facilitate the collective involvement of lay

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[18] See, for example, http://scienceblog.cancerresearchuk.org/2011/07/06/there%E2%80%99s-no-conspiracy-sometimes-it-just-doesn%E2%80%99t-work/

[19] See, for example, http://www.microbiologybytes.com/blog/

people, amateur scientists and professional scientists and all groups’ engagement with the process of science.

2.3 Science and the public

As noted in Chapter 1, the relationship between science and the public is multiply-faceted and operationalised in overlapping ways. As Bauer and Jensen (2011) argued, public understanding of science carries a double meaning, encompassing both the public’s understanding of science and scientists’ responses to the challenge of engaging with the public. This dichotomy echoes Wynne’s commentary, (cited by Burns and colleagues), in which he described ‘Public Understanding of Science [as] a wide and ill-defined area involving several different disciplinary perspectives’ (Burns, et al., 2003, p. 187). Beyond disciplinary information, public understanding could also cover areas such as developing scientific literacy, improving understanding of the subject matter of science, cultivating understanding of the nature of the scientific method, including the testing of hypotheses by experiment, enhancing awareness of current scientific advances and their implications, and more.

Dissatisfaction with the quality of public scientific literacy and discussion of the related need to improve public understanding of science has been noted since the mid-twentieth century. In the UK, Snow, in his famed 1959 ‘*Two Cultures’* lecture (and subsequent book versions), suggested that the breakdown in communication and understanding between the two cultures of twentieth-century society – the sciences and the humanities – was at the root of people’s inadequacy in coping with a technologically-focussed world (Snow, 1965). This narrative, of course, reflected communication – or the lack of it – between two academic cultures, rather than between an academic culture and the wider public. However, fifty years on, Snow’s basic points remain pertinent: a need for people to be able accurately to assess the strength of arguments and the soundness of the data when issues of science and technology are placed before them (Jardine, 2009) and for greater mutual understanding and better communication between scientists and members of the public. However, even in the 1980s, it was noted that:

> ...there was a tendency for scientists to retreat into their shells, frowning on those who ventured onto the public stage […] the Bodmer Report reflected a concern amongst the scientific establishment that this retreat had reached such proportions that it made funding for scientific research politically vulnerable (Miller, 2001, p. 115)

This urge to preserve and protect science funding fed into the development of the public understanding of science (PUS) movement, in which scientists were envisioned as carefully schooling an ostensibly ignorant and prejudiced public as a means of remedying opposition to new technologies and increasing public trust in science (Cook, 2009). In reality, the story was more complicated, with science and scientists varying between 'periods of great adulation and expectation, followed by disappointment and even hostility' (Miller, 2001, p. 115). For example, the USA's *Science and Engineering Indicators* reports series, which began publication in the early 1970s, offered the 'classic concerns of the scientific community: are [the scientists] held in high regard by the public and are [the public] willing to continue to pay for scientists' work?'. By the late 1970s, the focus of the *Indicators* had changed from 'concerns about the public regard for scientists to a broader understanding of the system through which adults acquire scientific and technical understanding' (Miller, 1992, p. 25).

Public understanding of science in many ways became a portmanteau term for the manifold forms of outreach undertaken by the scientific community or by others on their behalf (for example, science writers, museums and event organisers), so as to improve the public's understanding of scientific matters (House of Lords Select Committee on Science and Technology, 2000, para. 3.1). This one-way trajectory of science communication has also been imagined as a funnel, or continuity model, in which scientific ideas move from being intra-specialist (for example communicated via specialist journal paper), to inter-specialist (for example via popular science journal), to pedagogical (for example via textbooks), to popular (for example via science in the mass media) (Bucchi, 2004). While such flows need not be entirely one-way, it is not easy to visualise how information can be made to flow up the funnel from the popular to the specialist realm.

Thus, because it focussed 'on delivery of specific content rather than helping the public understand the process of research' (Bonney, et al., 2009, p. 10) PUS has been characterised as a 'deficit model', basing its efforts on the assumption that the public was ignorant about science and required 'a scientific education because it was essentially deficient in scientific knowledge' (Irwin & Michael, 2003, p. 21). Having had their ignorance remedied, the inference was, a more scientifically-literate public would be more supportive of research and enthusiastic about science.

Effecting such improvements in scientific literacy was, of course, heavily dependent on scientists' ability to communicate their expertise and enthusiasm for their subject. The 1985 Royal Society publication, *The Public Understanding of Science,* (commonly known as the Bodmer Report, after the chairman of the committee that produced it), however, noted scientists' apparent 'mistrust, lack of understanding and often unwillingness and inability to communicate adequately' (Royal Society, 1985, p. 6.1). One of the report's conclusions – linking back to earlier perceptions of public understanding of science – was that part of the duty of being a scientist was a responsibility to communicate the benefits of science to the public. The authors considered that improved public understanding would ‘be a major element in promoting national prosperity, in raising the quality of public and private decision-making and in enriching the life of the individual’ (Royal Society, 1985, p. 2.1). The Bodmer Report was (among other outcomes) the impetus for the formation of the Committee on the Public Understanding of Science (COPUS), supported by the British Association for the Advancement of Science, the Royal Institution and the Royal Society. COPUS’s aim was to ‘to interpret […] scientific advances and make them more accessible to non-scientists’ (COPUS, 2001).

However, gradually, the deficit model was affected by concerns that it ignored the considerable, if informal and personal, understanding and expertise possessed by members of the public. Not only that, it denied the benefits of such understanding to the scientific community. These considerations:

> … gave rise to what is termed the ‘contextual approach’ to public understanding of science. This approach sees the generation of new public knowledge about science much more as a dialogue in which, while scientists may have scientific facts at their disposal, the members of the public concerned have local knowledge and an understanding of, and personal interest in, the problems to be solved. (Miller, 2001, p. 117)

By 2000, the House of Lords Select Committee, in its *Science and Society* report, was ready to describe the PUS movement as a ‘backward-looking vision […] papering over the cracks that might allow dialogue to breath’ (House of Lords, 2000). Even its proponents recognised that ‘this approach was rarely successful’ (DIUS, 2008, p. 11); in 2001, COPUS ‘reached the conclusion that the top-down approach which COPUS currently exemplifies is no longer appropriate to the wider agenda that the science communication community is now addressing' (COPUS, 2001) and the programme was ended.

For its *Science and Society* report, the House of Lords Committee surveyed a range of participatory approaches, including deliberative polling, focus groups, citizens' juries, consensus conferences, stakeholder dialogues, Internet dialogues and deliberative mapping (Wilsdon & Willis, 2004). The report's conclusion was that there was a 'new mood for dialogue' and there needed to be a move away from isolated events and a cultural change towards 'direct, open and timely public dialogue' (House of Lords, 2000). Bauer and colleagues (2007) traced this as a development through three paradigms: science literacy, public understanding of science and science and society. Schäfer (2009) described this change in the relationship between science and the public as a move from '"Public Understanding of Science" to "Public Engagement with Science and Technology"' with an accompanying change of focus from 'deficits in the scientific literacy of the lay public towards a dialogue model [that was] increasingly open and egalitarian' (Schäfer, 2009, p. 475).

The 'dialogic turn' (Phillips, 2011, p. 80) characteristic of post-2000 activity, based on dialogue and participation, has been recognised by scientists, who acknowledge that they: 'have a duty not merely to tell people what we are doing [...] but also to listen to people's fears and hopes and respond to them, even when we feel their antagonism to be ill-founded' (Winston, 2009, p. 22). It has also been embraced by governments, as they are increasingly faced with the need to take decisions in contentious and difficult areas such as 'stem-cell research and cloning; evolution and science education; science, technology and national security; bioterrorism; energy policy; sustainable development; the environment; climate change; genetic medicine;

emerging infectious diseases; genetically-modified foods; space exploration; and nanotechnology' (McCallie, et al., 2009, p. 28). For example, the UK government report, *A Vision for Science and Society* stated that: 'We believe there is a pressing need to strengthen the level of high-quality science engagement with the public on all major science issues' (DIUS, 2008, p. 6).

However, meaning can never be taken for granted, even within a coherent community (Brown & Duguid, 1996); how much of the dialogic turn is real and how much is imagined is subject to debate. It is apparent that 'despite the talk of dialogue as a two-way communication process, the outcomes of dialogues have often implied [the existence of] a receiver' (Horst & Michael, 2011, p. 285); and the presence of a receiver entails the presence of a transmitter. As Trench (2008b, p. 2) wrote, even in the face of the 'grand narrative' of a shift to dialogue, the deficit model remained evident and persistent. Wilkinson and colleagues (2011a) further suggested that deficit-model interactions could be appropriate in some environments and even preferred by members of the public in some circumstances.

Organisationally, Davies and colleagues (2008) noted how events promoted as dialogues none the less operated under assumptions of scientific privilege, with equality affected by assumptions of deference and expertise, and how such events could readily revert to more traditional, approaching deficit-model, formats such as question-and-answer. These behaviours are inevitably 'in conjunction – and tension – with the newer language of dialogue, debate and lay agency' (Davies, 2009a, p. 413). Similarly, Wilkinson and colleagues (2011a, p. 392), observed that while there may be a cultural habit of understanding, scientists can shift between diverse notions of 'public understanding and public engagement, deficits, and dialogues [and] innovative engagements can be shrouded in traditional forms'. In contrast, Zorn and colleagues (2010) showed that, even in the face of overt public deference and expert disavowal, influence can be bi-directional: in the dialogue they observed, scientists' and laypeople's attitudes (in this case towards human biotechnology) both changed as a result of participation, with laypeople becoming less concerned and scientists more concerned, and an accompanying increase in both groups' communicative efficiencies.

2.3.1 Scientists' engagement with PEST

Under the banner of public engagement with science and technology (PEST), which Poliakoff and Webb (2007, p. 244) describe as 'any scientific communication that engages an audience outside of academia', scientists and members of the public may choose to take part in multifarious types of activity. Rowe and Frewer (2005, p. 257) identified some 100 participatory activities, extending (alphabetically) from ActCreateExperience to Whole System Development but noted that 'there are undoubtedly more'. Mesure noted (in the UK) 'as many as 1500 initiatives or programmes' (Mesure, 2007, p. 8); the NEF's *Participation Works!* (1999) described 21 participatory mechanisms in detail (with more sketched briefly). DIUS added 'science centres, [mushrooming] cafes scientifiques and a vibrant science festival scene' (DIUS, 2008, p. 10) and Bauer and Jensen (2011, p. 5) included (among others) public lecturing, giving interviews, writing popular science books or articles and collaborating with non-governmental organisations.

Many PEST activities are at least predicated on ideas of dialogue, mutuality and communal learning by publics and by scientists, in line with the perception that 'two-way dialogue [is] more likely than a one-way lecture to lead to maturing of views and resolution of conflict' (Winston, 2009, p. 22). Dialogue and resolution demand that scientists and members of the public are willing to engage under conditions of mutual respect. This:

> … allow[s] everyone who participates to develop new or more nuanced understandings of issues and opportunities [and] increased awareness of the cultural relevance of science, science as a cultural practice, and science-society interactions (McCallie, et al., 2009, p. 12)

These multiple demands call for an equally eclectic array of capabilities in participants: the ability to act competently across a range of skills, media, activities and dialogues (Burns, et al., 2003). Developing skills in communications, public relations, management and delegation, as well as research, may not be something all scientists want to do (Russo, 2010). However, it may be something they have to do: most members of the public believe scientists are the people best placed to explain the impacts of science and technology (European Commission, 2010, p. 90), which may lead to the expectation that scientists will perform this function.

Scientists have widely 'acknowledged the benefits *to scientists* [emphasis in original] of communicating their work with the public' (Burns, et al., 2003, p. 194). There is longitudinal evidence to support the view that the majority of scientists have a positive attitude to participating in PEST activities. In 2000, a considerable majority (91%) of respondents agreed scientists have a duty to communicate their research and its social and ethical implications both to policy-makers and to the non-specialist public and a majority (56%) had taken part in at least one communication activity in the preceding year (Wellcome Trust, 2000). However, for scientists, involvement in PEST was, at that time, almost always a voluntary or extra-curricular pursuit, as many considered their day-to-day activity left them little time to communicate about their work (Wellcome Trust, 2000). More recent studies showed that the voluntary nature of PEST work was not necessarily seen by scientists as a negative, because it allowed them an ‘autonomy with respect to public engagement activities’ which could be ‘undermined by more explicit formal measures [requiring] such activities’ (Burchell, et al., 2009, p. 7). However, even when compelled into PEST – the inclusion of public engagement activities designed to disseminate research outputs forming a mandatory part of some grants – scientists none the less recognised its potential to further their career (Poliakoff & Webb, 2007). Altruistically, scientists also described normative justifications, such as the belief that ‘it’s important to engage the non-specialist public’ (PSP, 2006, p. 9) or the recognition that ‘taxpayers’ money may ultimately fund their research’ (Poliakoff & Webb, 2007, p. 247). The wider economic view was supported by Marris and Rose (2010, p. 1), who suggested that PEST activities may lead to ‘innovations that perform better in complex, real-world conditions, or may be more socially, economically, and environmentally viable’.

Burns and colleagues (2003, p. 194) noted that instrumentally, engagement activities may develop scientists’ ‘communication skills, clarify their understanding, and provide useful feedback and a fresh perspective on various issues’. In contrast, Davies (2008) argued that some scientists persisted in perceiving science communication as difficult, dangerous and framed within an over-arching context of one-way transfer. Some scientists remained wary of standing out in public, citing the (perceived) controversial nature of their research, causing them to worry that their work would be misunderstood or misquoted (PSP, 2006). Scientists were also concerned about their lack of PEST skills or training in those skills (Poliakoff & Webb, 2007) and that PEST activities might be seen as ‘light and fluffy’ or ‘bad for [their] career’ (PSP, 2006, p. 11) causing their work to be taken less seriously by colleagues. There was also a perception that PEST work was mostly undertaken by those less fitted for an academic career (PSP, 2006). However, this was countered by Bentley and Kyvik (2011), who demonstrated in a meta-analysis of scientists' activities in 13 countries that academics participating in PEST activities published, on average, significantly more academic publications than those who did not.

Considering PEST entirely as the province of scientists is to overlook the contribution of specialists in science communication. The presence of other parties renders inadequate a simple linear one-way sender–receiver model, with scientist as sender and, below them in the hierarchy, member of the public as passive receiver. Instead, the paradigm becomes that of encouraging communication among mixed groups of actors, which might include scientists, members of the public, politicians, journalists, government and others (Dijkstra & Gutteling, 2011). In this more complex model, the inclusion of some form of mediator may be required. This third member, whom Bauer (2009, p. 226) characterised as 'private "angels" [moving] between a disenchanted public and the institutions of science' must be able both to understand the former and communicate with the latter, although their presence can introduce suspicions of distortion and re-arrangement (Bucchi, 1996) as the science becomes warped by the 'dirty lens' of the media (Bucchi, 2004, p. 108).

Mediators need not necessarily be professional; indeed, might be more effective if believed to be disinterested. Any participant in the process could potentially claim the insight, specialism, network resources, grounded understanding or experiential expertise needed for the role (Kerr, et al., 2007). However Davies and colleagues (2008), noted that equality of situation should not necessarily imply equality of contribution, rather that the merits or demerits of each contribution should be critically assessed. Burns and colleagues (2003), visualised science communicators as ‘mountain guides’, teaching people the skills of how to climb the mountain of scientific literacy, providing media ladders to help them over difficult sections, sustaining them through developmental activities, and remaining in dialogue about the progress and issues of the climb. It should be noted that Burns and colleagues did not automatically place scientists at the top and lay people at the bottom of the mountain; they emphasised that anyone could be anywhere in the range, depending on skills and experience. Nielsen (2010) criticised the mountain guide model, arguing that the concept of neutral mediators did not take into account the personal predispositions of science communicators and which group – for example public or scientists – they saw as having the greater needs.

2.3.2 Public engagement with PEST

In comparison to research into scientists’ motivations and the perceived benefits of undertaking PEST activities, ‘we have only partial knowledge of why the public engages’ (Science for All, 2010, p. 10). It is possible to draw some inferences from longitudinal national and regional surveys on public attitudes to science and technology, for example the *Public Attitudes to Science* series (UK); the *Science Indicators* series (USA); and the *Eurobarometer* series (EU). Although the questions in these surveys do not directly address people’s motivations for engagement – for example why they might choose to attend a talk or discussion or search for information on the Internet – they can shed a tangential light.

The 2010 *Science Indicators* report, for example, showed that about 25% of Americans had visited an informal science setting (such as a museum or science centre) in the previous year, about twice as many as reported visiting similar places in Europe (National Science Foundation, 2010, p. 7/15). Survey respondents in the UK expressed a desire for ‘more scientists to discuss research and its social and ethical implications with the public’ (RCUK/DIUS, 2008, p. 20), while ‘more than half of Europeans [felt] that scientists do not put enough effort into informing the public’ (European Commission, 2010, p. 88). They also considered that ‘scientists should listen more to what ordinary people think’ (IpsosMORI, 2011, p. 52), that the public should be informed about decisions about science and technology and even that public opinion about those decisions should be binding (European Commission, 2010).

These results suggest that people are apparently willing to become involved in discussion and dialogue with scientists, if the opportunities exist. However, although the respondents to the surveys had a firm view of who were the scientific participants, the identity of the public participants was less clear. While respondents said that members of the public should be involved in decisions about science and technology, involvement was more likely to be viewed in terms of something that should be done by members of society in general, rather than by a personal involvement in consultations or similar activities (IpsosMORI, 2011). This illustrates the complex notions of expertise and communicative ability that exist both in members of the public and, perhaps, scientists.

Meeting the needs of both scientists and members of the public and discovering how engagement activities can be ‘most effectively developed and delivered’ (Science for All, 2010, p. 10), is necessary if all participants are to be in a position to value the validity and importance of each other’s experiences. For open science to evolve as an effective mode for public engagement, approaches that ‘encourage and provide paths to those with enthusiasm but insufficient expertise to gain sufficient expertise to contribute effectively’ (Neylon, 2009) are likely to be needed.

2.3.3 Scientists’ and public expertises

Almost the defining feature of contemporary PEST activity is the notion that ‘publics, not only the scientists or “experts,” can make useful and valuable contributions to discussions and decisions about science and technology’ (McCallie, et al., 2009, p. 13). Despite this understanding, both deficit and dialogic models of science communication have struggled to respond adequately to the public distrust of how expertise is constructed. In the UK, this was exemplified by the discussion that emerged in the wake of controversies such as the aftermath of the Chernobyl nuclear power station explosion, the BSE crisis and the introduction of genetically-modified crops (Bickerstaff, et al., 2010).

In everyday life, ‘one does not have to be a scientist to participate in discourses about the state of affairs in the world’ (Webler, 1995, p. 64) and information arising from informal sources can be vital for fully understanding complex situations. While creating an *agora* in which groups with different levels of scientific literacy can mutually inter-communicate is desirable in principle, in practice, particularly in post-normal science, there is evidence that ‘community members are not always considered “peers” by researchers and community members do not always treat researchers as peers’ (Bidwell, 2009, p. 758).

This dichotomy was identified by Wynne (2003) in his study of Cumbrian farmers following the Chernobyl disaster of 1986. Regarding the relationship between the scientists of the Ministry of Agriculture and the sheep-farmers, Wynne argued that the farmers’ expertise in relation to their sheep and their knowledge of the local ecology should not have been ignored by the scientists in the way that he outlined. However Burri (2009), in her study of citizen panels on nanotechnologies (which also involved professional scientists), showed that, although cautious in their assessment, the public displayed a pragmatic attitude to this new technology, that understandings were founded on personal experiences, and no settled divisions were apparent among the participants. It may be, however, that this flexibility only remains while technologies are emerging and discourse remains malleable. Later in development, as ‘interest groups, policy-makers, scientists and mass media struggle to get their voices heard’ (Scheufele & Lewenstein, 2005, p. 665) – to which groupings, arguably, may be added the grouping of members of the public – the debate will inevitably become more solidly framed and broad, egalitarian discussion could be precluded.

Moving beyond discussion to active research, patient and carer groups have pioneered the move further and further upstream in their enquiries about the nature of research and the questions it can answer (Wilsdon & Willis, 2004). That this happened first in medicine may be due to the unique insight into and interest people have in their personal health and well-being, which render medicine ‘an arena more permeable to outside influence than other less public, less applied and less politicized domains of technoscience’ (Epstein, 1995, p. 409). The participation of patients often requires particular life-experience, rather than specific expertise, so it is possible for people to participate passively, for example by donating body tissue to biobanks. Such participation is supported by generally high levels of public willingness to participate but is not necessarily simply experienced as a ‘gift relationship’ (Titmuss, cited in Lipworth, et al., 2011) but rather, derived from a number of motivating factors including ‘altruism, “pragmatism” (i.e. a desire to contribute to research advancements as part of a balanced relationship between participants and researchers), and personal benefit through, for example, access to research data’ (Lipworth, et al., 2011, p. 792).

In the context of health research, public involvement has been reported as affecting the research agenda by influencing the identification of research topics, modifying research questions, guiding projects and shaping funding decisions (Staley, 2009). For example, Stilgoe and Wilsdon (2009, p. 23 ff) describe how the UK Alzheimer's Society set up, in 2000, the Quality Research in Dementia (QRD) network, a 'ground-breaking example of upstream engagement [through which] patients and carer volunteers shape research priorities, review proposals from scientists, assess researchers and monitor research' (ibid. p.23). The Alzheimer's Society funds research into the condition and its members could naturally be expected to take a close personal interest in the work their funded scientists perform. However, the QRD network also allowed patients and their carers to contribute their expertise in the realities of living with Alzheimer's, as research proposals submitted to the society were sent out for comment to the QRD, as well as to more conventional peer review. For patients and carers, the QRD network enabled them to ask questions that they felt could make a real difference to the research. For some researchers, the patients' and carers' expertise improved their proposals and was by no means 'tokenistic [but] real, good-quality help […] a fantastic collaborative approach to research' (Warner, cited in Stilgoe & Wilsdon (2009) p.24). However, not all researchers believed such collaboration to be valuable: 'I have a negative view because people did bring their own agendas and I really think that's a bad thing in research, to bring your agenda to the research strategy and proposal' (Staley, 2009, p. 27).

'Bringing an agenda' could be characterised either as a conflict of world-view or of views of expertise. If expertise is contested, both within the public and scholarly frames, a more 'nuanced understanding of how expertise is constructed and maintained […] would give us useful insights into whether or how the lay-expert divide is being bridged, blurred, or reified' (Kerr, et al., 2007, p. 387). Collins and Evans (2007) argued that 'lay expertise' is a confusing and unfortunate description; asserting that while lay people can have considerable experience in a particular area, despite a lack of formal qualifications, they cannot have specialist expertise. They offered instead a scheme of levels of expertises from (working upwards), 'ubiquitous expertise' (for example the ability to speak a native language) to 'interactional expertise' (the ability to hold a conversation with someone of a specific expertise, such as might be needed by a peer-reviewer or high-level journalist) to the top-level 'contributory expertise' (the ability to contribute significantly to a new domain of expertise).

For Collins and Evans, interactional expertise 'provides a bridge between the rest of us and full-blown physically engaged experts, and it touches on a wide range of professional activities' (Collins & Evans, 2007, p. 77). Leadbeater and Miller (2004) likewise attempted to bridge between professional and amateur in their description of the emergence of a community they called 'pro-ams': 'innovative, committed and networked amateurs working to professional standards' (Leadbeater & Miller, 2004, p. 9). Members of this group have:

> … a strong sense of vocation; they use recognised public standards to assess performance and formally validate skills; they form self-regulating communities, which provide people with a sense of community and belonging; they produce non-commodity products and services; [and are] well-versed in a body of knowledge and skill, which carries with it a sense of tradition and identity. (Leadbeater & Miller, 2004, p. 22)

However, the simple involvement of lay people does not automatically equip them to articulate their concerns or flatten existing hierarchies (Lengwiler, 2008). The notable growth in the number of projects that aim to involve members of the public as ‘citizen scientists’ may serve to reduce the separation between the roles of ‘scientist’ and ‘public’. However, it could be argued that the design of many citizen science projects, in which the citizen participants passively ‘carry out rather rudimentary observational activities, such as observing, counting and classifying’ (Ince, et al., 2011, p. 35) in fact reinforces the status of the different roles.

2.3.4 Citizen Science

> What this process of true public engagement requires is a different kind of scientific leadership – one that is committed to breaking down the ambivalence between science and citizens and taking responsibility for a partnership of respect and working hard. (Wooden, 2006, p. 1062)

Science owes a lot to its skilled amateurs: ‘some of history’s most influential scientists and polymaths – Hooke, Darwin, Franklin – started as gentleman scholars [yet pioneered] the foundations for modern enquiry’ (Johnson, 2011, para. 25). In domains such as ‘astronomy, archaeology and natural history, where skill in observation can be more important than expensive equipment’ (Silvertown, 2009, p. 1), legions of interested volunteers have long participated in a considerable range of different projects.

Undoubtedly, the growth in numbers of projects in which members of the public can participate has been facilitated by the growth in Internet access: while the Audubon Society (2011) first conducted its annual bird count by post in 1900, current participatory projects are almost all web-based (Butterfly Conservation, 2011; Galaxy Zoo, 2010; FoldIt, n.d.; ScienceForCitizens, 2010). The use of Internet-based tools certainly widens the reach of projects and facilitates the inclusion of new participants but also cuts project costs, by using the voluntary endeavour and personal tools of those participants, similarly to the economic model of collaborative creation described above (see Section 2.2.1 above).

Such participatory projects are typically labelled as ‘Citizen Science’ however the understanding of ‘citizen science’ has multiple roots. Irwin (1995, p. 166 ff), described citizen science (note the use of lower case) in a social constructivist sense, with the implied acknowledgement of a meeting point between different forms of knowledge and understanding: expertises, pluralities, emergence, reflexivity and flexibility. Independently, also in 1995, Bonney ‘coined the term “Citizen Science” to refer to the [Cornell Laboratory of Ornithology’s] growing number of scientist-driven public research projects’ (Bonney, et al., 2009, p. 15). The use of the term has subtly altered over time: in current use, the concept of Citizen Science has become pragmatic and distinctly more of a proper noun, covering projects in which volunteers:

> … collect and/or process data as part of a scientific enquiry [working] with professional counterparts on projects that have been specifically designed or adapted to give amateurs a role, either for the educational benefit of the volunteers themselves or for the benefit of the project (Silvertown, 2009, p. 1).

As is implied by Bonney’s description of projects as ‘scientist-driven’, Cohn (2008, p. 193) noted that many Citizen Science projects have the common feature that while ‘volunteers do not analyze data or write scientific papers [the volunteers] are essential to gathering the information on which studies are based’. Haklay (2011) criticised this constraining of citizen engagement, in which participation was either essentially passive, limited to data collection, or implicitly required an advanced level of education or affluence, as tending to limit the issues, questions and populations that could be addressed by Citizen Science projects. In her meta-analysis of service-user involvement in health research, Staley (2009), noted that while some researchers have suggested that they are not convinced that the public has much to contribute to the analysis of results, others suggest that increasing public involvement can enhance the process, either by reflecting alternative perspectives for the analysis or contributing to the accessibility of research outputs for particular user groups.

If, as Arnstein (1969) suggested, participation without power is frustrating, it is worthwhile asking why, none the less, people choose to become involved as data providers or organisers in Citizen Science projects. Raddick and colleagues (2010) interviewed volunteers in the *Galaxy Zoo* project to determine their motivations for participating. They found the predominant motivation (39%) was a pre-existing interest in astronomy, three times as many as the next-biggest categories, the desire to make a contribution to original scientific research (13%) and a sense of the vastness of the universe (11%). Blackman and Benson (2010) in case studies of three ecological projects that included interviews with 55 non-specialist volunteers, found they were motivated more by interest in the status of the projects as they happened and less by interest in the projects' final outcomes. Volunteers wanted to feel they were contributing to the project, were being kept informed of developments in the project, that organisers and scientists were willing to engage in the long term and that their input was valued by the professional scientists (see also Bell, et al. (2008); Powell & Colin (2008)). In the FoldIt programme (FoldIt, n.d.), participants collaboratively solve optimisation problems by competing to design, *in silico*, folded proteins with minimal energy computations (Hand, 2010). In some ways, FoldIt is a computer–volunteer hybrid, rather than professional–volunteer, as the software is refined through observation of the humans’ best practice and expertises. None the less, a survey of 48 FoldIt players (Cooper, et al., 2010) showed that the sense of contributing to science was a motivating factor for just under half of the respondents; players also mentioned achievement through point-scoring, social interaction and the immersive qualities of the game.

These projects used volunteer labour to pursue scientific goals. Other Citizen Science projects, such as The Birdhouse Network (TBN), as well as having the primary aim of gathering large datasets, also ‘aim to increase participants’ knowledge about science and the scientific process, and to change attitudes toward science and the environment’ (Brossard, et al., 2005, p. 1101). The TBN project was envisaged as an instance of ‘experiential education’, in which participants explored real research questions through systematic scientific processes. The participants were, none the less, given detailed scientific protocols to follow for the observation and reporting stages. In fact, Brossard, Lewenstein & Bonney found no statistically significant evidence to suggest that TBN participants’ understanding of the scientific process changed, nor that their attitude towards the environment was modified. They speculated this might be because participants were already highly motivated (for example, they had to purchase the materials they needed to take part) and had high existing levels of interest in the birds at the heart of the study, rather than in the scientific process behind the experiment. In contrast, Trumbull and colleagues (2000) concluded that participants in another ornithological project (the Seed Preference Test) showed evidence of thinking that demonstrated aspects of systematic enquiry rather than straightforward protocol-following, such as use of existing knowledge, additional observations, hypothesis-formulation and suggestions for modification to the experimental design. Trumbull and her colleagues placed caveats on their conclusions, noting their data-gathering was serendipitous and a significant majority of those from whom the data were taken (71.3%) were educated to first degree level or higher. They therefore suggested that care would be needed in extrapolating these conclusions to projects seeking to engage less-educated and less-motivated participants.

Citizen Science is not necessarily open science; ‘many citizen science projects share data, but may not make the full research process publicly viewable for comment and discussion’ (Wiggins & Crowston, 2011, p. 2). Therefore, although they have considerable elements in common, the public engagement that is likely to be facilitated by open science is closer to what has been termed public participation in research (PPR) than to Citizen Science. Bonney and colleagues (2009) identify three major categories of PPR projects: contributory, collaborative and co-created. Contributory projects are largely designed by scientists, with members of the public primarily contributing data; Citizen Science projects typically fit into this category. While they have been very successful in recruiting participants, ‘there is a danger of developing mechanisms simply because the technology is available to do so, with little thought of whether the participants really desire engagement through such processes’ (Rowe & Gammack, 2004, p. 51). That is, public participants may be satisfied by contributing or organising data and do not seek deeper involvement. Likewise, scientists may be satisfied by large-scale data collection or collation and may not require deeper involvement from their public participants. It is also possible that the growth in contributory and collaborative Citizen Science projects will exhaust the citizenry available; exploiting people’s altruistic desire to ‘contribute’ might decrease the goodwill of active citizen scientists (Hand, 2010).

As well as being a mechanism for scientists to inform and the public to absorb information, open science could lend itself to collaborative and co-created projects, providing the projects are able to incorporate mechanisms by which members of the public and researchers are able to engage in the necessary dialogue and discussion needed. For example, where open science projects make data available, members of the public can help to refine design and analyse data (Bonney, et al., 2009) but unless this re-working is to be done purely for the interest of the person concerned and not be fed back into the project, mechanisms for feedback and evaluation must be incorporated into the project design. Similarly, where projects are co-created by scientists and members of the public working together, open science could support the long-term involvement of all participants throughout the process.

Chapter summary

Since the beginnings of science as an experimental and philosophical discipline, scientists have always sought to communicate their findings and conclusions both to each other and to wider audiences. The increase in Internet access and the emergence of new social media technological tools for the social production, as well as the personal consumption, of information, have greatly widened the community of people who are able and willing to access scientific information. This is reflected in the rise of open access journals and institutional and subject-based open access repositories, and in the increasingly common requirement of funders that the results of publicly-funded research are made publicly accessible.[20]

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[20] The Finch Report, which addressed the question of how to improve access to research publications, was published after this research was completed. The conclusions of the Finch Report, which asserts that the principle that publicly-funded research should be freely accessible is ‘compelling and fundamentally unanswerable’ (Finch, 2012, p. 5) have, since publication, largely been accepted by the UK government (BIS, 2012).

From the mid-twentieth century, dialogue between scientists and members of the public has been seen as increasingly important, for a variety of reasons and through a variety of modes, notwithstanding that some have noted the continued survival of one-way transmission models. The shift from lecture to professional–public dialogue, from passive to active public, from science as a tightly-controlled private process to one with a variety of participants and range of audiences and from a focus on readily-transmissible single outcomes to an awareness of science as a dynamic process has profoundly affected the views, attitudes and concerns of private, professional and governmental actors alike.

Chapter 3. Research Methods

The overall aim of the research performed in this study has been described earlier (see Section 1.2 above). Primarily, research must be credible; that is, its data, analysis and conclusions should be convincing and trustworthy (Lather, 2007). Credibility, and thus the trustworthiness and value of any findings or conclusions that are drawn from the research, may be determined through establishing validity or showing reliability. The object of this chapter is to outline the methodological basis by which the research objectives were met, including how validity was addressed, the selection of data collection methods, the units of analysis, sampling strategies, analytical approach and data management and ethical issues (Hart, 2005).

3.1 Introduction

This research employed both qualitative and quantitative research strategies: two methods of qualitative enquiry (interviews and case studies) and one method of quantitative enquiry (a web-based questionnaire survey).

Qualitative enquiry is a ‘complex, interconnected family of terms, concepts and assumptions’ (Denzin & Lincoln, 1994, p. 1), applicable across many disciplines, fields and subjects. Its interdisciplinary character supports the study of phenomena in natural settings, recognising the socially-constructed nature of such research, in which the relationship between researcher and the object under study is central to the process. The flexibility of qualitative enquiry, focussing on the relationship between processes, offers the advantage that new information can be added to the enquiry, or new questions conjured during the research or at any stage of the analysis, so as to be able to follow emerging leads (Charmaz, 2006).

Qualitative research typically prizes validity – the ‘degree to which the sample data authentically represent the concept or phenomenon under study’ (Jensen &

Holliman, 2009, p. 59). Lather (2007) suggested validity could be pursued by, for example, the use of different methods for sampling, the taking of detailed notes, participants' confirmation of accuracy of observations, recording of data (for example sound recording of interviews), use of quotes from participants and the active search for discrepant data. Quantitative research classically respects reliability – the extent to which the same result would be found in repeated trials (McNeill & Chapman, 2005), with requirements for repeatability and objective statistical representation in sampling.

The strategy of using mixed methods of enquiry, to enable the strengths of one approach to offset the weaknesses in another has, under varying descriptors, gained increasing acceptability since the 1960s (Creswell & Piano Clark, 2007). Mixed methods is particularly valued for the facility it offers to support validation through methodological triangulation, one of the earliest validation techniques described for mixed methods and still one of the most common. As defined by Morse (1991) methodological triangulation involves the use of at least two methods (usually a mix of quantitative and qualitative strategies), either (i) to ensure that the most comprehensive approach is being taken to solve a research problem, (ii) to ensure the validity of the instruments being used or (iii) to obtain different but complementary data on the same topic. Methodological triangulation is especially useful when wishing to compare and contrast quantitative and qualitative findings, to validate quantitative results through qualitative findings or vice versa.

Triangulation may take the form of one of four variants. First, it may be convergent: qualitative and quantitative data are collected around the same subject and the results are converged by comparing and contrasting them. Second, it may be transformative: qualitative and quantitative data are separately collected but the data are mixed during analysis by transforming one type into another, to facilitate comparison and further analysis. Third, it may be validating: qualitative data are used to validate quantitative results, often by collecting both types within the same instrument (for example by including open-ended questions in an otherwise quantitative survey). Finally, it may be multi-level, when different methods are used to address different levels within a system (Creswell & Piano Clark, 2007).

The four variants offer solutions to the different challenges of methodological triangulation, for example the ability sensibly to combine data sets of different sizes and very different forms. For this research, transformation was not appropriate, as the data remained separate up to the point of synthesis; neither was validation, as this does not generally result in rigorous qualitative data, although such transformed data can be very useful to embellish and enrich quantitative findings; nor was multi-level, as this approach is best suited to the study of one system with several different internal levels (for example a company) and this research involves both different systems and individuals. The most appropriate triangulation method for this study was therefore convergence, which involved using different methods to 'reach valid and well-substantiated conclusions about a single phenomenon' (Creswell & Piano Clark, 2007, p. 65).

Analytical approach

Ethical, financial and practical considerations dictated that for this research, the data collection and analysis were carried out entirely by the author. While reliance on one investigator could arguably increase bias and reduce repeatability and validity, there are advantages to such consistency and close association with the material. Conducting the interviews, carefully listening (several times over) to the recording while creating the transcript, designing and creating the survey and then managing the numbers by hand, together with observing and recording in the case studies, enabled the author to become thoroughly conversant with the data content. This meant data analysis and the emergence of ideas could begin very early, even before formal analysis began (Gibbs, 2007). This continuing process was mirrored by the keeping of a research diary; the reflexive activity of creating a record of developing thought and action complementing the data and insights yielded by the research (Hughes, 1999).

3.2 Qualitative enquiry: (i) interview component

This component sought to satisfy objective (i): through interviews, determine the views of researchers and members of the public on open science's principles, methods, values and benefits and the implications and potential of open science practice for public engagement with science.

Grounded theory

A grounded theory approach was chosen both for the sampling and acquisition of interview data and for its analysis. In the grounded theory approach, theory is allowed to emerge from data, evolving 'during actual research, through [the] continuous interplay between analysis and data collection' (Strauss & Corbin, 1994, p. 273). Grounded theory emerged from Glaser and Strauss's collaborations in the late 1960s; at a time when sociological research tended towards defining research in quantitative terms, Glaser and Strauss advocated developing theories from research grounded in data, rather than deducing testable hypotheses from existing theories (Charmaz, 2006). As Creswell (2007) further noted, as opposed to experimentally testing an hypothesis, grounded theory allowed for development of theory during the research process. Similarly, Charmaz (2006) suggested the advantage of using a grounded theory approach was that it enabled the experimenter to learn about gaps and holes in their data from the earliest stages of research. However, it is important that, to avoid bias and genuinely allow theory to emerge, researchers adopting a grounded theory approach must be aware of their individual conceits and how these may affect the research, and be ready to set aside pre-existing personal ideas.

As a way of conceptualising data, grounded theory is particularly suited to the study of phenomena in complex fields, where a combination of methodologies must be integrated in one study. This ability to deal with complexity also makes grounded theory appropriate in new fields of study, whose theories and constructs are not yet well developed (Flick, 2007). Therefore, given that the interviewees in this project were not expected to be, in the context of their interviews, representative of organisations or projects, and that there was limited existing practice in open science, and therefore limited existing data from which to derive testable hypotheses, grounded theory suggested itself as a fruitful approach in the development of the research questions (Creswell, 2007).

Following a grounded theory approach involves a cycle of data gathering → analysis → reflection → gathering. The cyclic nature of the process and the fundamental place of data gathering in theory formation can make it difficult for researchers to know when further data has ceased to contribute any new insights and they should stop amassing data (Denscombe, 2005). While some theorists (notably Glaser) have argued that there is no special need to attend to the amount of data being gathered, because conceptual categories can emerge from relatively low data densities, limited data none the less offer an insecure footing on which to ground persuasive or definitive statements (Charmaz, 2006). Therefore, small grounded theory studies risk becoming disconnected from their social context, whereas rich data enable researchers to recognise conditions under which differences and distinctions arise.

To address this issue and enhance effectiveness, a central interpretive strategy of grounded theory is the use of constant comparative analysis (Denzin & Lincoln, 1994), in which new data are repeatedly compared with previously-analysed data until the point of saturation – when new data no longer create new insights or reveal new properties – is reached. A description of the strategy followed to determine data saturation in this research will be found following Section 3.2.2 below.

In summary, used carefully, grounded theory gives considerable latitude for ingenuity and creativity (Strauss & Corbin, 1990). In particular, it allows ideas to emerge, with no prejudice towards previously-existing concepts. Later in the process, as concepts emerge through the researcher's sensitisation to the data, initial ideas can be pursued and the researcher enabled to follow emerging questions (Charmaz, 2006).

3.2.1 Interview guide

The design stages of the interview component of this research involved consideration of two factors: the drawing up of the interview questions and the recruitment of interviewees. Interviewee recruitment is discussed in Section 3.2.2 below.

Angrosino (2007, p. 42) described interviews as a 'process of directing a conversation so as to collect information'. Given that natural conversations rarely follow a pre-determined pattern, it follows that an interview need not be an unvarying list of questions, for example as might be typically experienced in a market research survey. As Strauss and Corbin (1990, p. 177) noted, to 'adhere rigidly to [the questions] throughout the research study will foreclose on the data possibilities […] and limit the amount and type of data gathered'. In adopting a grounded theory approach, it is important that neither are interviewees limited to answering a strict list of interview questions nor the interviewer restricted to asking only those questions. Broad, open-ended questions, of the nature of “could you describe …”, “tell me about …”, “where do you see X in five years’ time? …” allow richer data to emerge. Nevertheless, flexible as the method is, such semi-structured interviews require careful planning so that the questions are sufficiently open and yet allow the interviewer to improvise in a careful way, prompted by theory. This structure allows the interviewer to reflect their ‘concerns and initial theoretical framework’ (Wengraf, 2004, p. xxv), while allowing a narrative to flow from the interviewee.

The questions in a semi-structured interview thus offer a common nucleus from which the conversations can begin. Also, through reflection and deliberation on the effectiveness (or lack of it) of the questions in eliciting rich data, the interview questions can subtly evolve throughout the research process. Therefore, an interview schedule was developed to guide semi-structured interviews lasting between 35 and 45 minutes. For professional scientists and other researchers, the questions covered three broad areas: public engagement with science, perceptions and experiences of open science, and scrutiny, promoting understanding and barriers to engagement. Questions for members of the public and amateur researchers additionally addressed issues of access to and availability of information, and public engagement and expertise. All interviews concluded with an opportunity for free comment. The interview guides are reproduced in full in Appendix 8.3.

3.2.2 Interviewee recruitment

Jensen and Holliman (2009, p. 61) characterised the community of practitioners of science outreach and public engagement as ‘an ill-defined, hard-to-reach and still-coalescing population’. This is equally true of the open science community, which is yet in a nascent, emerging stage, populated by relatively isolated individuals and still evolving its concepts and strategies. Similarly, in a relatively new practice, members of the group at the opposite end of the continuum – who might be termed ‘open science sceptics’ – are likewise scattered and hard to reach. These constraints meant that the identifiable, accessible population of potential professional interviewees, from which a sample could be drawn, was likely to be quite small. As well as being limited by the characteristics of the group being studied, the sample size was also constrained by factors relating to the researcher, for example available time, financial resources, equipment resources, ability to travel and so on (Angrosino, 2007). These constraints mean that it would have been difficult to design a quantitatively representative group, for example a random or quota-selected sample of the professional population (containing members with specified features, for example balanced for age, sex or profession).

Similar constraints had to be borne in mind when designing the strategy for approaching members of the public. As noted in Chapter 1, ‘public’ is a fluid concept, never absolute but constructed and grouped through processes of categorisation and classification and in the context of cultural and social processes (Burns, et al., 2003; McCallie, et al., 2009; Braun & Schultz, 2010; Wilkinson, et al., 2011b). People are mobile between one grouping and another; at one time, a person may be a member of many different public groups. A parent may be a policy-maker or a student a senior citizen; no form of participation offers an unlimited variety of positions (Lezaun & Soneryd, 2007).

Therefore, given that ‘a complete census […] is rarely a feasible goal’ (Jensen & Holliman, 2009, p. 60), the selection technique applied becomes important, to enable a thoughtful generalisation from the results obtained. Qualitative research is able to capture variation and variety by being built around the notion of purposeful sampling, in which the researcher ‘purposefully selects individuals and sites that can provide the necessary information’ (Creswell & Piano Clark, 2007, p. 112). Patton (2002) recommends that sample should include deviant (extreme) as well as typical cases, sensitive and critical participants, a variety of participants (so that even if there are only a few, they are as different as possible) and have an intensity of interesting features. This has parallels with Gerring’s (2007) delineation of case-study selection techniques (see Section 3.3 below).

In such circumstances, theoretical sampling (an important component of grounded theory), which involves ‘seeking pertinent data to develop [an] emerging theory … to elaborate and refine the categories constituting the theory’ (Strauss and Corbin, 1990, p.178), is both theoretically and actually appropriate. Theoretical sampling is related to, but different from, gathering until data saturation point is reached; it involves aiming data-gathering at the explicit development of theoretical categories derived from analysis. The data collection may strengthen categories but also enables the location of gaps within categories and so lead to saturation (Charmaz, 2006).

Theoretical sampling, because it allows the inclusion of ‘variation and process, as well as density’ (Strauss & Corbin, 1990, p. 38), means researchers can remain ‘open to those persons, places and situations that will provide the greatest opportunity to gather the most relevant data about the phenomenon under investigation’ (ibid.

p.177). Especially at the beginning of a project, when one cannot be sure which concepts are theoretically relevant and therefore who are the most opportune people to approach, using theoretical sampling widens the possibilities for data gathering, since ‘openness, rather than specificity guides initial sampling choices’ (ibid. p.178).

A loose design, with relatively unfixed strategies, allows the gradual selection of participants chosen so as to best develop the theory (Creswell, 2007) and thus helps obviate the biases that can arise from convenience and self-selective sampling. Such flexibility to pursue initially unforeseen avenues of exploration that subsequently prove to add new perspectives to the investigation allows researchers to ‘choose those avenues of sampling which bring the greatest theoretical return’ (Strauss and Corbin, 1990, p.177).

To gather a purposeful and illustrative sample of interviewees, the author therefore employed the techniques of snowball sampling (targeting one member of a population, often but not always a member of a difficult-to-reach group, and subsequently asking them to connect a researcher with other members of the group); convenience sampling (using readily-available participants, for example people known to a researcher or their colleagues); and self-selective sampling (using participants who volunteered to take part).

Such sampling techniques combine well with a grounded theory approach to make the best use of the people available within a relatively small population. However, they are techniques that must be used with care, to avoid researcher bias that could compromise the validity of the results (Jensen & Holliman, 2009). Despite the biases they may introduce, they have the advantage that they support the gathering of authentic views and experience from participants without putting too much stress on the constraints on the research project, noted above.

The interviewee recruitment was conducted in two phases: first, fields of research or activity considered to be related to this project and thus likely to offer useful insights were identified and people working in those areas were approached with a request for interview. Some of these potential interviewees were already known to the author, or could be introduced by a colleague, while others had a public presence on the Internet which enabled them to be identified and approached. This first group of interviewees comprised a professional scientist who practices open science, a researcher in public engagement, a member of the public who voluntarily organises public engagement events and an amateur scientist. Consistent with the principles of theoretical sampling (see above), the analysis of the results of their interviews then enabled the identification of appropriate future professional interviewees (or if not specific named people, at least the identification of roles or areas of interest in which interviewees would be needed) as it became apparent where the gaps in data and fruitful avenues for exploration lay. This reiterative process continued throughout the active research period. Ultimately, as well as adding more interviewees in the four areas mentioned above (to mitigate potential bias from single interviewees) the pertinent areas of interest identified through theoretical sampling eventually widened to include: open science sceptics, library studies, information science, public engagement practice, journalism, publishing, digital communications, citizen science and medical research (specifically, charities with interests in patient involvement in research). The identification of potential interviewees in these areas of interest took a three-pronged approach: Internet searching, snowball sampling and searching using research literature and other media. Using more than one approach was necessary to ensure – as far as possible – that no group of potential interviewees was excluded from discovery. For example, those sceptical about open science or the growth in digital media might very well not be identifiable through an Internet search but would be more readily discoverable through output in traditional media.

Members of the public were recruited through an emailed appeal to audience members of the UK café scientifique network. This route was chosen as it enabled the researcher to appeal to an accessible audience, spread throughout the UK, whose members were likely (by virtue of their attending a café scientifique) to be interested in science. However, using this route did mean that the potential pool of respondents was circumscribed and unlikely (though not impossible) to contain people completely uninterested in science. The email was sent to the organisers of 50 cafes and was worded to ask for respondents who were not professional scientists; in the event, a small number of professional scientists responded to the appeal but were not interviewed. None of the members of the public were personally known to the author. It is difficult to estimate the likely pool of respondents but a survey carried out in 2007 (Cafe Scientifique, 2007) suggested the average size of a café audience was 42, so the request could have reached around 2000 people. However, it is not possible to know how many actually heard the request; café organisers may not have received it or may have chosen not to pass it on to their participants and therefore the pool was likely to have been somewhat smaller.

In total, thirty interviews were conducted. Thirteen interviewees were members of the public, twelve were professional or amateur researchers in various fields and five were professional or amateur public engagement practitioners. A further eight potential interviewees either did not reply to requests for an interview (repeated requests were made, to allow for holidays, illness, etc.) or were unable to arrange a mutually suitable time for the interview to take place.

It must be acknowledged that these sampling strategies have contributed to a configuration of a set of interviewees who may be seen as prejudiced towards a positive view of either open science or public engagement with science and this therefore may have affected the findings discussed later. For example, one of the themes which emerged from the early interviews was the potential negative features of open science and certainly, a deliberate attempt was made to invite interviewees who were perceived, through their writing or reputation, as likely to hold sceptical views; unfortunately, none agreed to participate. Therefore, to remediate such gaps as far as possible, the interview questions were developed to encourage the interviewees to reflect on the likely difficulties posed by open science (see Section 4.1.4 below). Further, the author made use of secondary sources, by focussing literature research on, for example, the effects of open access publication, the development of ‘citizen science’ and the effects of the growing use of social media (see Sections 2.2 and 2.3).

Most interviews were conducted verbally, either in person or by telephone, digitally recorded and transcribed as soon as possible. Four interviews were conducted by email, at the interviewees’ request, but were carried out conversationally, that is, the questions were asked singly and developmentally, rather than posed all at once. All the interviews were conducted and transcribed by the author. To avoid a potentially confusing multiplicity of descriptions, in extracts from interviews (see Chapter 4), interviewees have been placed in four categories: (i) member of the public, (ii) amateur scientist (while self-identified as such, this group comprised members of the public with a high-level but non-professional interest in science, evidenced by, for example, journal publications) (iii) professional researcher (this group included both scientists and researchers in other fields) and (iv) practitioner (for example, public engagement practitioner or journalist).

Analytical approach

Consistent with grounded theory, the analysis of interview data was emergent and inductive, with coding categories developed through analysis, rather than designed beforehand. This data-driven approach to analysis – although it must be acknowledged that no one can approach analysis with a completely open mind – allows the researcher to start, as far as possible, with no preconceptions (Gibbs, 2007). As noted earlier, researchers adopting a grounded theory approach must be prepared to acknowledge existing personal biases and be ready to set them aside. In constant comparative analysis (Denzin & Lincoln, 1994), as analysis proceeds, concepts emerge; and as each new set of data is added, it is compared with previously-analysed work. Such necessary re-reading of transcripts and cross-checking of data coding addresses some of the perceived problems of bias, enhances the effectiveness of the grounded theory approach as a methodology and increases reliability (Flick, 2007).

Data from the first four interviews were therefore first analysed manually, to establish a coding frame, and then re-analysed using a standard software package (Nvivo8), to deepen and extend it. (The coding frame will be found in Appendix 8.4.) As each new subsequent interview was analysed, the text selected was compared with previously-coded selections under that category. To increase reliability, a random selection of interviews was re-coded by a colleague unconnected with the project (Lavrakas, n.d.). The two coding sets were placed alongside each other and compared to identify selections placed in the same category and selections placed under different codes, resulting in an inter-coder agreement level of 80%. In addition, some time after all the interviews were completed, the author re-read and re-analysed the entire data set, to enhance consistency and ensure that all the interviews were reliably categorised under the same coding frame.

3.3 Qualitative enquiry: (ii) case study component

This component sought to satisfy objective (ii): through case studies, explore how open science principles are being implemented in practice.

Case study involves the investigation of a ‘contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident’ (Yin, 2003, p. 13). When researchers wish to define topics broadly, include contextual conditions as part of the study, introduce multiple sources of evidence or generally when the phenomenon under study is closely tied into its context, case study can form an essential part of social scientific enquiry (Yin, 1993). Case study may involve either the intense study of one instance, or the study of several systems, over time. This longitudinal element, combined with the ‘natural advantage [case studies] enjoy in research of an exploratory nature’ (Gerring, 2007, p. 39) means this approach is therefore particularly appropriate when a subject is new, its study is novel or the subject is appearing in a completely new way. As the consideration of how open science may support public engagement with science is being studied for the first time in this research, case study was therefore identified as a suitable instrument for enquiry.

A case study schedule can be formulated either in the expectation that it will generate hypotheses and so shed light on phenomena beyond the cases studied, or that it will test hypotheses proposed before the case study begins. Yin (1993) considered case study from the perspective of hypothesis-generation, separating studies into *exploratory* – undertaken to suggest research questions or hypotheses for future study, *descriptive* – presenting a complete description if a topic is embedded in its context and *explanatory* – a study which aims to link causes and effects. In contrast, Stake (1994) categorised case studies from the perspective of the breadth of approach and defined three types: *intrinsic* – the study of a specified particular case to develop an understanding of that case (typical of a medical case study), *instrumental* – the study of a case or cases chosen to allow insight into an issue or refinement of a theory and *collective* – an instrumental study extended into a group of cases, which allows for better understanding and theorising. Gerring (2007, p. 88) emphasised the importance of selection criteria and created a typology of nine types: '*typical, diverse, extreme, deviant, influential, crucial, pathway, most-similar* and *most-different*'. The typical, influential, crucial and pathway types are classically appropriate where hypothesis-testing is a desired outcome and the extreme and deviant types where hypothesis-generating is required. The diverse, most-similar and most-different can be used in both circumstances.

Although open science is a novel approach to carrying out the process of science, none the less there are a number of existing projects which, to some degree at least, espouse an open approach, albeit with different definitions and practices of openness. These projects are likely to have developed strategies that could have a wider applicability. Therefore, in Stark's terms, to inform this research the author sought to select *collective* cases, in Yin's terms *exploratory* cases and in Gerring's terms *extreme, diverse* or *most-similar/different* cases, to support the elicitation of common themes and the derivation of reasonably widely-applicable hypotheses.

In terms of data collection, case study is not necessarily a solely qualitative form of enquiry; the interest lies more in the cases chosen than in the methodology of their study. Therefore, elements of both qualitative and quantitative data collection may be involved (Yin, 1993; Gerring, 2007; Stake, 1994). This means case study rarely relies on a single data collection method but rather, allows the researcher to draw on many different sources of evidence. Sources can include interviews, observations of events and meetings, documents, emails, websites, brochures, press releases, minutes of meetings, branding, logos and environmental elements (Emerald, n.d.). Such use of different sources, together with formal study protocols, has the advantage of increasing validity (Yin, 1993) through enabling cross-comparison.

Observation

Ethnography – the scientific description of a people and the cultural basis of their peoplehood – has developed from its origins as a method of (avowedly though not necessarily actually) disinterested and detached observation of one culture by another. In current practice, an ethnographic viewpoint incorporates the 'otherness' of cultures within the Western societies that had previously provided the observers. However, despite this shift of perspective, 'pure' ethnography fundamentally remains atheoretical and concerned with description. Through the addition of elements of interviewing and archival research, ethnography has expanded to include observation of communities with a common interest, and even of virtual communities (Angrosino, 2007). Whatever type of community is under study, the ethnographical approach relies very much on a researcher's ability to interact with and observe people in the performance of their daily lives.

Ethnographic methods are 'qualitative, inductive, exploratory and longitudinal, [achieving] a thick, rich description over a relatively small area' (Emerald, n.d.). More broadly, ethnographic research therefore usually displays defining features such as an emphasis on exploring the nature of social phenomena, data being unstructured at the point of collection, the detailed investigation of a small number of cases and the product of the research largely being achieved through verbal descriptions and explanations (Denzin & Lincoln, 1994). The chief utility of an ethnographic approach thus lies in its ability to assist with the definition of complex research problems. Examples of such complexities might include the need to study an amorphous topic, the need to identify participants, particularly initially unknown participants who will become obvious through their social setting, or settings in which social processes need to be documented and where research methods must be designed to be appropriate (Angrosino, 2007). These qualities rendered ethnography of particular use in this research, which sought to address the applicability of a new medium (open science) to public engagement purposes and from that study, derive hypotheses of wider applicability.

Ethnography has been adopted as an approach in several different cultures of research, despite the fact that no one ‘single philosophical or theoretical orientation [can] lay unique claim to a rationale for ethnography’ (Atkinson & Hammersley, 1994, p. 257). Rather than being seen as a research paradigm in its own right, ethnography is perhaps better visualised as a process with a number of strands, each of which may be useful for answering different types of research question.

One such strand – observation – was used as an instrument for data collection in these case studies, as described below. Observation is the process through which a researcher watches or listens to actions or events within a context and over a period of time (Hammersley, 2007) and is a key component of ethnography, particularly because observation is usually considered well suited to natural, rather than experimental situations. In the natural situation of a team meeting, for example, interviewing team members involved in the open science components, or distributing questionnaires, would have interfered with the situation being observed (Emerald, n.d.). The value of observation, therefore, lies in its ability to enable the observer to become a ‘temporary member of the setting [and thus] more likely to get to the informal reality’ (Gillham, 2010, p. 28).

The role of the observer can vary greatly but broadly, a distinction can be drawn between non-participant and participant observation. In the former, the observer remains detached and disinterested; in the latter, he or she becomes a member of the group they are studying. Angrosino (2007) refined this broad classification into a four-part typology: (i) the complete observer, in which the researcher remains as anonymous as possible while carrying out their observation; (ii) the observer-as-participant, in which the researcher is recognised as such, but remains detached from the culture under observation; (iii) the participant-as-observer, in which the researcher is a degree more engaged and less neutral with regard to the observed culture; and (iv) the complete participant, in which the researcher integrates fully with the community being observed.

Data collection for the case studies in this research was three-part: first, documentary evidence from the projects’ websites and the materials contained on these websites. These were visited several times over the course of the study, to provide a longitudinal view of their development (where such changes took place). Second, further evidence came from interviews with people involved in two of the projects (Bloodhound@university and DART). Third, for two of the projects (AC and Bloodhound@university), the author was invited to observe a variety of project team meetings. It must be acknowledged that, in part, these invitations were able to be issued and accepted because the projects were led from the university attended by the author, potentially a source of bias. However, attendance at such meetings also supported the obtaining of more first-hand information and therefore a deeper perspective on the issues. In both cases, the observation evolved. At the beginning, the observations were relatively unstructured and the author's participation in the events minimal. Over time, the observations became more structured and the author was welcomed as a participant at events (see Section 3.3 above). Hand-written field notes were taken at meetings and events, including notes of comments and personal reflections on the event (Gillham, 2010) and written up later.

Thus, different patterns of data collection occurred for each project (see Table 1 below). To summarise, for the Artificial Culture project, data were collected through document analysis and observation, for DART through document analysis and interview and for Bloodhound@university through document analysis, interview and observation. These differing patterns largely occurred because the projects under study were at different stages in their lifecycle and provided contrasting degrees of information via the various existing resources. For example, Bloodhound@university and Artificial Culture were already active projects when this research began, and were beginning to develop their open practice, whereas DART began later; its website was in development during the time (Spring 2010 to Summer 2011) in which the case studies were conducted.

3.3.1 Case study selection

As noted earlier, case study tends to focus on the intense study of a small number of cases that in some way represent relationships across a wider group of cases. The value of following a sample of a number of cases lies in the shift of emphasis from one single case and the support for cross-case comparison (Gerring, 2007). Other than for intrinsic studies, it is rarely feasible to represent every possible case in a study, therefore when choosing cases, researchers face the twinned problems of representativeness and selection. However large the number of studies able to be included, the cases observed can only ever be a sub-set of a wider population (Gerring, 2007). In large collections, representativeness may be ensured by some form of randomisation in sampling but the small numbers involved in case studies make this difficult. Therefore, a procedure must be developed to ensure the sub-set is adequately representative, so that within a relatively small number of cases, the phenomenon under study is well covered.

When deciding which case studies to follow, constraints such as ‘access, available resources, research goals, time and energy’ (Strauss & Corbin, 1990, p. 23) inevitably apply. While it would undoubtedly be illuminating to consider as many cases as possible, resource levels dictate that at some point, it will no longer be possible to investigate multiple cases intensively. To support rigorous selection, some form of purposive, non-random, sampling is usually adopted, with cases selected depending on the use to which the study will be put and the quality of representativeness desired (Gerring, 2007). Purposive, rather than random, selection also helps to ensure the uncovering of a maximum amount of information and to ‘help identify the specific conditions and characteristics of a phenomenon’ (Mills, et al., 2010, p. 61).

Different selection methods have been described in the literature. Denzin and Lincoln (1994) suggested developing a typography and using it to create a matrix which thoroughly describes the phenomenon under study. Cases for study may then be selected from as many cells as possible, depending on the resources available. Yin (2003) suggested a replication approach, in which the development of theory suggests the first choice of cases, the study of which may then lead to a re-working of theory (equivalent to hypothesis-testing) and the selection and study of further cases, until the eventual theory saturation allows cross-case comparison and supports final reporting (see Yin, 2003, Fig. 2.5). In this project, given that open science was a reasonably novel method of conducting science, the population of cases (projects) from which to choose case studies was relatively small. It might almost have been possible to treat all discoverable open science projects as deviant or intrinsic studies and describe them individually. However, since one of the objectives was to generate hypotheses regarding how open science affects public engagement with science, Denzin and Lincoln's matrix-selection method was deemed the most appropriate.

The use of a matrix also supports the definition of most-similar or most-different cases, as defined by Gerring (2007). In Most Similar Systems Design (MSSD), the systems chosen should be as similar as possible, to keep a maximum quantity of variables constant. In Most Different Systems Design (MDSD), the systems should be as different as possible with regard to variables. While it is robust in allowing isolation of the variable under study, MSSD suffers from the shortcoming that it may never be possible to keep all explanatory factors constant; however, it is very appropriate in cases where the variables of interest operate at the system level. Although a classic Popperian approach would involve the specification of a number of control variables and one independent variable, a looser application of MSSD is also possible, in which the cases are ‘similar in as many background characteristics as possible, but where the researcher never systematically matches the cases on all the relevant control variables’ (Anckar, 2008, p. 390). Therefore, to select the cases for study, a descriptive decision matrix was created (see Table 1)[21] and used to assess a range of projects against a list of criteria. The development of dedicated selection criteria had the subsidiary advantage that they could be further used in the case study process, to understand to what extent the selected projects had, or had not, been successful in meeting them. Most of the criteria were derived from the literature, with the addition of two factors, specific to public engagement through open science, which emerged from early interviewee data. (For full details of the criteria, see Appendix 8.4.)

The list of projects was produced by carrying out a series of online searches (using Google™) on the search terms ‘open science’, ‘citizen science’ and ‘open access’. The search settings were depersonalised, to reduce bias arising from previous use. Nevertheless, certain limits to this technique must be acknowledged: the use of English search terms tended to limit the results to English-language websites and the use of only one search engine limited the results to projects that had relatively high Google rankings.

The projects were then judged against the specified criteria (see Table 1 and Appendix 8.4), to determine the richest projects for further study. Broadly, the scoring criteria developed fell into three groups. The first group related to the public engagement aspects of the projects, seeking, for example, evidence of participation by both public and experts (Royal Society, Wellcome Trust and RCUK, 2006; Poliakoff & Webb, 2007), evidence of information flow – either one-directional or

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[21] Table 1 lists projects as they existed in February 2010.

bi-directional (ACU, 2002; DIUS, 2008) and evidence of mutual learning and multiple perspectives (Ballard, et al., 2009). The second group of criteria was concerned with the ‘open’ aspects of the projects, for example, were there raw data available (Science Commons, n.d.), a full project description (OpenWetWare, 2009), a permanent record of activity (Poynder, 2008) or access to open source software (Open Source, n.d.). The third group extrapolated into potential criteria that would support public engagement through openness, for example was there evidence of public accessibility (Poynder, 2008), full-text publications (Suber, 2004) or encouragement of public contributions (Nature, 2009; Ballard, et al., 2009). In addition, this group contained speculative criteria that had emerged from early interview data, for example, was there evidence of high public visibility of the project or contextual information (background information, project history and so on.

From this matrix emerged three cases that appeared particularly rich for further study: the Bloodhound@university project, the Emergence of Artificial Culture in Robot Societies (AC) project and the Detection of Archaeological Residues using remote sensing Techniques (DART) project. Although broadly similar in that their matrix scores were close, none the less, they exhibited certain differences. For example, two were entirely academic research projects, one was not; two involved multiple sites, one did not; two had elements of engineering sciences, one did not; one (at the time of selection) offered raw data, the others did not.

Table 1 Case study selection matrix

			Public Engagement				**Open Science**						**Open Science + Public Engagement**						**Data collection (for case studies)**		
Project	Classification *	Discipline §	Public and expert participation	Transfer of information / understanding / opinion	Mutual learning	Multiple perspectives	Raw data available	Full project description	Permanent record of activity	Electronic lab notebook /wiki	Public accessibility	Access to project-derived software	Public accessibility	Full text publications	High public visibility (tagging, etc)	Project context information	Encourages public contributions	Dialogic activities	Website	Interviews	Observation
BBC Amateur Scientist	CS	-													X	X					
Evolution Megalab	CS	Bio	X	X			X	X					X		X	X	X				
FoldIt	CS	Bio	X				X	X				X			X		X				
Galaxy Zoo	CS	Phy	X	X				X							X	X	X				
Open Dinosaur Project	CS	Bio	X				X	X					X			X	X				
Encyclopedia of Life	CS	Bio	X					X	X				X			X	X				
Artificial Culture	OS	Mul						X		X	X		X	X	X	X	X	X	x		X
Bloodhound@university	OS	Eng						X	X		X		X		X	X		X	x	x	x
DIYorg	OS	Bio	X			X					X						X				
myExperiment	OS	Inf					X	X				X		X	X	X					
UsefulChem (wiki)	OS	Che					X	X		X				X							
Open Research Online	OS	-							X				X	X							
Open Science Project	OS	Inf										X			X	X					
OpenWetWare	OS	Bio					X	X		X											
DART	OS	Arch					X	X	X		X		X	X	X	X	X		x	x	
British Geological Survey	OA	Geol						X	X												
Perimeter Institute	OA	Phy																X			
Pulse	OA	-																X			

NB URLs of these projects will be found in Appendix 8.6;
* CS – Citizen Science, OS – Open Science, OA – Open Access
§ Arch – Archaeology, Bio – Biology/bioinformatics, Che – Chemistry, Eng – Engineering, Geol – Geology, Inf – Information Sciences, Mul – Multi-disciplinary, Phy – Physics, - – not applicable.

Of these three projects, two (AC and Bloodhound@university) were both led from the university attended by the author. Additionally, AC was led by the author's Director of Studies. Notwithstanding the high matrix scores – and therefore the potential for wide-ranging deductions – this relationship could undoubtedly have biassed both investigations and reflections. It was therefore incumbent on the author to acknowledge this possibility and to exercise a degree of detachment. This was particularly necessary when observing meetings, first because the author was known to some of the other attendees and second because observation of such events inevitably involves participation to some degree. The fact that the events observed were largely semi-formal team meetings meant the participation of the researcher could be reasonably detached, close to Angrosino's (2007) description of the observer-as-participant. However, although detached, non-participant, observation was not possible, this was balanced by the value of becoming a member of the observed community; a situation which, as noted above Gillham (2010) suggests is likely to enable the observer to understand the situation. Indeed, as Atkinson and Hammersley (1994) argued, in some respects all sociological research is a form of participant observation, since it is impossible to observe the world without being part of it. Therefore, the separation into participant and non-participant may be an overly-simple and relatively non-meaningful dichotomy.

Analytical approach

In designing the analytical approach, further caution was taken to avoid possible bias in interpretation. As noted above, the author acknowledged the need to exert a degree of detachment in the selection of case studies, which also had to be continued into the analysis. The study selection criteria were used to provide an objective basis for analysis and the author was further supported by the two members of the supervisory team who were not part of the case study projects and were thus in a position to offer disinterested advice on research methods and analysis techniques.

Although comparative case studies are valued for the support they offer for the discussion of similarities and differences across a phenomenon, they can be criticised for not gathering sufficient depth of data about each individual case (Mills, et al., 2010). Therefore, it is necessary to observe and collect as wide a range of evidence as possible for analysis.

The basic documentary evidence for the case studies was provided by the websites of the chosen projects. These were visited several times over the course of the study, to provide a longitudinal view of their development. The websites were analysed to establish parameters such as types and quantity of data available, for example experimental data, project documents and publications, existence of news and background information about the project, and numbers and authorship of postings and comments on any project blog.

Further evidence came from interviews with people involved in two of the projects (Bloodhound@university and DART). These participants were interviewed twice – once at the start of the case study and once towards the end. This allowed the interviewees to reflect on developments within and around their projects and the author to compare their responses over time. However, it must be acknowledged that returning to the same interviewees could have introduced an element of bias, in that the interviewees were more aware of the aims and objectives of the research. These interviews were recorded and transcribed, then collected and analysed using Nvivo8. Some of the more widely applicable material from these interviews was included in Section 4.1 below.

For two of the projects (AC and Bloodhound@university), the author was invited to observe a variety of project team meetings. In both cases, the observation evolved. Hand-written field notes were taken at meetings and events, including notes of comments and personal reflections on the event (Gillham, 2010) and written up for later analysis and use. The project leaders also kindly supplied analytic data on website traffic, although as the service providers differed, so did the datasets, and therefore it was not possible directly to compare all the data points for all the projects.

3.4 Quantitative enquiry: survey component

This component sought to satisfy objective (iii): through survey, establish baseline data on the scientific and cultural background, motivations and opinions of visitors to open science project websites.

Quantitative enquiry – the use of statistical or mathematical techniques for conducting investigations – is perhaps more easily defined in terms of the type of data collected than of the methods used to collect it, which may be specific to the experimental situation involved. Although quantitative enquiry is occasionally portrayed as having the aura of somehow being preferable to and of higher quality than qualitative methods, ‘the supposed distinction between qualitative and quantitative evidence is essentially a distinction between the traditional methods for their analysis rather than between underlying philosophies, paradigms or methods of data collection’ (Gorad, 2003, p. 10). Properly used, the empirical techniques of quantitative enquiry contrast with, and support, qualitative enquiry.

Broadly, quantitative enquiry gathers closed-off information, collected as experimental data, instrument readings, checklists, closed-question surveys, or from documents such as census records (Creswell & Piano Clark, 2007). Denscombe

(2005, p. 7) noted that the distinctive features of quantitative enquiry are ‘a commitment to a breadth of study, a focus on the snapshot at a given point in time and a dependence on empirical data’. These features are not unmixed advantages: the data provided by a broad, snapshot survey may not be sufficiently deep and complex, nor provide sufficient context for interpretation, compared to data provided by qualitative investigation. The strategies of quantitative enquiry have much in common with the empirical scientific method, involving the development of methods for measurement, collection of data, data analysis and evaluation of results. Its other major distinction is that whereas qualitative techniques such as interviews and case study target relatively small groups of participants, one of the strengths of quantitative enquiry is its ‘ability to describe a large population’ (Gaiser & Schreiner, 2009, p. 68), although this can mean the researcher must cope with large quantities of data. None the less, quantitative enquiry offers a high degree of reliability, because its techniques are easily replicated and the data produced can be independently verified (McNeill & Chapman, 2005).The nature of open science – that is, the fact that it takes place almost entirely on-line – made a web-based survey the best practical choice for the quantitative component of this research. The Internet was an appropriate milieu in which to establish data on the scientific and cultural background, motivations and views of visitors to the websites of research projects being conducted under open science principles.

Although the use of web-based surveys offers researchers new ways to question participants, new contexts in which to question and the possibility of employing a variety of interdisciplinary approaches (Ess & AoIR, 2002), their use also means that the researcher loses certain contextual information, such as verification of the actual sex or age of the respondent and of the social situation in which the respondent is completing the survey. While the data obtained from surveys can only be taken at face value – for example, believing that the respondents are who they claim to be – a degree of possible error must be acknowledged.

As noted above, one of the features of quantitative enquiry is its ability to gather data from a large population. However, it is rarely feasible to collect data from every member of a population and therefore a decision must be made as to what constitutes an acceptable sample of the population, such that any conclusions drawn from the results can be relied upon to be representative (McNeill & Chapman, 2005; Relevant Insights, 2012). While Gaiser and Schreiner (2009, p. 69) suggested that ‘to be able to make a statement from findings about a given population with some level of assurance, the larger the sample the better’, Denscombe (2005, p. 24) noted pragmatically that ‘the simple fact is that surveys and sampling are frequently used in small-scale research involving between 30 and 250 cases’. In practice, the decision of what constitutes an adequately representative sample size is based on three factors: precision, statistical confidence level desired and the variability or variance assumed in the population (Singh, 2007). A small survey’s credibility can be enhanced by enabling comparisons with other datasets. This not only enhances reliability but enables cross-comparisons if studies include replicable measures, for example by incorporating questions from existing surveys.

3.4.1 Survey design

The issues that need to be borne in mind when designing web-based surveys are similar to those facing the designers of paper-based or face-to-face surveys. These issues include the wording of the questions, completion time, the physical design of the survey, distribution methods, sampling techniques (see Section 3.4.2 below) and obtaining informed consent (Balch, 2010). However, web-based surveys have the particular property of not only being the tool by which the survey is conducted but, because there is no human interviewer present to provide information and guidance, the survey instrument can also offer motivations and stimulations that encourage respondents to complete the survey (Couper, et al., 2002).

One set of design issues concerns the survey questions. First, the questions should be clear, understandable, unambiguous, specific, easy to answer, interconnected and relevant to the research question (Kent, 2001). Second, questions should use response formats that make it easy for participants to complete the survey. Finally, questions should be single and closed, with no ‘double’ questions (for example “who and what would you say are …”), although this does not preclude the use of open questions where appropriate (Greasley, 2008).

Broadly, the questions were divided into three sections. The first concerned the project website from which respondents were recruited to the survey. This section asked questions about their impressions of the site, whether they had downloaded any resources from the site and if so, what they had used them for and whether they would return to the site. The second section widened to consider public participation in science more widely and the third section asked questions relating to the position of science and scientists in society. The full survey will be found in Appendix 8.7.

The questions in the latter section were based on questions used in the *Public Attitudes to Science* series (RCUK/DIUS, 2008). These questions were incorporated to enable cross-comparisons with baseline data of large surveys, as suggested by Brossard, Lewenstein and Bonney (2005, p. 1100), who noted that while ‘good baseline data exist at national and international levels for documenting public knowledge and attitudes towards science, evaluations […] rarely compare their results to that baseline data’.

Survey completion should not take an unreasonable amount of respondents' time; common sense suggests that 'the easier it is to complete a survey, the more likely people will do so' (Gaiser & Schreiner, 2009, p. 71). Opinions vary on the optimum length of time a survey should take to complete, ranging from a few to twenty minutes (Balch, 2010). However brevity is not necessarily a supervening issue: Witmer and colleagues (1999) found that length made no significant difference to return rates, suggesting there may be other issues of concern such as 'ease of answering questions, interest in the topic, and online interaction with the researcher' (cited in Gaiser & Schreiner, 2009, p.70). Informal tests among colleagues, family and friends (of both sexes and ranging in age from late twenties to early fifties) showed the time for full completion of this research's survey to be between ten and twelve minutes. Respondents were free not to answer any question if they chose; no question (other than the age question at the start of the survey) was mandatory.

In terms of the physical appearance of the survey, readability is most easily accomplished when the structure and function of the survey pages are kept as simple as possible, especially in relation to the issue of accessibility for users with visual or physical handicaps (Balch, 2010). It is also important that each question can be clearly seen, together with all its responses and with no one response obviously emphasised (Brace, 2008). To meet these criteria, the survey was therefore created using the commercial program, SurveyMonkey®.[22] At most, four questions were presented on a page, which allowed each question a reasonable amount of space. Although the author could have no control over how respondents viewed the survey, at common screen resolutions, all the possible responses to a question would have

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[22] www.surveymonkey.com

been seen at the same time. A print-style design was used, with a standard, plain, sans-serif font, with black text on a white background.

While in most respects the design of web-based surveys operates under the same principles as paper-based, telephone or personal surveys, web surveys offer extended opportunities for designers to be:

> … more creative in the way in which they ask questions, to ask more complex questions that do not appear to be so, and to use prompt material that would not otherwise be possible (Brace, 2008, p. 150)

While the prompts, motivations and stimuli that web-based surveys can use can be valuable (Couper, et al., 2002), unless a survey is targeted only at people who use specific, probably advanced, technologies (for example a particular web browser or certain software), web surveys should be designed using standard software and interaction objects, so that: ‘a button should look like a button […] not an image that participants might not identify as a button’ (Balch, 2010, p. 25). As noted above, this was achieved through the use of standard online survey software; most questions could be answered by ‘ticking’ one or more (as appropriate) of a range of answers. Many questions also offered free-response text boxes for respondents to complete if they wished.

Invitations to participate in the survey were posted on the front page of four websites (see Section 4.3 below). Consent procedures are discussed later in this chapter (see Section 3.5 below). There was no intercept or invitation; respondents were entirely self-selecting and therefore non-probabalistic. Within the survey, none of the substantive questions was mandatory, which left open the possibility of non-response effects. Response effects are not exclusive to Internet-based surveys; any method of obtaining a response introduces such effects. For example, in interviews, respondents may refuse to answer questions, under-report socially undesirable information (or over-report desirable information), exhibit a bias towards moderate response categories or tend towards agreement with the questioner. However, evidence suggests that there is less distortion in responses to computer-administered questionnaires than to face-to-face interviews (Rowe, et al., 2006). It is possible that the anonymity of self-administered questionnaires (which must include Internet-based surveys) reduces respondents' concern with presenting themselves positively and therefore offers greater data reliability. In this research, it was considered useful to make response voluntary, as some of the questions concerned novel issues or issues of which the respondents might not have experience.

3.4.2 Survey sampling

Web-based surveys potentially have a large target audience but it is very unlikely that the entire audience will be surveyed and therefore, the respondents will be limited to a sub-section of that audience. While the sampling frame and selection technique can be adapted to suit the needs of an individual survey, no online sampling method can guarantee complete representativeness and generalisability (Andrews, et al., 2003). Samples of Internet users are particularly 'vulnerable to systematically ignoring certain attributes of nonusers and generating misleading conclusions about the general population' (Best, et al., 2001, p. 132). Although the same might be said of any sample drawn from a limited population, none the less caution must be exercised when extending conclusions from a sample to the wider public. In deciding on what would therefore constitute a useful sample size, it must be borne in mind that response rates to web-based surveys are both highly variable, ranging from 1 to 80%, and highly dependent on the coherence of the audience at which the survey is targeted (Truell, et al., 2002; Deutskens, et al., 2004; Ray, 2008).

Data on numbers of website visitors to two open science sites (obtained via personal communication) showed an average of just over 100 visits per month over the eighteen-month period between October 2008 and April 2010. Approximately half of these visitors were first-time and half return visitors. If this research's survey had been online at one of these sites for six months and achieved a very modest response rate of 5%, this would have resulted in 30 responses – clearly at the lower end of an acceptable range (Denscombe, 2005). Assuming a confidence level of 95%, response percentage of 50%, margin of error of 10% and population size of 600 (Relevant Insights, 2012), an acceptable sample size would have been closer to 90 respondents but it must be accepted that this is still not a very large number from which to generalise.

Response numbers can be increased either by leaving the survey in place for longer or by increasing the number of locations from which the survey is available. As linking the survey to more than one website had the additional advantage of widening the sample of potential respondents, this was the method chosen and the survey was eventually linked to four websites (see Section 4.3 below).

Even though the survey was linked to a number of sites, the audience was, none the less, restricted. It was in the first place limited to those people who chose to visit the websites to which the survey was attached and furthermore, to those of that group who elected to complete the survey. As previously discussed, any sampling approach introduces error, through over- or under-representation of particular cases, compared to the population as a whole. For example, the sex, age or geographical location of respondents may be unrepresentatively skewed (Best, et al., 2001; Kent, 2001). Self-selected sampling (as in this survey) makes it difficult to operate any kind of quota or systematic sampling targeting specific demographic groups. However, the survey did ask for biographic and geographic data (although a response was not mandatory), to enhance understanding and analysis and make it possible to adjust for obvious biases in a self-selected sample, by weighting the results and enabling analysis against particular criteria, for example respondents' location or sex. (Kent, 2001)

Analytical approach

As noted above, the survey data were collected using SurveyMonkey® software. This gathered the data on to Excel™ spreadsheets, one for each collector (website). Each respondent was automatically allocated a unique identifier and their responses were codified numerically, separately for each question. The data were imported into SPSS19 by hand and checked for errors relating to completeness, range validity, routing and consistency (Bethlehem, 2009). They were then synthesised and analysed using SPSS19 to record the questionnaire data numerically, graphically and in tabular form. The majority of the responses to the survey were categorical variables, capable of being summarised in univariate measures and, where appropriate, as bivariate cross-tabulations to measure the strength of association between two variables, for example occupation and view of ease of use of website.

In the design of the survey, no questions (other than the 'adult' question) were mandatory (see Section 3.5 below). As described above, this left open the possibility of item non-response, which tends to increase bias and put validity at risk (Bethlehem, 2009). Analysis of any individual question was based on the number of responses to that question, rather than the total number of responses, although in some cases this raised issues regarding whether useful conclusions could be drawn from relatively small numbers of responses.

3.5 Ethical Issues

Ethical approval for this project was completed via the University of the West of England's Faculty of Health & Life Sciences Research and Governance System.

Any research involving human subjects requires the researcher to consider its ethical aspects; ethically sound research, appropriate to the style of research and the subjects involved, supports both the subjects' and the researcher's well-being and safety and the researcher's contribution of new knowledge to the scientific process (Flick, 2007).

In personal interviews, strict ethical conditions may be 'incongruent with interpretive and interactive qualitative research methodologies' (Kvale, 2007, p. 25) and could be seen as militating against the production of rich data. Therefore, while trying not be unduly restrictive, at the same time procedures were set up to ensure that all interviewees gave their fully-informed and entirely voluntary consent, that participants' confidentiality was ensured and their privacy respected, that harm was avoided and participants' well-being considered, that there was no omission or fraud regarding the data collection or handling, and that the outcomes of the research in the context of the wider research community were considered (Gregory, 2003; Flick, 2007).

For this study, to obtain the informed consent of interviewees, a request for interview was sent by email, with a brief outline of the aims and purposes of the research and what was offered in terms of the location, medium and length of the interview. Interviewees signed and returned a consent form before the interview (see Appendix 8.1) and were supplied with an information sheet with details of how to contact the author for further information. The eventual transcripts of the interviews were shared with the interviewees, to allow them to check and point out errors that arose, whether from inaudible recording, amateur transcribing or other causes (Lather, 2007). Transcripts were sent to interviewees as soon as possible after the interview.

Making data collection anonymous is conventional practice and commonly seen as an effective way to assure interviewees of the confidentiality of their comments (Gregory, 2003). However, as at least some of the interviewees in this research were people already committed to openness in their personal research behaviour, a departure from convention was included, in that interviewees were given the choice of either to be anonymous or to allow their names and other identifying factors to be disclosed as part of the process of dissemination of information. This was made clear by offering interviewees two consent forms (anonymous and non-anonymous) from which to choose. For this reason, in the results reported later (see Chapter 4), some interviewees are identified by their real name, while others remain anonymous.

Informed consent is less easy to obtain for a web-based survey, as it is not generally possible to acquire a signed consent (Balch, 2010). For this reason, an introductory page, with information on the context of the research, formed the first part of the survey. Only adult respondents (over 18 years old) were sought and no questions were mandatory, thus meaning that the disclosure of biographical or geographical data was a matter of choice. Respondents were informed they could (before a given date) request their data be deleted. To achieve this, respondents entered a four-digit code of their own choice, which if emailed to the author, would have enabled the identification and removal of their data. In the event, no requests were made for withdrawal, either of interviewee or survey data.

Storage of personal data within the UK must meet the principles of the Data Protection Act (1998) regarding how data are obtained, processed and stored (ICO, n.d.). To meet these requirements, all data were stored on a password-protected computer in password-protected files, with strict conditions in place to prevent them being passed on to any third party. Any material that was printed out (including consent forms) was stored in a locked drawer in the author's office. In addition, the web survey was designed using software that met the principles of the Act, as some common programs store information in jurisdictions beyond the European Economic Area, which may not meet its strictures.

As described in Section 3.3 (above) the case studies presented possible opportunities for bias, in that two of them were led from the author's university. One solution could have been to choose other projects; however, given that these projects emerged from a decision matrix as having the richest possibilities for study, any second choices would have offered more limited scope.

In the data collection phase, the documentary study was focussed on the projects' websites and the publicly-obtainable material on them; for this, no personal contact was sought or needed. Interviews were conducted with members of two of the projects (see Table 1); the same consent protocols were followed as for the interview component (described above). No interviews were conducted with members of the project led by the author's Director of Studies, to avoid possible partiality. The author sought to minimise the bias that could have arisen when attending meetings with people known to her by adhering to a set of personal rules: (i) confining her role to observer as far as possible, unless directly questioned or referred to and (ii) taking notes at meetings that were written up later, offering the opportunity for reflection and deliberation. In the interpretation, the author sought to avoid bias first by making use of the projects' own terms of reference to judge their achievements, second by judging the projects against a defined list of criteria (see Table 1) and third by making use of the members of the supervisory team who were not involved in the case study projects.

Chapter summary

This chapter has considered the methodological basis for this research. The route chosen was to use a mixed methods approach, involving interviews, case studies and a web-based survey. Given that open science is a new field of study, with immature theories and constructs, limited existing practice and therefore limited existing data from which to derive hypotheses, a grounded theory approach was used in the qualitative components of the research, to enable theory to emerge from data. In addition, participant observation techniques were employed, particularly in the case study component. These were supported by the use of a web-based survey to provide data on opinions of visitors to open science project websites both about the websites they visited and public participation in science. This use of mixed methods supports methodological triangulation and allows each component to contribute towards the credibility and validity of the overall research.

Chapter 4. Results

This chapter presents the results from the three components of this research: interviews, case studies and online survey. Thirty interviews were conducted, three case studies were carried out and the survey was placed on four websites.

4.1 Interview data

As discussed previously (see Section 3.2 above), the interview data were coded using a grounded theory approach, allowing the coding themes to emerge through repeated constant comparative analysis (Denzin & Lincoln, 1994), rather than being designed beforehand.

The full coding frame can be seen in Appendix 8.4. The three major node headings covered (a) data related to open science, (b) data related to public engagement and (c) data related to open science and public engagement. Within each of the major headings, sub-nodes emerged which were then cross-linked into the themes discussed below: (i) what is meant by open science, (ii) what new opportunities are offered by open science, (iii) the motivations for practising open science, (iv) the difficulties inherent in practising open science and (v) what methods and tools will be needed to practise open science.

As discussed in Section 3.5 (above), in a departure from standard practice – but one the author considered to be consistent with the open practice of some interviewees, interview participants were asked whether they wished to be anonymous or to allow their name and other identifying factors to be used. Table 2 lists the interviewees, together with brief biographical details for those who chose to be identified.

Table 2 Interviewees

Identifier	Description	Details	Method of interview	Date of Interview
Beck	Professional researcher (archaeology)	Research Fellow, Computing, University of Leeds, UK; Project champion and grant holder for the DART project (see Section 4.2.3). Remote sensing specialist and consultant, including GIS, data management, knowledge management and field capture. NESTA Crucible programme member.	Phone	6.5.10 & 27.5.11
Bradley	Professional researcher (chemistry)	Associate Professor of Chemistry and E-Learning Coordinator for the College of Arts and Sciences, Drexel University, USA. Leader of the UsefulChem project, which aims to make the scientific process as transparent as possible by publishing all research work in real time	Email	5.3.10
Hendy	Professional researcher (physics)	Professor of Physics, Victoria University of Wellington, New Zealand. Research interests in Computational Materials Science and Nanotechnology particularly the theoretical description and modelling of nanostructures at the atomic scale. Blogs at http://sciblogs.co.nz/a-measure-of-science/	Phone	10.9.10

…/cont.

Holliman	Professional PE researcher	Senior lecturer in Science Communication, Open University, UK; research and teaching interests in how (techno-) sciences are communicated via a range of media and genres, and how ideas about (upstream) public engagement with science and technology may be shifting and extending social practices.	Phone	17.9.09
Horton	Amateur scientist	Amateur meteorologist; host of local weather data site: http://www.afour.demon.co.uk/weather1.htm	In person	8.7.10
McCracken	PE practitioner (online events)	Managing Director of Gallomanor Communications, which specialises in citizen engagement campaigns and e-democracy. Gallomanor run the "*I'm a scientist, get me out of here"* project, a free online event in which school students interact on line with scientists.	In person	6.6.11
Millard	Professional researcher (information science)	Senior Lecturer of Computer and Web Science, University of Southampton, UK. Associate Director for Research in the Centre for Innovation in Technology and Education (CITE), which aims to create 21st century learning tools for University staff and students and develop a more digitally literate university community.	In person	8.9.10 & 31.8.11

…/cont.

Murcott	PE practitioner (journalist)	Science journalist, writer, science correspondent and radio producer; programmes include Home Planet and Connect for BBC Radio 4. Part-time lecturer in science communication at the University of Glamorgan. PhD in biochemistry.	In person	1.4.10
Nason	Amateur scientist	Professional artist; amateur scientist interested in robotics, artificial intelligence, evolution and biology. (Location and further details withheld by request.)	Email	12.10.09
Neylon	Professional researcher (physics)	Interdisciplinary biophysicist; advocate of open research practice and improved data management. Senior Scientist in Biomolecular Sciences at the ISIS Neutron Scattering facility at the Science and Technology Facilities Council (STFC).[23] Research and writing focusses on the interface of web technology with science and the successful (and unsuccessful) application of generic and specially designed tools in the academic research environment. Founder member of the Open Knowledge Foundation Science Working Group; blogs at http://cameronneylon.net	In person	27.7.09

…/cont.

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[23] Since March 2012, Director of Advocacy at the Public Library of Science (http://www.plos.org/staff/cameron-neylon/)

Raddick	Professional PE researcher	Education and Public Outreach Specialist in the Department of Physics and Astronomy, Johns Hopkins University. Member of the Galaxy Zoo project.	Phone	31.3.10
Sanderson	PE practitioner (broadcasting)	Former science television producer, explored alternative approaches to public service children's media via the NESTA/Institute of Physics-funded project Planet SciCast (www.planet-scicast.com). Consultant, trainer, lecturer and workshop leader on science/media/web projects; clients include the STFC, Wellcome Trust Sanger Institute, the Royal Observatory, Edinburgh, and the National Coordinating Centre for Public Engagement.	In person	18.11.09
Anonymous 1[24]	Member of the public		Phone	4.11.10
Anonymous 2	Member of the public		Email	30.3.11
Anonymous 3	Amateur scientist	(artificial intelligence)	Email	6.11.09
Anonymous 4	Professional researcher (Librarian)		In person	1.12.09
Anonymous 5	Practitioner (repository)		Phone	15.4.10
Anonymous 6	PE practitioner (events)		In person	15.6.10
Anonymous 7	Member of the public		Phone	1.11.10
Anonymous 8	Member of the public		Phone	28.8.10
Anonymous 9	Member of the public		Phone	21.3.11

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[24] Members of the public were not asked for any biographical information other than to establish that they were not professional scientists

Bloodhound@university 1	Professional researcher (engineering)		In person	12.5.10
Bloodhound@university 2	Professional PE researcher		In person	13.7.10 & 3.5.11
Cumming	Member of the public		Phone	28.9.10
Eaton	Member of the public		Phone	2.11.10
Foster	Member of the public		In person	2.9.09
Guinamard	Member of the public		Phone	2.11.10
Marks	Member of the public		Phone	1.11.10
McKay	Member of the public		Phone	2.11.10
Pepperdine	Member of the public		In person	6.7.10

4.1.1 What is open science?

> *On the face of it, open science, it could be anything* (Foster, member of the public)

As noted in Section 2.2 above, open science is still a young concept and practice. As might be expected of something that is relatively new in the professional and public consciousness, definitions of open science therefore varied greatly among interviewees. Some were not aware of the concept or hadn't heard the term before:

> *Really, I don't know what that means – is it something to do with open university? ... doubt it ... I really don't know.* (Anonymous 1, member of the public)

However, some interviewees, even those who hadn't previously heard of the precise term 'open science', linked it to activities of which they were already aware:

> *I hadn't heard the term before but as soon as I saw it, I knew exactly what it meant. I'd heard of SETI and the protein-folding stuff, and various mathematical things, like prime searches [...] I think of public participation in the data collection area at least.* (Pepperdine, member of the public)

Other interviewees made a link between 'open science' and other 'open' activities, particularly if their background was in an area where openness has already made an impact. Horton, as well as being an amateur scientist, had a background in computer programming, so knew about the existing open source movement and therefore extended this understanding:

> *Because I've got a computing background, I kind've understood it as open source. I know about open source, so I had heard about it but I didn't really put it together as open science.* (Horton, amateur scientist)

Overall, as Millard recognised, there is by no means a consensus about definitions of open science:

> *... it's such a multi-faceted word. ... used in different contexts in different ways. I would personally use the term 'open' to a certain extent to talk about the transparency that we've mentioned, about allowing people to see what's going on; that's an important aspect of being open ... I would say that being open means having visibility and transparency and probably some level of engagement.* (Millard, professional researcher)

It should be noted that many of the interviews were conducted at a time when access to climate information data was a prominent topic in the news, which may have influenced interviewees' thinking about data availability and the importance of transparent practice. As Millard's comment showed, some researchers extended the idea beyond records and data to include transparency and visibility; others extended this to a sense of transparency of process, although they expressed a parallel diversity of views about what was included in 'process':

> *... you could open it out further ... what are all these different types of jobs that scientists do on a routine basis? ... there's an awful lot more going on around the open thing than just the process and product, I guess is what I'm trying to say.* (Holliman, professional researcher)

Researchers who have already adopted an open practice agreed that open science involves the sharing of information and data but even they reflected that there is a variety of practice and activity under the label. (Neylon and Bradley are both researchers prominent in the open science/open data movement):

> *What* I *take it to mean is the movement that advocates making more of the research record available. The reason why I'm quite so vague about it is precisely because there is very little agreement.* (Neylon, professional researcher)
>
> [Open science] *means sharing more data than you otherwise would as a scientist. It ranges from simply making regular articles free to the public (Open Access) to sharing every detail of laboratory work in progress (Open Notebook Science).* (Bradley, professional researcher)

Bradley's comment shows further that open science need not necessarily be a radical change to researchers' behaviour; it can be a gradual shift of emphasis and involve a range of activities.

While professional researchers tended to employ the concepts of sharing, visibility, transparency and engagement, some members of the public expressed a perspective that could be described as close to a 'deficit view'; conceptualising open science as potentially a scientist-led mechanism for conveying information or explaining new work:

> *I imagine open science is making science open to non-scientists to understand and get interested in.* (Marks, member of the public)
>
> *... the opportunity to explain it to the general public, not only to the community that the research is in.* (Cumming, member of the public)

Marks's and Cumming's comments support the argument, discussed earlier, that even within dialogic engagement models the deficit view is persistent, surviving within and alongside more conversational and less hierarchical models (Trench, 2008b; Davies, 2009a; Wilkinson, et al., 2011b). However, McKay, while bracketing his comment with notions of transmitting information and demonstrating the benefits of science, also extended his conceptualisation of open science into regions beyond science and into policy:

> *Conveying the results to the public, to non-scientists ... particularly, I'd suggest, about the political and ethical implications of the issues science raises. To my mind, that's the most important thing; people don't necessarily need to know all the nitty-gritty details of the research. […] It's got to be about distilling the implications of that, so that public policy can be steered in an informed way. And also so that people can see the benefits and values of science.* (McKay, member of the public)

This amalgam of interpretations is reflected in other comments from members of the public. For example, some explicitly included elements of non-hierarchical engagement and collaboration between members of the public and professional researchers in their descriptions:

> *... science with lots of people taking part ... big experiments, with lots of people doing the same thing ... Science by non-professionals* (Eaton, member of the public)
>
> *... collaboration between researchers nested in established academic or professional institutes and willing participants from the general public. But the public is not a 'guinea pig'; rather, they are on the same side of the metaphorical microscope as the researchers.* (Anonymous 2, member of the public)

These comments are interesting in that they include not simply collaboration between professionals and non-professionals but egalitarian collaboration between researchers and the public. Professional researchers likewise noted open science could support dialogue, exchange and collaboration between members of the public and professionals:

> *Rather than just access information and do something separate,* [science] *becomes something they genuinely have some input into … something that has some kind of two-way exchange, so people can do something that they can put back in …* (Bloodhound@university 2, professional researcher)

The existence of considerable diversity in the conceptualisation of participation and contribution has been noted above (see Section 2.3). Members of the public participating in an activity may express a preference for receiving current information and listening to experts' views and perspectives, even though they may feel perfectly able to contribute their own views if necessary (Wilkinson, et al., 2011b; Lewenstein, 2011). Similarly, even the instigators of activities described as participatory may none the less construct them as locations for knowledge production and education, rather than collaboration and discussion (Braun & Schultz, 2010). Therefore, while it is unsurprising that some interviewees understood open science in terms of knowledge-transmission, it is notable that the potential for collaboration was expressed both by members of the public and scientists.

4.1.2 What does open science offer?

> *It's not about knowing details or technicalities; it's about knowing and understanding how science is done … the whole process of science.* (Murcott, practitioner)

The beneficial features most often mentioned in connection with open science can be grouped into two categories: authenticity and transparency, and the potential to bring together new collaborators.

Considering first the concept of authenticity and transparency, as noted above, several interviewees' definitions of open science mentioned its ability to capture a complete record of 'the day to day slog in the laboratory, the grant application process, the paper-writing process, the interactions, the meetings' (Murcott, practitioner). Open science thus has the potential to reflect science in action:

> *You give people a window into science as it's going on. You can see ... some of the mistakes and some of the strangeness of science.* (Raddick, professional researcher)

Such real-time, complete accounting of processes is made possible both by the use of specialised tools and techniques (see Section 4.1.5 below) and also by using widely-available social media tools. Hendy described how one of the tools he used – blogging – supported this accountability:

> *When you're writing a paper, it's very much about the perfect, I understand it all, we've completed this piece of work and it's now part of the record and we'll all move forward from here. Blogging's different. It's more real*-time *and it shows the full processes you've gone through, the discussions with people. That's nice.* (Hendy, professional researcher)

Bradley also noted that open science reflected the complexity, ambiguity and uncertainty of science, even to other scientists, and also how this can be resolved through discussion:

> *I have yet to work on a scientific project that did not have lots of ambiguous results. We can get to the truth much more quickly by openly discussing these ambiguities and not giving the impression to scientists that progress along a single track is the only research outcome that should be rewarded* (Bradley, professional researcher)

Authenticity, honesty, 'real-time', sharing the 'full process' all imply that researchers must be ready to share problems as well as successes. The sharing of failure can be valuable not only scientifically, but also economically. As an editorial in *The Economist* in 2009 noted: 'At present, scientists often share only the results of successful experiments […] endlessly re-running failed experiments helps nobody' (The Economist, 2009, p. 18). Although acknowledging failure may not be easy, Cumming neatly encapsulated the value of such transparency:

> *... pushing back the boundaries of knowledge means finding things that are not going to work, as well as finding things that are going to work. So I would expect them to say 'we're doing this because we hope to find so-and-so; we really want to find out if this is going to work or not; whether there's some point to pursuing this or whether it's simply a dead end'. Knowing things that don't work out is just as important as knowing those that do.* (Cumming, member of the public)

Such transparency and completeness also has the potential to bolster levels of trust among different participating communities, through the provision of the rich circumstantial context, data and information that enable observers mentally to reconstruct an experimental scene. As Shapin and Schaffer (1985, p. 60) argued, such 'virtual witnessing […] constitutes a powerful technology of trust and assurance that the things [have] been done and done in the way claimed'. Replication, alongside peer review (as described in Section 2.2.3 above) and publication are the basis of the informal quality assurance system that has served science since the seventeenth century. The rise of the use of digital media challenges these practices but at the same time, creates opportunities for wider involvement (Ravetz, 2012).

Second, as introduced in Section 4.1.1 above, interviewees reflected that open science has the potential to bring together new contributors, both other professionals and interested amateurs:

> *We're working towards trying to write and submit an astronomy paper about irregular galaxies, where the first professional scientist-author will be fifth or sixth author down the list and the entire project will be co-ordinated by volunteer citizen scientists.* (Raddick, professional researcher)

Collaboration and dialogue through open science can provide a route for information not just from corporate or institutional providers to members of the public but also for contributions to come from amateur scientists, members of the public and similar groups. This would both increase the pool of collaborators available and also offer, as Anonymous 3 noted, a route for amateur scientists to enter the mainstream:

> *In theory, my own papers would also be made available to a wider audience and in this way they could finally enter the main stream of scientific discourse*. (Anonymous 3, amateur scientist)

New participants inevitably bring new skills. Both professional researchers and members of the public recognised that the collaborative possibilities in open science may enable new kinds of participants to make discoveries that will benefit science:

> *the fact they've got all these amateur ... amateur but interested people watching means they might discover something they wouldn't have spotted themselves.* (Anonymous 7, member of the public)
>
> *... there would be a chance that a member of the public could do the analysis. And if they saw something before the scientists did, that would be a big bonus for everyone.* (Pepperdine, member of the public)
>
> *If you underestimate the intelligence of your audience, you'll get what you expect. If you allow them – the audience, the community – if you allow them to surprise you then they will.* (Neylon, professional researcher)

The value of extending the range of collaborators, for example by welcoming the contribution of amateur participants, was noted by some interviewees:

> *not just crowd-sourcing data, but also crowd-crunching as well […] Galaxy Zoo and Fold-it come to mind.* (Anonymous 2, member of the public)

Galaxy Zoo[25] is a well-known example of a Citizen Science project, which used an enormous corps of volunteers (estimated at about 200,000 at its height) to classify very large numbers of images of galaxies. Not only has this volunteer effort supported the publication of several papers by the professional astronomers leading the project (see for example Lintott, et al. (2010)) but new discoveries have been made and published by amateur participants (see for example, Cardamone, et al. (2009)). However, as noted in Section 2.3.4 above, non-professional participation in 'Citizen Science' projects, while embraced by considerable numbers of people is, in many examples, limited to data gathering and organisation. As McCracken commented, for some, such modes of participation can be unsatisfying:

> *I look at the Galaxy Zoo-type stuff – and I've participated in one or two of those on a very small basis – and I found they didn't seem to be using me as a scientist but just as a ... ... what would be the right word? Just as a clerk ... Amazon has a thing called 'the mechanical Turk' and that's what it feels like: 'look at these two images, do another, do another'. That, to me, is slightly disappointing.* (McCracken, practitioner)

It is possible that the collaborations supported by open science will enable amateur participants to be more than 'clerks', as McCracken described it. As science seeks to involve non-professional groups in greater numbers and to move the initiation of

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[25] http://www.galaxyzoo.org/

research questions further and further upstream (Wilsdon & Willis, 2004) (see Section 2.3.3 above), such active involvement will become increasingly important:

> *If we don't share data with different user communities, then it becomes an ivory tower endeavour, just self-iterative and – in my opinion – serving a very limited purpose. Academia just isn't like that anymore.* (Beck, professional researcher)

Involvement throughout the process, supported by open science, could enable wider community participation in developing research questions and designing the methodologies, as well as contributing or analysing the data. Thus, open science could be seen as a means to reduce the (whether real or perceived) isolation of science and increasingly site it in new, extended and 'real world' communities.

4.1.3 Why practise open science?

> *I think it's a duty to engage, to be more open.* (Millard, professional researcher)

As discussed in Section 2.3.1 above, scientists have expressed a diversity of motivations for participating in PEST activities. Some motivations were intrinsic, either personal, such as the development of new skills; or more altruistic, arising from a sense of duty or an acknowledgement of the importance of communicating with the wider public. Some motivations were extrinsic, such as the need to respond to funders' mandates for accountability and the dissemination of research outputs, or a desire to further a career (Wellcome Trust, 2000; Burns, et al., 2003; PSP, 2006; Poliakoff & Webb, 2007; Burchell, et al., 2009).

Similar patterns can be seen in interviewees' responses. For professional researchers, the motivations for practising open science may be grouped into five categories: ethicality and accountability, enhancing the value of research, enhancing repeatability and scrutiny, improved collaboration and lastly, inevitability.

First, researchers expressed a sense of duty; that being open was simply the proper way to conduct research:

> *I think ... it feels right. Ethically, it feels like the right thing to do.*
> (Beck, professional researcher)

Others extended this into a sense that being in receipt of public funding carries certain obligations. Funding bodies are increasingly committing to strategies for accessibility and dissemination, creating 'guiding principles that publicly-funded research must be made available to the public and remain accessible for future generations' (Research Councils UK, 2009) and researchers were aware of this:

> *On the 'must' or the 'pushing' side, there's obviously funder policy. I have a suspicion that we're moving pretty steadily towards an environment where funders just dictate but I don't think funders will take the final step of driving to instantaneous release.*
> (Neylon, professional researcher)

Researchers in receipt of grants will of course be aware of funder mandates, although the extent to which they are followed is still variable (see Section 2.2.2 above). However, the sense of obligation can also be personal; acknowledging a direct link between publicly-funded research and the public who pays for it:

> *We have paymasters; that is, the public [...] because the vast majority of the money that I get comes from the public purse, I do need to respond to what the public want ... to provide information to them, access to data so they can do with the data what they will.*
> (Beck, professional researcher)

Second, there was a sense that openness increases the return that can be obtained from research, thus demonstrating its value not only to funders but also to the wider public:

> *... with the current financial situation, showing public value – value to the public in general, rather than just to your students – I think is important.* (Millard, professional researcher)

Anonymous 4 also noted the possibility of enhancing the value of a piece of research by enabling re-use and re-purposing of datasets:

> *There is – nationally, internationally – a concern that not only should the research be made widely available but also the dataset should be there [...] What a lot of public money to spend on gathering the data, out of which a single piece of research has been done. That data might actually support all sorts of other enquiries and it's such a waste of that resource not to make it available to people.* (Anonymous 4, professional researcher)

A third issue raised by interviewees was the possibility that openness could not only support traditional means of scientific validation such as reproducibility and scrutiny but also bring in new kinds of scrutinisers. Scrutiny by many eyes, whether or not they belonged to professional observers, could increase the pace of science:

> *Scrutiny is just another word for feedback. The more feedback we get the faster we can get things done. I think a problem arises when there is an incentive to promote scientific work with hype, which involves showing one's work only in a favourable light. Then scrutiny can lead to the realization that things are not as clear-cut as they might have seemed initially.* (Bradley, professional researcher)

Nisbet argued that communication inevitably involves negotiation of meaning and that 'scientists must strategically "frame" their communications in a manner that connects with diverse audiences' (Nisbet, 2009, p. 3). Bradley (above) and Beck (below) could be seen as suggesting that openness could enable both a more neutral and more complete framing:

> *My aim is that we do the joined-up thing – we have data, we have algorithms, we have papers, so the research will be reproducible … you can see what we've got, you can see how we've processed it and you can see how we've synthesised it.* (Beck, professional researcher)

Inevitably, the means which researchers use to engage in communication affects which communities are able to engage: some communities are hard to reach and thus excluded from debate (Lezaun & Soneryd, 2007). Anonymous 5 sought to extend the reach of his output to a wider community by maintaining a blog but, as he notes, his readership, while greater, is nevertheless still limited to those who choose to read and use blogs:

> *I felt a blog would be a good way to keep […] academics informed – or at least those who use blogs. But also to engage with the repository community.* (Anonymous 5, practitioner)

Fourth, extending the idea of sharing research outputs, whether within a community of practice or beyond into a wider community, interviewees suggested that openness could overcome geographical boundaries and support greater communication, connections between researchers and collaboration among researchers:

> *We're a small country – you don't have many peers, people you can work with, in New Zealand. […] You don't have the opportunities for interchange of ideas.* (Hendy, professional researcher)

Hendy's location and comments especially highlight the potential for open science to support trans-national, multiple-site collaboration. (This is further explored in Section 4.2 below.) But whether the collaborating sites are within one country (as for Beck, below) or multi-national (as for Bradley, below), open science could offer pragmatic solutions to the difficulties of aligning practices and methods among collaborators and at the same time foster honesty and transparency:

> *We have Principal Investigators running at five or six different universities ... data sharing is going to be an inevitable issue, so let's do something where we can all benefit and everyone else can benefit by proxy.* (Beck, professional researcher)
>
> *The most tangible benefit of working openly has been finding collaborators who also feel strongly about working openly. […] I think it also keeps the work as honest as possible. Since people will see all the data it makes it harder to hype results.* (Bradley, professional researcher)

However, it should be noted that online collaboration is perforce restricted to those who have access to an adequate technology infrastructure. Online engagement can extend the reach to new participants but by no means guarantee it; as noted in Section 2.2.4 above, world-wide access to online services remains very uneven (World Bank, 2011; USC Annenburg, 2011).

While processes and procedures are important, for the overall coherence of a project it is 'the practice of the people who work in the organization that brings process to life and indeed, life to process' (Brown & Duguid, 2000, p. 96). Both professionals and members of the public recognised the social context of collaboration:

> *... what you need as well as the technical fix is, of course, all the social practices that sit around it.* (Holliman, professional researcher)
>
> *Reporting what's happened is important but science is not done in a vacuum. Science is done in a social ... it is a social construct.* (Murcott, practitioner)

> *… if you don't have a social side to it, it won't work, because people won't get anything out of it. You can't expect people to put something in if they're not going to get anything out. It doesn't have to be anything particularly concrete either; so long as there's a community feeling.* (Pepperdine, member of the public)

Interviewees identified the need for the development of shared manners and ethos among researchers. Researchers working in the same office or lab can form a 'community of practice' (Wenger, 2000), where behaviours can arise from the interplay between proximity and experience but for disparate groups, implementation may have to be more explicit:

> *Trying to provoke a sense of community among a dispersed group of academics who haven't met each other is really hard. […] It helped that we'd explicitly vocalised and talked about was what sort of culture and community we wanted. Not necessarily set any guidelines; just raised the issue and raised the idea that it could go very badly wrong and that we couldn't afford it to.* (Sanderson, practitioner)

Even with supportive practices or technologies in place, it can be hard to support the sense of collaboration among far-flung partners. Hendy, for example, works in New Zealand but has collaborators around the world. He suggested that online collaboration might not suffice alone:

> *I work with people in the UK, in the United States, but I find we get a lot more work done when I fly there or they fly here. It's interesting how someone who can personally walk into your office can grab your attention, an hour of your time in a way they can't on Skype […] It's certainly easier to work with people in your local proximity than it is to keep these far-flung collaborations going. There's the time-zone issue as well. And you can't nip out to the pub!* (Hendy, professional researcher)

However, Millard and Sanderson noted that the act of collaboration itself can provide the means to overcome such difficulties:

> *We like to work in a way that's quite participatory, so we work with [colleagues] to try to figure out what they want and what the barriers are to their use and then we try and solve those problems.* (Millard, professional researcher)
>
> *... we increasingly have academics who are willing and able and have the tools and techniques available to talk about and discuss their work in a very open and ... bi-directional manner.* (Sanderson, practitioner)

Finally, some speculated that openness will, sooner or later, simply become the way science is done:

> *It could be that some as yet unforeseen process may force established institutions to embrace 'open science' to the benefit of us all.* (Anonymous 3, amateur scientist)
>
> *The argument that I and others make is that if you want to be in the information web, then you have to make the content available. If you're not wired in, then you go nowhere […] If you follow that through to its logical conclusion anyone who wants to get ahead is just going to have to live with it.* (Neylon, professional researcher)

Both Anonymous 3 and Neylon's comments express a degree of negativity; that openness may be 'forced' and 'just have to be lived with'. In this way, they reflect the comments of the Russell Review (into the aftermath of the leaking of emails from the University of East Anglia's Climatic Research Unit), which noted that demands for access to data and for the opportunity to comment on and challenge science are a 'fact of life' and indicative of a 'transformation in the way science has to be conducted in this century' (Russell, 2010, p. 15).

Although not as well investigated as scientists' motivations (see Section 2.3.1 above), as for professional researchers, the reasons why members of the public choose to engage with scientific projects are diverse. It is very likely that motivations for engaging via open science will be equally varied. As noted in Section 2.3.4 above, a number of studies have shown that although interest in a subject is very often the most important factor for persuading members of the public to collaborate in research, the desire to contribute to science was almost always also an important motivation. Raddick and colleagues (2010), in a survey of participants in a citizen science project, concluded that a previously-existing interest in the subject was primarily important. However, when interviewed for this research, Raddick showed his perception to be slightly different:

> *... nobody does it for one reason; everybody has many different reasons but when you ask people to choose what their main reason is, an overwhelming number say that their number one reason for participating is they want to make a contribution to science.* (Raddick, professional researcher)

For members of the public, it is thus possible that open science will support a return to older modes of participation and contribution:

> *If you go back to Victorian times – to the nineteenth century – there were a lot more amateurs, in our sense, because people could actually go out and experiment and do things for themselves. [...] I think we might change back to something more active, simply because of the facility the Internet gives you to find other people, to talk, to start contributing to things you feel you know something about or happen to be in the right place for.* (Pepperdine, member of the public)

Pepperdine's comment expressed the possibility that open science could enable members of the public to further their engagement with science and scientists. As

Anonymous 3 commented, it can be hard for amateurs to engage personally with professional scientists:

> *There are two universities near where I live. […] I have tried on various occasions to engage in face to face conversations with the mathematicians, physiologists, philosophers and physicists, of both schools, but the results have lacked depth and substance* (Anonymous 3, amateur scientist)

Currently, however, the involvement of members of the public in open science projects is very limited (see Section 4.2 below). More research would need to be undertaken in this area before any widely-applicable conclusions could be made.

4.1.4 Difficulties posed by open science

> *What happens if someone steals my research and publishes it before me?* (Beck, professional researcher)

Although interviewees were on the whole positive about the value of openness, its possible hazards and negative aspects were equally well understood, even among those who were strong advocates. These aspects were categorised into issues to do with commercial and legal problems, issues to do with the practice of science, including data quality, and issues to do with researchers and their skills.

First, interviewees recognised the possible conflict between the free sharing of information and companies' or institutions' desire to obtain a return on their investment through patenting or other protection of intellectual property:

> *A company is not going to want to give away intellectual property without gaining some recompense for their outlay.* (Holliman, researcher)

> *Universities and other research institutions often require employees to sign waivers giving up financial rewards that may result from their discoveries. The royalties from patents on vaccines for certain communicable disease could conceivably run into the hundreds-of-millions* (Anonymous 3, amateur scientist)

However, as discussed in Section 2.2.1 above, Cribb and Sari (2010) argued that while it can certainly support innovation, patenting is an onerous and expensive process and can cost more than the technology can financially return. Greater openness may, therefore, offer alternative ways to gain value and hold the commercial edge, as Neylon reflected:

> *The other major pushback is obviously commercial interests. Though again, if you accept the argument that it's knowledge and information that are key to the knowledge economy – that they are important things, where the innovation's going to happen – then you have to accept the argument that you will become commercially more competitive by taking an open approach.* (Neylon, professional researcher)

Second, in terms of the practice of science, several interviewees commented on the fear that greater openness could lead to them being 'scooped'; that is, beaten to publication by other researchers who had taken advantage of openly accessible data. The standard pattern of 'work, finish, publish' (a comment attributed to Michael Faraday in JH Gladstone's 1874 biography) is time-honoured as a force in maintaining the value of science. In particular, the desire to establish ownership of work is perhaps unsurprising when professional reputations can depend on being the first to publication. As Foster put it, sharing data might be to the advantage of science in general but possibly not to the personal reputations of the scientists:

> *Who owns the data? If everyone's putting their data into a melting pot, who owns it? [...] I can see how this would help science perhaps but not necessarily the scientists.* (Foster, member of the public)

Related to the issue of scooping is the possibility that shared data might be mis-used, as Beck commented:

> *The balance – if there is a balance to strike – is how do we protect this data? Do we take this data away from everybody else so that we don't give it to the minority who are possibly going to abuse it?* (Beck, professional researcher)

However, against this common view, some practitioners have argued that openness offers its own safeguards, although the difficulties are perhaps more subtle than Bradley suggested in this interview:

> If someone actually did try to scoop you, it would be very easy to prove your priority – and to embarrass them. […] with open science, your claim to priority is out there right away (Bradley, cited in Waldrop, 2008b)

In Waldrop's article, Bradley mentioned, for example, that publishing material on a wiki means it is automatically time-stamped, providing an increased level of sophisticated protection than a traditional laboratory notebook. However, not only does such protection require the use of tools such as wikis and electronic notebooks, which not all researchers will be comfortable with (Research Information Network, 2010b), it takes publication outside the established realm of peer-reviewed journals. The social nature of science is particularly well expressed in the established methods for validation and peer review that are traditionally performed by members of the scientific community for other members. Some interviewees expressed concerns about whether the quality of the traditional markers of academic respectability might be affected by open publication and access:

> *One of the big concerns from the academic side is that if you actually tinker with the model ... How do you maintain quality?* (Anonymous 4, professional researcher)

As discussed in Chapter 2, some journals have experimented with ‘tinkering with the model’, investigating forums for open review and comment, but the outcomes of these experiments have not been consistent. As Millard commented, under present models, researchers can assume that work will be commented on by peers, whose level of expertise can be judged against existing criteria. The expertise of commenters in the wider community may not be known or understood:

> *Thinking about myself as a reader, if I was reading a paper and I wanted to see comments, annotations, citations, I want to see them made by people who are judged by their peers to be at a certain level of work or professionalism.* (Millard, professional researcher)

Not only are there concerns about the quality of judgement of work, as noted in Section 2.3.4, the issue of the quality of information produced by non-professional participants has been raised in some projects. It also arose as an issue in the case studies undertaken for this research (see Section 4.2 below) and was mentioned by one of the amateur scientists interviewed:

> *... we do need to know about the quality of that data ... some write-up about its quality assurance and how it was got […] It’s all very well saying ‘let’s just open the doors to the data’ – I just want it to be done responsibly.* (Horton, amateur scientist)

As Horton went on to discuss, open science could open the doors to quantities of data; other interviewees similarly raised concerns about the quantity of information that open science could make available:

> *I have got an awful lot of data, because this is now an automated system that collects just about everything every ten minutes. There's an awful lot that I don't make available on the web because it's just too much for me to manage.* (Horton, amateur scientist)

The problem of how to cope with data in quantity was mentioned by some interviewees. Besley and Nisbet's (2011, p. 4) meta-study suggested that scientists considered information presented to the public needed to be 'simple, carefully worded, visual and entertaining'. While not necessarily subscribing to this level of simplification, some interviewees expressed concerns that consumers could be overwhelmed by large amounts of unfiltered information:

> *You will obviously have an enormous amount of redundant information – redundant in the sense that unless you have the skills to access it and the skills to sift it and use it in interesting ways, some of it's going to be ... redundant.* (Holliman, professional researcher)

Beck suggested that presenting data in an interesting and understandable way might be difficult, given that its basic form is not necessarily instantly appealing:

> *As regards presenting that out to the public, that's going to be hard. It's going to be a lot of machine-processed digital data – hardly sexy!* (Beck, professional researcher)

For Neylon, the difficulty of presenting data lies with the many different sources from which it arises and the different uses to which it can be put:

> *A problem we've talked about for a long time, and we haven't solved at all, is layers in the record. My lab notebook is in some ways the bottom layer of the record. It's almost the machine code kind of level: 'this happened – that happened – this happened'. There's often a tension in that record about actually putting reasons, rationale and analysis in at that level. It doesn't seem to feel right; it doesn't fit terribly well in the information framework as we have it. My strong suspicion is that we need some sort of layer on top of that. Maybe you need several layers of reporting, of analysis.* (Neylon, professional researcher)

As Holliman and Neylon suggested, it may be that information providers will need to develop ways of allowing users to navigate with ease around quantities of material or that information users will require appropriate levels of skill. However, as Murcott commented, it may be that access to such large quantities of information could offer users a context in which they could develop such skills:

> *Once you are immersed in the blogosphere, then you will start to develop those journalistic skills yourself. You will start to be able to say 'this person here, is left-field, outlier, rarely brings anything other than random rants, whereas this person here is a provider of good-quality information and something I should be aware of'.* (Murcott, practitioner)

As noted in Section 2.2.1 above, information-sharing is becoming one of the more contentious issues in modern science. While many recognise the value of making data available for re-use and re-purposing, this raises issues of data ownership and how established systems for reward and recognition can be adapted to acknowledge the value of providing datasets. However, these interviewees are describing a situation in which the provision of data is accepted. The issues they raise are about how to make it usable, whether by organising the data – as Neylon suggested – or by supporting consumers in developing the analytical skills that enable them to make good use of the data in whatever form it is produced – as Holliman and Murcott described.

Other interviewees mentioned the problem of usability, suggesting that raw data is not necessarily either useful or understandable:

> *If you look at the raw data that comes from a satellite about ... sea level height ... it's huge numbers of 1s and 0s. You cannot do anything with it. It needs to be processed, it needs to be dealt with.* (Murcott, practitioner)

Taken together, quantity and rawness led some interviewees to suggest that there may need to be filtering put in place:

> *I don't know what kind of raw data I would be able to use and I imagine there would be an awful lot of it. What do I do with that? In what form is the data going to be accessible to the public? Is it just going to be a photocopy of lab books? Is it going to be the scientists' summary of the data …?* (Foster, member of the public)
>
> *It's not enough just to upload papers and place them on the web. I would like to see some sort of initial assessment or filtering process. Papers that purport to have solved the Riemann Hypothesis using only simple arithmetic, or prove the existence of Bigfoot, or some such nonsense like that should not be allowed* (Anonymous 3, amateur scientist)

Although Anonymous 3 made no suggestion as to who might do the filtering, the implication is that the assessment must be performed by someone who has the skills needed to make an appraisal of quality and 'vouch for the reliability or credibility of the content' (Keen, 2008, p. 65). As Millard commented (above), annotations and other additional material are typically provided by people judged to be working at a particular professional level, thus providing some assurance that uncriticised content has been filtered out. However, summarising and filtering undoubtedly conflicts with the wish to have access to complete datasets:

> *You don't just give a sub-set, you give the whole lot. That's what I would expect, what I would want.* (Horton, amateur scientist)

The fact that scientific information may be channelled through widely-used social media and via the Internet could affect how its quality is perceived. Anonymous 1 suggested this in a question he put to the author:

> *Can I ask … do you think using Twitter and Facebook devalues the science? I just don't have a high regard for them; I think if I saw science coming out of them I'd almost think it was pseudo-science, a bit trashy really, not well thought through or considered. I might take that view without even reading it or looking at it.* (Anonymous 1, member of the public)

However, this view contrasts with Hendy's, who has found blogging to be a supportive and friendly environment in which to discuss new ideas:

> *As a scientist, when you put out a scientific publication, it has to be very very rigorous, very well thought-out or the comments you get back from peer-review will be very harsh. Even if the paper's very good, you'll tend to get very harsh criticism. It's very different, blogging; the type of feedback you get is very positive, so gradually that's changed my reticence about putting stuff out on my blog.* (Hendy, professional researcher)

While Hendy has found social media to be a supportive environment in which to engage with a wider public, Mandavilli (2011) noted that other researchers reported mixed experiences in similar contexts. While for some researchers the rapid responses made possible by social media help to uncover lax or inaccurate work, for others the speed of attack, or its person-to-person nature (in contrast with the *politesse* of traditional commentary couched in the third person), can feel intimidating.

Third, there is a cluster of issues to do with researchers themselves and with their skills. One concern was how open science affects privacy. As Neylon commented, accepted ethical practices protect not only the research and the researched, but also the researcher:

> *The obvious active push against* [open science] *would be privacy and researcher safety – research privacy as well as subject privacy.* (Neylon, professional researcher)

Indeed, in some countries, such members of the EU, the protection of private data is enforced by legislation (ICO, n.d.; European Union, 2010). However, privacy can extend beyond legal concerns to a sense of a protective environment:

> *... one of the reasons we're in a private forum is that the idea of typing live on to a public site – which is the other extreme – is pretty scary. In a 'sandbox', we can watch each other's backs and check details. That's quite important.* (Sanderson, practitioner)

Sanderson's comment is made in the context of a large-scale public engagement activity, in which the public posed questions to a bank of scientists. The scientists collaborated in a private forum, and were assisted by a professional editor, so that agreed, collaborative and edited answers eventually emerged from their conversations and were posted on a public forum.

Sanderson suggested that protecting his collaborators' privacy helped prevent inadvertent errors appearing on a public website. However, beyond mere errors, there is a perception of a danger that information might be misinterpreted when it appears in a dynamic space:

> *I think there's still a maturation required, both in terms of scientists blogging being clear about what they are and are not saying and among journalists in not misconstruing what they've read on a scientist's blog […] there needs to be a recognition that there's going to be some disruption and a few problems along the way.* (McCracken, practitioner)

McCracken's mention of 'misconstruing' links to Murcott's point (above) that users of publicly-available data may well need to develop journalistic skills of interpretation. However, misconstructions do not only arise from lack of skill; misunderstandings can be born of a lack of shared language between scientists and members of the public:

> *[an] original paper would probably be too technical for me. If it were written in English – everyday English – I might read it!* (Guinamard, member of the public)

Scientists recognised they do use specialised and sometimes obscure language, not necessarily only in the public sphere; what is understood and accepted by researchers in one discipline may be incomprehensible to those in another:

> *It's not 'here are these people with their pointy heads who are somehow different to other people'. It's that 'here is a bunch of people with specific domain knowledge that speak specific sets of dialects and can converse with each other'.* (Neylon, professional researcher)

Murcott viewed specialised language as a function of the audience being addressed, with problems chiefly arising when such jargon is used inappropriately:

> *Actually, scientists, in my view, don't use jargon. Jargon is designed to exclude and obfuscate; it is not designed to facilitate communication. What scientists actually use are abbreviations, TLAs* [three-letter-acronyms], *shorthand, but these are designed to help them communicate amongst their peers. You just need to think, if you're communicating to a different audience, you need to be aware of the language that audience uses.* (Murcott, practitioner)

As Murcott concluded, successful communication involves being aware of the needs of the audience. It is possible that the very consciousness of the needs of a wider audience could afford greater clarity in communication:

> *I can also imagine, for example, reading the notes and not being able to understand them fully because they'd just been written for the person …* I *understand my notes; who else cares? Whereas I think that it would breed a wider sense of awareness in what you're doing if you were making your notes for … whoever. You'd be thinking have I made this clear? Have I made this in a logical sequence? Have I ordered my notes properly or are they all random?* (Foster, member of the public)

As Murcott and Foster suggested, communicating with new audiences and using new tools, such as social media or blogs, means both sides may have to develop new behaviours. Millard recognised that while most people will cope perfectly well, some will struggle:

> *We all had the realisation that what we were asking people to do was unrealistic and we had people who not only struggled with online systems, or perhaps weren't as digitally literate as we assumed they would be but we also had people who had no strategies for managing their own stuff, let alone for sharing it or packaging it or describing it with xml or anything else.* (Millard, professional researcher)

A further major issue for researchers is that practising openness will add to work burdens and take researchers' time away from their 'real' work. This is implicit in Foster's comment (above), in which he envisaged the note-writer as at the very least taking extra time to consider if their notes were legible, logical and organised. Scientists already spend time communicating: talking to their peers, giving talks, writing, teaching and more. Crotty argued that 'every second spent blogging, chatting on FriendFeed, or leaving comments on a PLoS paper is a second taken away from other activities [that] have direct rewards towards advancement' (Crotty, 2010). This view was echoed by some interviewees:

> *It's difficult to persuade people to take time because you don't see how it can get built into your standard work pattern.* (Neylon, professional researcher)
>
> *There are some people that are still very negative towards* [depositing their publications in] *the repository, that it's a time-consuming thing, that they don't need to fill in yet another database – that sort of thing.* (Anonymous 5, practitioner)
>
> *... if I'm in my office, I feel guilty blogging. So a lot of it's done in my personal time. That's partly because there's a lot of time demands, doing science ... even if I could say it was a core part of my job, I'd still find it hard, finding time in my working life to put time into that.* (Hendy, professional researcher)

These considerations of how researchers and members of the public use their time and skills leads on to consideration of the methods and tools that can be used for open science.

4.1.5 Methods for open science

> *We will have to cross the bridge of how we translate 'you've signed up to open science' into 'this is how we're going to translate open science in practice'.* (Beck, professional researcher)

Interviewees mentioned a wide range of tools, many of which already exist, are relatively simple to learn and are in common use. These included blogging software, citation-sharing software, wikis, shared documents, repositories, data tagging, webpages, email, communication tools and social media software, such as *FriendFeed* or *Twitter*. Some interviewees (for example Neylon, Bradley and Millard) were already using various tools; others considered tools theoretically. However, it was recognised that many of the tools and techniques that will be needed are still to be developed and are likely to emerge only as the need for them becomes apparent:

> *We need something that actually lets you do something. Which means that you need the questioning, parsing, phase, that lets you get in and triage what is more data than has ever existed before – by orders of magnitude – in a way that people can ask a question and get an answer which is useful to them; contextual for them. Or at least brings them in at the right level that they can then drill down to the point where they need to be.* (Neylon, professional researcher)

Neylon's comment links to the issue (see Section 4.1.4 above) of how users will navigate the enormous data flow that could be made available through open science. However, as he noted, openness is also tied up with issues of accessibility and usability. Accessible means more than just available; information may be available on a system but not necessarily accessible:

> *I don't want the public to come to a repository or our system and want access to something and then get a 404 error*[26] *because they're not allowed access.* (Millard, professional researcher)

Information can, for example, be rendered inaccessible if it is supplied in a format that requires unusual or expensive software, rather than being produced in popular and supported formats:

> *Just physically,* [the data] *has to be changed into a different format, because the guys here are working with software that isn't readily available to Jo Bloggs in the street. You have to change it into another format to make it accessible to other people.* (Anonymous 6, practitioner)

Information also needs to remain accessible over time. For example, online journals might cease publication[27] or researchers might choose to delete personally-created archives, meaning the reassurance of institutionally-supported long-term stability could be an important factor in persuading researchers to archive material. Anonymous 4 noted that a university repository could provide such a guarantee:

> *You want to be able to say to people that it is a safe haven for their research. If you put it in here, one, it will be a url that will be persistent and two, the thing itself will not fall apart, suffer from bit-rot, be kept in a format that no one will support any more so in twenty years' time you won't be able to get at it.* (Anonymous 4, professional researcher)

Pay walls and other barriers that companies or institutions place around information were a particular problem for members of the public:

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[26] A standard response code that indicates the computer server could not find the page requested, for example because the website address is mis-typed, the resource has been removed from the website or – particularly germane in this context – the user does not have the requisite permissions for access to that material

[27] As an example, the online journal *e-biomed: the journal of regenerative medicine,* began publication in 2000 but ceased in 2003 (http://online.liebertpub.com/ebi)

> *There are so many websites behind pay walls, which makes things really difficult. [...] They don't do themselves any good at all – neither the authors nor the journals – in my opinion. It leaves a sour taste and so we go elsewhere. Somebody casually coming in and picking something up once every six months is not going to harm anybody.* (Pepperdine, member of the public)
>
> *It would be nice to have a website where you could maybe have one subscription that covered a number of things. Or maybe one free visit or something ... but I'm probably being utterly impractical. But it's not just the time that it would take to subscribe to all these things, it's also knowing whether they're genuine* (Anonymous 8, member of the public)

Anonymous 8's comment additionally revealed another facet of access; important as free access is, information also needs to be trustworthy, clear and comprehensible, so that users are able to make sense of what they see:

> *It should be accessible to a non-expert, not using complicated language so that every time you looked at the website you had to look up what a thing means* (Marks, member of the public)
>
> *Another obstacle is that the public may sometimes not understand the science they have access to – as access does not guarantee comprehension of what is available* (Nason, amateur scientist)

Nason's comment implied people may need to attain certain levels of knowledge or understanding to be able to access the science. In some minds, this applies particularly to members of the public but it could equally apply to professionals venturing into new fields:

> *... my lab notebook ... I suspect it's totally incomprehensible ... and I imagine it would be pretty much totally incomprehensible to most scientists ... so in that sense, other scientists may as well be the general public* (Neylon, professional researcher)

The need to be comprehensible as well as accessible could mean that information providers find themselves called upon to support users in finding their way through the information flow:

> *'Available' for me, is about ... it needs to mean something to the person that's accessing it. It's only 'available' if it means something; it's not 'available' if it's just there but means nothing or there's no map to navigate through it in some way or no support to find your way through* (Bloodhound@university 2, professional researcher)

Where projects involve professional researchers and scientists, a certain degree of common understanding and shared language may be assumed. Professional–public collaborations through open science are in their infancy (see Section 4.2 below) but interviewees noted that when public audiences or collaborators are involved, there is a concomitant need to contextualise research data and other outputs; indeed that there may be a prerequisite for mediation of what may be quite complex data:

> *Some level of mediation, I think, is necessary and to be fair it will be within the process anyway because* [*...*] *any way of presenting information will require some level of mediation just to put it up on the Web in the first place* (Holliman, professional researcher)

As mentioned in Section 4.1.4 above, such mediation may certainly involve the filtering or organising of quantities of raw data. However, some interviewees suggested there would need to be a level of mediation beyond organisation. Murcott (practitioner) suggested that having access to the narrative of a project was 'utterly, utterly essential'. Horton and Foster used similar metaphors:

> *You need to know the hinterland of the data, the context in which the data can be set* (Horton, amateur scientist)

> *A project has a history … and links all the way back … who is funding it, why they're funding it, what they're expecting to get out of it. … I can imagine creating a story out of a project which would be quite interesting.* (Foster, member of the public)

Open science practice could provide the circumstantial and background material that sets research content, data and information in context. Creating the narrative of a project not only allows the data to be set in context but can also serve to remove technicalities that can be a barrier to comprehension and usability. However, interviewees acknowledged that, as noted in Section 4.1.4 above, such contextualisation of complex science will inevitably place demands on researchers' skills and time. Further, as Anonymous 2 reflected, narration can differ according to the subject and the narrator's skills and confidence. It can also be a two-way experience, in which the learned becomes the learner:

> *Online, I'm only a disseminator when I'm very confident about my understanding of the matter at hand. So if a person seems to be a bit young, asks a question about the tides, well in that case I'm comfortable writing a whole page on the subject. A question about lasers and quantum tunnelling, I'm going to sit back and wait for other people to handle that one. Many of the people participating in* [a video game forum] *are university and graduate level students – I'm learning from them, clearly.* (Anonymous 2, member of the public)

There are however, likely to be rewards for projects that provide rich context. As McKay commented, such an ideal of open science would serve a multi-layered understanding and interpretation:

> *… on a purely intellectual level understanding the methodology and working practices … on a more general level, where research connects with policy issues … the processes behind the research – why things were selected for funding or for research, who's providing the funding or making those decisions … the political and institutional circumstances of the research* (McKay, member of the public)

Interview component summary

The interview component of this research explored definitions and understandings of open science and its practice among researchers, practitioners of public engagement and members of the public.

As may be expected of an emerging protocol, there is a considerable variety in definition, interpretation and what is included under the heading of open science. Some interviewees focussed on the open protocol's capacity to support access to the results of work, perhaps as an access route to publications but others saw it as a route for knowledge transmission from professionals to public audiences. Many saw open science as concerned with science in action and with revealing the full process of research, even though that may reveal complexity, ambiguity, tentativeness and uncertainty as much as sound method and clear questions.

Access to open science is, by its nature, limited to audiences that have the necessary technology and thus some potential participants are excluded. However, several interviewees suggested that for those who can participate, open science offers the ability to scrutinise research and judge its reliability and could thus support and sustain public trust and reduce the isolationism for which science is sometimes reproached.

Researchers who choose to work openly may do so either for philosophical or practical reasons. Several respondents suggested open science can be an ethical practice, supporting interviewees' belief that publicly-funded research should be publicly-accessible and, as noted above, enabling members of the public and other researchers to scrutinise and validate research. However, a number of interviewees noted the possibility for conflict between openness and commercial imperatives, particularly concerning data ownership and commercial interests.

Open science has practical aspects, for example enabling multiple colleagues or groups of colleagues to work collaboratively. It also has the potential to support collaboration with new participants, previously separated by either geographical or community boundaries. However, few interviewees offered evidence that, for example, members of the public are making use of the opportunities potentially offered by open science; a point which is explored further in Section 4.2 (below). There is also a perception that such widely-spaced collaborations may be hard to sustain – although open science can reflect current social practices, it cannot replace all of them.

Working openly is likely to make available large quantities of raw data and unfiltered information. However, respondents suggested that while for members of the public, open science may offer a route for direct engagement with science (rather than with scientists or science writing), the resulting data deluge (McFedries, 2011) may be difficult to cope with, possibly requiring massive computation resources and potentially the development of new skills. The tasks of contextualising such complex data, using appropriate language, will possibly fall to researchers, making demands on their skills, time and communication abilities.

4.2 Case studies

This section comprises case studies of three projects: the Bloodhound@university project (Bloodhound@university), the Emergence of Artificial Culture in Robot Societies (AC) project and the Detection of Archaeological residues using Remote sensing Techniques (DART) project.

As described in Section 3.3.1 above, the selection of these cases for study was supported by judging them against a set of criteria. The full list of criteria can be found in Appendix 8.4; also see Table 1.

4.2.1 Bloodhound@university

Bloodhound is a Bristol-based engineering project that is attempting to build a car capable of reaching 1000 mph, which would break the world land speed record. When the project began, one of its primary aims was to inspire young people to enter the science and engineering professions. Therefore, from the outset, the project declared an intent that ‘all the information about the research, design, build and testing of the car [will be] available to teachers and students, and of course to anyone that wishes to visit the website’ (BloodhoundSSC, 2010). As well as its website, Bloodhound had an education team, which developed Bloodhound-based materials for use in school lessons and special events, an ambassador team, largely composed of interested volunteers, who visited schools and young people’s groups to lead project-based activities and a fee-paying supporters’ club. Bloodhound@university was a linked but separate project, focussing on education-engineering co-ordination between the Bloodhound project and members of higher education institutions

(HEI). Bloodhound@university was led by the University of the West of England, Bristol (UWE).[28]

Although neither Bloodhound nor Bloodhound@university used the specific term ‘open science’, as noted above, the intent of the Bloodhound project was certainly that information should be openly available. The project website stated that there would be ‘full open access to the design, build, test and record breaking attempts of BloodhoundSSC via the website’ (BloodhoundSSC, 2010) and the Bloodhound project director was known to articulate the principle: ‘[the Project Director] when he stands up, says “it’s open, everything’s there”’ (Bloodhound@university 2). Quoting the text of the website, Bloodhound@university 1, a project member, expressed it thus:

> *The project set out to be an ideal of open, they said they were an open project, that they want to give a ‘warts-and-all’ view of the project to the world* (Bloodhound@university 1, May 2010)

However, another member of the Bloodhound@university project acknowledged that creating an agreed definition of ‘open’ in a project with fluid membership was difficult, expressing a more pragmatic, nuanced view:

> *Defining what is open is very difficult ... Ideally it would be as open as possible.* (Bloodhound@university 2, May 2010)

Bloodhound@university aimed to provide data from the engineering project to HEI academics for them to create subject and teaching materials – such as lecture material, case studies, tutorial materials and design exercises – for use by students and staff in their institutions. These materials would then be made publicly available. (Bloodhound@university, 2007). This process depended on mutual support,

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[28] Note: this is the university attended by the author.

collaboration and interaction between the engineers of the main Bloodhound project, Bloodhound@university, university students and academic colleagues.

In collaboration with the E-learning Development Unit at the University of the West of England, Bristol,[29] in 2007, Bloodhound@university therefore set up a website to be a location where information concerning the car – and eventually data from test and actual runs – could be gathered and accessed, together with the teaching resources created using those data. Thus, the website was intended to support the development, sharing and re-use of teaching and other resources for use in higher education institutions:

> [Bloodhound@university is] *facilitating a community of academics within UK higher education institutions, helping them to access data, information, experience, from the Bloodhound project, so they can turn that into learning objects or things that they can use within their teaching, or their project work, at their own institutions.* (Bloodhound@university 1, May 2010)

The fields covered were considered to be wider than the simply the engineering factors of designing and building the car. The website aimed to include 'issues such as materials technology, design analysis using computer-based methods, project management, environmental assessment and impact' (Bloodhound@university, 2007).

However, between spring 2010 and summer 2011, the resources available on the website were limited and largely unchanged. The website's design laid out the 'context' of the resources as being split into four areas: Car (covering aerodynamics, structure, driver and suspension), Data (covering project management), Design Lifecycle and Collaboration. Of the four context areas, two – the Car and the Data –

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[29] http://www.uwe.ac.uk/elearning/

comprised six sets of graphics/design drawings and two case study project specification documents. The two remaining areas, Design Lifecycle and Collaboration, had no resources. The website had a ‘comment’ facility on each page but, as of summer 2011, no comments were visible. There was no evidence of authorship for any of the resources, which is notable in view of Metzger’s (2007) conclusion that expert users (which as members of HEI, the anticipated audience for this site arguably was) pay particular attention to the quality and source credentials of information on websites.

The rationale of Bloodhound@university was that students in the HEI sector would be the audience most capable of benefitting from access to genuine data coming from a genuine project, and could in their turn feed the results of their work back to the engineering team:

> *The HE level is the one where the students are most able to engage … where it could be a mutually beneficial relationship, because the students are the people that can really crunch the numbers in a meaningful way […]. At a university level you can give them the real numbers off the project and they can engage with those. The other way is that the students and the academics can say ‘we have a better way of doing this … have you thought about …’* (Bloodhound@university 2, May 2010)

Thus, Bloodhound@university recognised the critical aspect of public engagement described by McCallie, et al., (2009) and DIUS, (2008); that is, the requirement for mutual transfer of information and understanding, both from experts (project members) to the public (in this case, HEI students and academics) and back from the public to the experts. Although team members recognised their public could be wider than the HEI community, pragmatically, it focussed on that audience:

> *There's a broad range but that's the primary audience, higher education institution academics.* [The other] *communities might be primary school teachers, might be further education tutors, might be secondary school teachers, might be ambassadors or just generally interested people who've got in touch.* (Bloodhound@university 1, May 2010)

Defining the user community as members of HEIs implied an expectation of a certain level of understanding: that they were a community able to engage with and make use of 'the numbers'. To try to meet the needs of this user group, Bloodhound@university explored several options. To accelerate the development of useable educational resources, the project team set up a Special Interest Group (SIG), bringing together academics from different universities who had expressed an interest in using information and working with data from the project. In early 2010, some of these academics met members of the Bloodhound engineering and education team for the first time. The author attended and observed this meeting.

At this meeting, although they discussed a number of challenges, the SIG participants particularly focussed on the challenges of dealing with data, including the problems of dealing with high data volumes and multiple types of media (photographs, articles, numerical data), problems of access and routes for data to flow from the engineering team, how best to develop authentic resources for using data, lack of context and missing meta-information for the data, how to enable stored data to be interrogated by multiple stakeholders, how to deal with data organisation, and finally, how to ensure information would continue to be available after the completion of the Bloodhound project.

The founding concept had been that the 'engineers would do the engineering stuff but make [it] open' (Bloodhound@university 2) but it had become clear that despite the online nature of the data, which meant they were theoretically highly accessible, they could not simply be caused to flow from the engineers and on to the web. The data were largely raw, complex and of high volume; therefore systems to facilitate access were needed, which potentially required external expertise and certainly some degree of funding. To meet this challenge, the Bloodhound@university team later investigated creating a Knowledge Exchange Partnership with a commercial company used to handling high volumes of data. (The author attended the first exploratory meeting.) They also applied for funding to set up pilot programmes for resource production and data handling but these applications were unsuccessful.

Two further issues were the lack of context for the data and idiosyncratic data storage and structures. In large part, these problems arose from the flat organisational hierarchy of the Bloodhound project at the time: the engineers charged with designing and building the car each produced and stored information in ways suited to their own needs. While this flexibility in the Bloodhound personnel was rightly held to allow for considerable creativity and individual responses to problems, it also meant the Bloodhound@university team was unable either to decree or implement consistent data curatorial practices. ‘Archiving at the point of generation’ (Bloodhound@university 1) of the data was an innovative step and one that the project team recognised would require time and skills to establish, whether the process involved the engineers capturing the narrative as they experienced it or whether it involved post-production tagging and classification of the data. Bloodhound@university 1 summarised the simultaneous problem and strength:

> *I think Bloodhound is a really exciting project in lots of ways, like the way it really capitalises on volunteers, on enthusiasm, on that really wide-eyed, wonderful, brilliant-ness, but what that means is you get a lot of different people coming in from all over, with different working practices, with different team dynamics, and in order to be open I think we needed to have a structured approach, we needed to have things in place that meant we were able to store, archive, curate data in ways that made it easy for that then to be accessible and open.* (Bloodhound@university 1, May 2011)

The desire to allow the engineering team to work in a creative, untrammelled manner conflicted with the desire to have data organised, stored and accessible for use by Bloodhound@university's audiences. At a project meeting, the author noted the team's discussions on the difficulties downstream users might face in using and interpreting information:

> Bloodhound has 'an enormous amount of valuable data in a very raw format' […] The web enables remote access to this data which is key to allowing wide access. However, for this to be workable the data needs to be tagged/structured/organised in a manner that makes sense to end users. (Meeting notes, November 2010)

Tautologically, the problems of data curation meant that very little data, either raw or mediated, was available. In turn, this meant that very few resources were produced, which meant that there were few available for SIG members to use as exemplars, which meant few resources were used, re-used or adapted. In September 2011, the site held the same data that had been there in March 2010. To a considerable extent, the SIG lapsed until early 2011:

> *The SIG's been really quiet for the best part of a year, so hopefully we can get people re-interested. As long as we have a place for the stuff to go, somewhere it will appear and a plan of action to get information out of the engineering team, hopefully the community will be able to form around that but we can't really afford to do any more than that.* (Millard, August 2011)

The move to re-awaken members of the SIG (in March 2011) focussed on developing a customised version of a repository based on EdShare software (University of Southampton, 2010). At a meeting (which the author attended and observed), questions of how to obtain, store and use raw data, and how to involve a user community beyond academics, were again discussed but not resolved. As at the first SIG meeting, the discussion focussed on how to create an accessible, searchable and contextualised repository of teaching and learning resources created by SIG members. An application for major funding to support the development of the repository had been unsuccessful, which meant development had to proceed on a smaller scale, supported by the remains of previous funding. The hoped-for date to re-launch the repository was April 2011 but as of autumn 2011, this had not occurred.

In many ways, concerns at the second SIG meeting were reflective of concerns at the first: formats of information, whether to supply raw data or ask producers to process data in some way, use of academics' time to produce resources and how to sustain the relationship with the user community. Initially, anticipating a free flow of data from the engineering team, it had been intended that resources would be created based on all aspects of the car's design and production:

> … we will have a ‘warts and all’ access, so we will be able to share not only the solutions that worked, but also the ideas that did not succeed. Additionally we will have access to the design team’s decision making and evaluation criteria – why a solution was selected or rejected. (Bloodhound@university, 2007)

However, in spring 2011, the engineering team decided to offer a strategy of staged releases of ‘packages’ of information concerned with specific parts of the car – for example the steering. The Bloodhound@university team hoped that shadowing this strategy was likely to offer improved access to data:

> *We’ve now completely embraced this strategy of packaged releases. We can put together a bundle of materials and in that bundle will be narratives about what’s going on, multimedia stuff. Still fairly lightweight for the engineering team, so that team isn’t put under stress. The intention is that* [the packaged release] *will go into the repository and have a presence on the website, then as people use those materials they will put the results back in and the website effectively indexes those repository materials in the right section* (Millard, interviewed August 2011)

To summarise, the intent of this project to be open and make data available in quantity, in real time and in the raw has not been entirely met. As noted in Section 4.1.1 above, understandings of ‘open science’ are varied and flexible; therefore, it is unsurprising that definitions of openness varied within the project teams. Moreover, Bloodhound@university did not generate its own data; these had to be drawn from the engineers of the Bloodhound team, whose natural focus was on the challenge of the scientific and technical elements of designing and building the car. To obtain data, Bloodhound@university had to negotiate with its partner project and while they recognised that using methods for obtaining and curating data that did not impinge on the engineers’ time were vital, the processes through which this could be achieved had not been resolved. It was hoped that the adoption of a packaged release strategy would allow a greater variety of data to be acquired. The aim of producing new, re-usable resources, in an open-source model, has certainly been affected by the paucity of data. The level of funding also affected resource production, in that the amount of time required – and the need – to interpret, mediate and categorise the data were greater than originally foreseen; without external funding, the project was unable to deliver the raw material from which HEI academics could create and write resources.

4.2.2 The Emergence of Artificial Culture in Robot Societies

The aim of this project was to address the question of the emergence and evolution of culture in groups of social animals. Its experimental approach was to create societies of simple robots, set up with conditions postulated as fundamental to social activity, and to observe the robots' behaviours as their society evolved:

> This project aims to address and illuminate that question in a radical and hitherto inconceivable new way by building an artificial society of embodied intelligent agents (real robots), creating an environment (artificial ecosystem) and appropriate primitive behaviours for those robots, then free running the artificial society. […] we will aim to create the conditions and primitives in which proto-culture can emerge in a robot society. (Artificial Culture Project, n.d., Project Abstract)

The project had members in six UK universities and was trans-disciplinary; as well as robotics, team members worked in the social sciences, philosophy, complex systems, computer science and art history. The project was led by the University of the West of England, Bristol.[30] It began in 2007, was due to end in 2012 and was funded by the UK Engineering and Physical Sciences Research Council.

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[30] Note: this is the university attended by the author.

On its home page, the project described itself as being an:

> … open science project, which means that we will be uploading here not only project results and conclusions but also the data collected from experiments, together with discussion as the project evolves and proceeds (Artificial Culture Project, n.d.).

Although the project began in 2007, the website dated from mid-2009. A commercial design team had been commissioned to produce a website but the team had experienced difficulties (occurring before the start of this case study and therefore unable to be discussed here) over this. The project team had therefore set up its own site, based on Google Sites™ software, managed by the project leader but with all project members enabled as contributors. Only project members were able to edit pages but no part of the website was password-protected; all pages on the project website were freely viewable. The ‘comment’ facility on individual pages was disabled (in order to prevent unauthorised editing); however to facilitate communication, the project had its own email address and blog, which were both linked from the website. At the beginning of its development, the website was set up with pages for all the team members to post information about their work but gradually, those that remained empty were removed. By summer 2011, most of the project team had added links to profile pages (or similar) hosted at their own university, with details of publications, other projects and so on.

As of summer 2011, six sets of data from experiments were freely available from the website. These included .csv files of experimental robot-tracking data and graphics and discussion offering the experimenters’ interpretations of the results. Seventeen publications, including the original project description, were available as full text; titles and authorship details were given for publications in press. There were three image galleries (sets of photographs of the robots, the laboratories and members of the project team), press and media information and links to complementary websites. In addition, the ‘Project News’ pages on the website held information on PEST activities undertaken by project members, such as discussions, talks, workshops, science cafes and so on. Finally, there was a blog, with (at summer 2011) 31 posts created by four team members, discussing various aspects of the project’s development. The blog had a facility for comments, although at that time, the five comments were all from team members.

It is notable that the only raw datasets available came from the experimental robotics component of the project. Griffiths suggested (in a blog post) that disciplinary practices and ethical concerns militated against other components posting information to the website:

> *So far my reasons for ‘not yet’* [posting details of the research process] *are bound up with the research disciplines in which I work – sociology and health sciences (Griffiths, 2010).*

For example, one team member examined children’s perceptions and interpretations of robots and robot behaviour; it would have been inappropriate to make available any information which could be linked to individual children and certainly, it is a common practice in the social sciences to make all contributors anonymous. Since, for the moment at least, the robots evinced fewer concerns about their privacy, it was probably less contentious to make available detailed files of tracking information from the robot experiments. However, this still left lacunae from other project components, that is, the philosophical, art history and complex systems areas.

Recognising that the open science aspect of the project was not working in the way it had hoped, in March 2011 the project team included sessions on open science at one of their regular meetings. One of the sessions was led by the author and the second was a mutually-supportive workshop for team members. In the author's reflections, three issues emerged from these discussions: the need to agree an understanding of the meaning of 'open', concerns around confidentiality and maintaining precedence, and how to fit open activities into daily work patterns, so that researchers were not taking time away from other activities or having to perform activities outwith their normal work. Leading on from this discussion, the project team identified the use of the blog and creation of blog posts as a worthwhile and achievable activity, perceiving it as a simulacrum of the kind of inter-personal discussion that might normally happen via email. Therefore, in the workshop, members of the team worked on the project blog, creating new posts and comments reflecting the issues that had arisen during the project's evolution.

To summarise, this project certainly sought to fulfil its aim of being an 'open science' project. The website was freely accessible and held both data and publications, although coverage was uneven between different parts of the project. It is notable that the fuller areas were those where usable outputs were a normal part of everyday work – for example publications – rather than those that required some kind of extra activity – for example uploaded datasets.

4.2.3 The Detection of Archaeological residues using Remote sensing Techniques

The aim of this project was to examine the problems of detecting archaeological residues and heritage information gathered by remote sensing techniques, such as geophysics, soil sensing and aerial photography. It was a three-year project, which began in early 2010. It was funded by the AHRC and the EPSRC under the Science and Heritage scheme. Both the project's manager and champion and the principal investigator were based at the University of Leeds. The project consortium included members from seven other UK universities, curatorial and heritage professionals and industry specialists in, for example, geophysics and photographic interpretation.

The DART website specifically mentions a commitment to open science principles; that is, its aim to be an exemplar for how 'data, tools and analysis can be made available to the wider academic, heritage and general community' (DART, 2010). The project made information, software and other resources available for sharing and re-use under Creative Commons licensing.

For this project, open science is a core methodology, rather than an add-on activity, as the project champion reflected:

> *Open science is one thing in its own right but it needs to be part of the whole framework, the* raison d'être *as to why we're doing this. If open science doesn't lead to impact, be that pure academic impact – which I think is becoming less of a priority – or impact in its broadest sense, then there's very little point in doing it; it becomes just an academic navel-gaze.* (Beck, August 2011)

To populate the website, the team had chosen to develop an aggregation framework, using different storage and access systems, based on a set of readily-available, often open source applications, suited to the medium in question. For example, methodologies, meeting notes and progress reports were made available as graphical mindmaps, using a free software application. Images were stored in Flikr, videos were placed on YouTube and full-text publicly-available publications (approximately eight) used Scribd. Presentations given by members of the project were available via SlideShare.

There was not, at summer 2011, any raw data available; although provision had been made for it, the project team considered that not enough had been collected at that time ('we haven't got to the stage of open data because data is only just starting to trickle through', Beck, August 2011). Each PhD student, and the project champion, had a blog. At summer 2011, four of the five bloggers had created a total of 16 posts, which had generated 16 comments, five from team members and 11 from non-team members.

Thus, a considerable range of information about the project programme and history was made publicly available. However, the mosaic of different applications meant the process was not entirely seamless; access depended on the visitor having the right software, albeit in many cases the software was free and/or open source. While the need to maintain a complex assortment of different systems could be viewed as adding to the difficulties of working openly, for this project, it was seen rather as reducing the amount of effort needed to maintain the site:

> *I'm dealing with pretty much everything at the moment, although it doesn't have to be that way [...] all I've got to do is upload my document, wherever I need to upload it and it takes an RSS feed from it and represents that on our home page. That's great; it's no work for me.* (Beck, August 2011)

As well as a professional community, archaeology also has a strong 'pro-am' (Leadbeater & Miller, 2004, p. 4) tradition of skilled and interested amateurs working to high standards. This project has encouraged the participation of community archaeology groups:

> [April 2011] the first DART community workshop was held at Leeds University. Given the time of year it was well attended with 30 community participants and the DART team bringing this up to a total of 40 people. We managed to get a good cross-section of academics, curators, practitioners and community groups (DART, 2010, Summary of the DART community workshop)

One of the ways in which open science can support local and amateur communities is by providing clear guidance, methodologies or protocols (Brossard, et al., 2005; Worthington, et al., 2011). Some interviewees in this research expressed concerns that the quality of the protocols – and thus of the data collected – may be reduced where the work is carried out by amateurs (see Section 4.1.4 above). However, the DART project meeting notes showed that community groups were aware of the need for their work to be seen as good quality:

> Both community groups and commercial practitioners feel constrained in what they can achieve in terms of data quality. Community groups feel that they lack guidance in terms of what techniques work in their areas and as a result feel that they are often wasting their limited resources collecting data in non-optimal conditions […] It is anticipated by this audience that DART could help them acquire better data by producing clearer guidance as to when they should survey. [DART could aim to] create a set of protocols to establish better practice for obtaining high quality data. (DART, 2010, Summary of the DART community workshop)

Therefore, enabling such groups to work to high standards so that the data they produce are valued by professionals was a useful service the consortium could provide, as well as enabling the project to keep a complete record of its history and the changes that have taken place:

> *We can start to look at how we've taken our raw data, processed it and generated a synthesis. So we have an open methods store, which we haven't started populating yet but we hope we'll get it out really soon. It's probably going to start as a wiki base, where you deposit your method but being a wiki-based thing, the nice thing is we can start to discuss our methods and how they change, so we're then collecting the history of the development of the science.* (Beck, August 2011)

While this project has developed a rich and well-populated website, there are, none the less, areas which are less rich and less well-filled than others. The dated updates on the website show that parts of the site are used as resources by the project team, as does the information about upcoming events. At the beginning, the project champion was uncertain how the differing anticipations of the project members would affect the project:

> *I think the consortium probably bought into it for different reasons ... as far as I'm concerned, the underlying science is good and that's the main thrust and driver. I built on the open science because I believe in it and I think it adds value ... the balance of pros versus cons is far and away in favour of the pros.* (Beck, May 2010)

A year on, it appeared that the consortium partners have largely subscribed to the open agenda:

> *... the philosophy is permeating through, the fact that we have an active and open engagement with people ... that has gone down very well [however] one of our partners has been very iffy about dealing with data and putting data out into public.* (Beck, August 2011)

This comment makes it clear that there are some exceptions to the general philosophy; the lack of completeness of some sections of the website possibly reflecting the concerns the consortium has faced in in dealing with the different expectations of project members.

In summary, this project has used a range of web resources to offer a reflection of the entirety of the project, from funding application, to meeting notes, to resources, using appropriate software to aggregate data from a number of sources. While there are gaps in the information available, and issues about differing understandings and approaches to openness that the partners have yet to resolve, the members of the project are both contributing to, and making use of, the website to a considerable degree.

Case study component summary

The case studies component of this research sought to explore how open science is being implemented in practice.

All three projects' websites make explicit their commitment to open availability of data, information and results. Two projects also include descriptions of the classes of audience who might access them; in both cases those audiences extend beyond the specialist (teachers, students, academics) to the wider community. The Artificial Culture project website intended to make available 'not only project results and conclusions but also the data collected from experiments, together with discussion' (Artificial Culture Project, n.d.). The Bloodhound@university website noted that 'all the information about the research, design, build and testing of the car [will be] available to teachers and students, and of course to anyone that wishes to visit the website' (BloodhoundSSC, 2010). For the DART project, the 'data, tools and analysis [will be] made available to the wider academic, heritage and general community' (DART, 2010).

Despite this, all the projects have, in differing ways, faced problems in getting information on to their websites, resulting in gaps in information and resources. None completely matched their intent to be 'an open science site' (Artificial Culture Project, n.d.). Bloodhound@university's website offered no datasets but did have a small number of drawings and case study project specifications. Moreover, during the year in which the website was observed, no new data or information was added to the site. The Artificial Culture project added datasets from one set of experiments over the course of the year, together with contextualising information such as images and media information but removed other potentially useful information, such as team members' pages. It was more successful in adding full-text publications and other information regarding conventional publications. The DART project had not at that time begun data collection and therefore had no datasets but over the year did add a range of documents, including methodologies.

The projects show low levels of interaction through dialogue on their websites. Bloodhound@university had no comments on its pages; the Artificial Culture blog posts and comments were all from team members. Only DART had evidence of activity beyond the projects team, with a small number of blogpost comments from non-team members. This low level of comment is not in itself remarkable; small numbers of active participants are a common phenomenon of interactive websites. As .Nielsen (2006, Summary) noted: 'in most online communitites, 90% of users are "lurkers" who never contribute, 9% of users contribute a little, and 1% of users account for almost all the action'.

Traffic data (see Table 3) from the three sites show that the Artificial Culture and Bloodhound@university projects are broadly comparable in terms of visitors. Over three months, both had visitor numbers in the low hundreds, which in Bloodhound@university's case came from a higher percentage of unique visits. Bloodhound@university's visitors had much the shortest dwell time on the site Although its visitors visited more pages than Artificial Culture's, they spent less time (an average of 12 seconds) on each page; Artificial Culture's visitors spent an average of 50 seconds on each page. DART had almost ten times as many visitors as the other two sites; the percentage of first-time visitors and number of pages visited per visit were approximately the same as Artificial Culture's. Visitors dwelt almost three times as long on the DART site and spent an average of approximately two minutes per page.

The most obvious deduction is that these statistics almost certainly reflect the content of each site; the greater the content, the more there is for visitors to browse and the longer visitors are able to spend on the site. Subjectively, DART had more content than Artificial Culture, which likewise had more content than Bloodhound@university.

Table 3 Selected traffic data for case study websites

	Bloodhound @university	Artificial Culture	DART
Visits	229	351	2236
Pages viewed	1640	1008	16505
Pages viewed per visit	5	3	2.8
Unique visitors	82%	54%	~ 58%*
Average dwell time on site	1.01 min.	2.45 min	6.65 min
Top search term	bloodhound ssc	artificial culture	dart project
Most visitors from	United Kingdom	United Kingdom	United Kingdom
Most common landing page	Home page	Home page	Home page
Data collected	May–July 2011	March–May 2011	May-July 2011

* Calculated

They have also faced issues in their relationship with the wider community. Scientists working with non-professionals, where data will be pooled for analysis, have sometimes offered participants detailed instructions and protocols in an attempt to ensure data collected will meet the expected rigorous quality standards (Trumbull, et al., 2000; Silvertown, et al., 2011). While this practice can undoubtedly contribute to participants' data being valued and valuable, it cannot be forgotten that local conditions and experiences may have an impact on what are intended to be national or international comparisons (Irwin, 1995; Trumbull, et al., 2000). While defined standards provide a means of distinguishing robust and weak data or trustworthy and untrustworthy information, they can also provide grounds for excluding non-scientists from decision-making and, more broadly from citizen participation in science (Ottinger, 2010).

It is not possible to comment on how Bloodhound@university will use its anticipated repository to develop community relationships but concerns regarding the provenance and quality of community-produced data have been observed in meetings. However, as its community comprises members of higher education institutions, it may be expected that existing community norms will service the relationships. The DART project has taken advantage of the existence of the established skills of amateur archaeological communities, with whom they are seeking to establish common methodologies. The Artificial Culture project does not have the advantage of such a defined community; although there are many skilled and enthusiastic amateur robotics groups world-wide,[31] they are neither as long-established a community as amateur archaeologists nor as structured as HEI.

Finally, the potential of the narrative element of the websites should not be underestimated. On a website, authors are able to 'create their online identity in a much more deliberate and calculated way than is permitted in other aspects of everyday life' (Vazire & Gosling, 2004, p. 124). To paraphrase Trench (2009), using story-telling strategies could illuminate the workings of science, its struggles against uncertainty and give audiences a sense of the limits and achievements of science. Trench is commenting on the use of the Internet in the context of the reporting of science by journalists but his comments could equally apply to websites such as these, where the scientists themselves describe their own work.

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[31] See for example the Dallas Personal Robotics Group (US) – www.dprg.org/; RobotStoreUK (UK) – www.robotstoreuk.com; EFREI Robotics (France) – http://robot.assos.efrei.fr/

Only one of the websites (Artificial Culture) offered images of the team members. This is notable, in view of the acknowledged role of physical appearance in enabling the judgement of personality (Naumann, et al., 2009), the role played by the personalising of the scientific context in journalism through interviewing or profiling the work of individual scientists as a means for illustrating the wider narrative (Bocking, 2010) and the role of biographical information in enabling judgements about quality ((Metzger, 2007).

Team members of the Artificial Culture and DART projects have used blogs and comments as a means of communication; both have posts deliberately intended to be conversations among team members but which are publicly readable, rather than private. It is not possible to discuss how this element will be developed in Bloodhound@university, but the Edshare software (University of Southampton, 2010) that they intend to use has facilities for commentary and comment-tracking. However, data from all the projects show that team members have concerns regarding members using time to contribute resources to websites.

4.3 Survey data

The survey was linked to four websites of projects with elements of open science. To expand the data collection possibilities of the case studies, two sites (Artificial Culture and DART) belonged to case studies. (The author had aimed for consistency by requesting a link for the survey from the Bloodhound@university site. However, this was not possible, as the site was undergoing redesign at the time.) The third site, the CoSMoS project (Complex Systems Modelling and Simulation infrastructure (CMOS)), was therefore chosen as a non-case study example of a university-based, multi-site project, to contrast with Artificial Culture and DART. The fourth website, Machines Like Us (MLU), was an example of a site with a large, international audience of amateur and professional scientists.

The website controllers were offered the opportunity to amend, edit or alter any questions (for example to match them more closely to the style of their website). None requested any changes. The controllers placed a link to the survey on the front page of their websites, which remained visible on the sites' front pages for the duration of the survey. A separate collector was set up for each website, so that responses from different sites remained separate but could also be analysed together. Every respondent to the survey was automatically allocated a unique identifying number. The surveys remained active for three months from the date the collectors notified that they had placed the link on the site. The first survey (on MLU) ran from March–May 2011; the last (on DART) ran from April–June 2011.

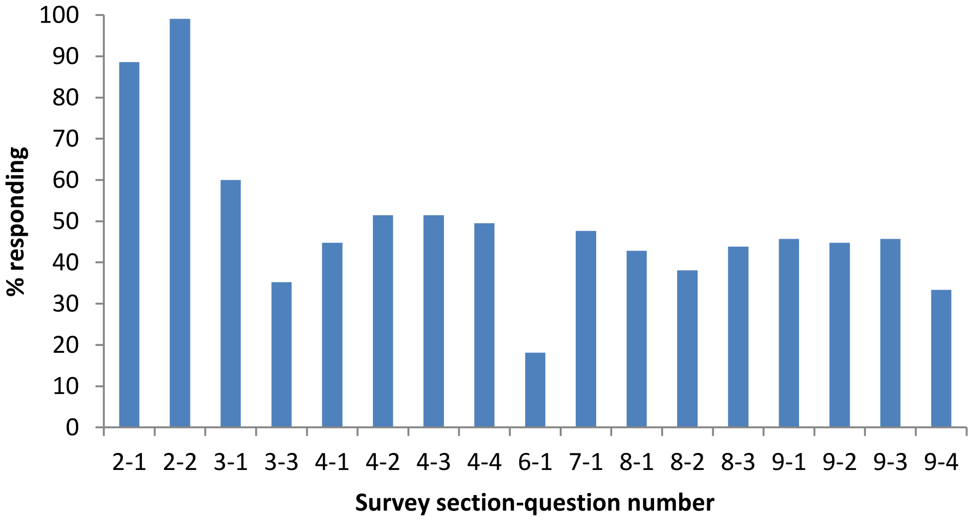
Response rates were not high. In total, 144 responses were collected; of these, 39 were removed from the dataset before analysis because none of the questions had been answered. Three responses were blank because the respondents had indicated they were less than 18 years old (the survey was restricted to adults, to comply with ethical criteria, see Section 3.5 above). Of the rest, two possible explanations are that (i) the responses were created by computer programs searching the Internet ('trawler-bots') or (ii) respondents abandoned the survey for indeterminable reasons. This left 105 analysable responses.

The first estimate (see Section 3.4.2) of a suitable sample size (90) was based on visitor numbers to two small websites. Including the much more visited MLU site, with an audience size of approximately 20,000 (see Table 3) increased the acceptable sample size to 96 (Relevant Insights, 2012). However, the responses were very unevenly distributed among the four websites, with a considerable majority coming from MLU (see Table 4). Therefore, while the overall number of analysable responses was close to the statistically valid sample size, the results were considerably influenced by respondents from one website and overall, were a small group from which to generalise.

The data were organised and analysed using IBM® SPSS®19. All responses remained in the dataset but analysis of any individual question was based solely on the valid responses to that question, rather than the total number of possible responses.

On average, respondents answered 49% of the questions, with a high degree of clustering at either end of the scale. However, here was a rapid drop-off in responses (see Figure 2).

Figure 2 Drop-off in response rate



NB Questions which depended on a positive answer to the previous question are not shown

Just under half of the respondents answered 20% of the questions and only around one-third answered more than 80% of the questions. From section 3 onwards, less than half of the respondents were answering any individual question. This indicates a level of initial engagement which was not sustained by all respondents. However, as none of the questions were compulsory, it cannot be said if the membership of the group completing later questions was consistent.

The traffic data supplied by the website controllers show that the response rate was reasonably consistent across three of the four sites (see Table 4), however, the actual numbers of responses were, as previously noted, low.

Table 4 Comparison of response rates across websites

Site	Count	% of total response	Unique visits	Average number of visitors per day	Conversion rate (%)	Link response rate (%)*
AC	2	1.9	206	2.2	0.97	
CMOS	3	2.9	712	7.9	0.42	50
DART	6	5.7	1012	11.2	0.59	
MLU	94	89.5	20713	220.3	0.45	13.43

*6 visitors to the Cosmos site clicked on the link leading to the survey; 3 completed surveys were received from this site. 700 visitors to the MLU site clicked on the survey link and 94 completed surveys resulted.

While there is no reason to suppose that the survey data do not accurately reflect the views of those who responded, however, the lack of response is equally telling. Calculating the average number of visitors to the sites over the period of the survey (90 days) shows that the low number of respondents is a reflection of low levels of activity and possibly (as noted in Section 4.2 (above)) reflective of current low levels of public engagement with open science projects.

The low numbers of respondents may also be reflective of the ‘participation inequality’ noted by, for example Nielsen (2006), McConnell & Huba (2006) and Wikipedia (2012),[32] in which very small numbers of participants in online communities actively contribute to the community. Therefore, this survey is likely to reflect the views of a small – but highly-engaged – group of participants, which may be a biassed view of the whole community of visitors to the websites.

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[32] Data from Wikipedia (http://en.wikipedia.org/wiki/Wikipedia:About) note the site has about 77,000 active contributors, compared to numbers of unique visitors in the millions (410,000,000 in July 2011 - http://www.google.com/adplanner/static/top1000/)

4.3.1 Demographics

The majority of respondents who gave their sex and age were male (74% of 47 responses) and the largest single group was in the age group 25–44 years (31% of 47 responses). Assessed against the 2010 USA census data (Howden & Meyer, 2011), it can be seen that the age and sex profile of respondents to this survey was unbalanced compared to general population data (see Table 5).[33]

Table 5 Age categories of respondents

	This survey						USA 2010 census		
	Female	%	Male	%	All	%	Female %	Male %	All %
18-24	0	0	6	17	6	13	3.4[+]	3.6[+]	9.9
25-44	6	50	15	43	21	44	13.3	13.3	26.6
45-59	4	33	8	23	12	26	14.1	10.7	26.4[*]
Over 60	2	17	6	17	8	17	10.2	8.2	16.2[$]
No answer					58				

[+] Actual age range in census was 20-24 years

[*] Actual age range in census 45-64

[$] Actual range over 62 years

Such an imbalance is consistent with other studies that have shown the demographics of web users to be significantly different from those of the general population (Best, et al., 2001). For example, Dunwoody (2001) found that 70% of visitors to a science news site were adult males and 10% were under 18 years; Miller (2001) established significant sex-based differences in information-seeking behaviour on the Web and also significant age differences, with younger people more likely to use the Web than adults. This shows that the demography of visitors to these open science sites is consistent with the demography of web users, rather than of the general population. This is mirrored in the interests and occupations of respondents. Of those who answered (n=39) all were either very interested or

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[33] The USA census was deemed to provide the best demographic comparison because a preponderance of the respondents came from the USA.

moderately interested in science and worked in a scientific or technical job or were professional researchers (77% of 39 responses).

This consistency is also shown when considering the reasons people gave for visiting open science websites. Just under 20% (n=19) of all respondents had visited at least one other site that encouraged public participation in research. Approximately a quarter of respondents (24%, n=26) offered a reason for visiting other websites. Their responses were broadly spread across the options offered, with the desire for information and general interest in the subject being the most popular reasons. A larger number (approximately 50%, n=54) offered at least one reason for visiting the surveyed websites, again, information-seeking and interest were the most common reasons.

Respondents (n=104) were almost evenly split between first-time and returning visitors to the websites. This agrees with figures from the sites' analytics data (see Table 3), which also show that for two of the sites, around half of the visitors to these sites are first-time visitors.

Table 6 Length of stay on site

	All sites		AC	CMOS	DART	MLU
	Count	%	%	%	%	%
less than 10 min	25	23.8	0	9	0	41
10 to 30 min	20	19.0	0	0	4	33
more than 30 min	9	8.6	2	0	0	15
Total	54	51.4				
Average*			2.45 min	1.44min	6.65 min	6.65 min
No answer	51	48.6	2	0	7	85
Total	105	100.0				

*Average from site analytic data

The majority of respondents who answered visited the websites for short periods, typically fewer than 30 minutes, as shown in Table 6. Although the figures in Table

6 were self-reported estimates, they agree with figures from the websites' analytics data; it would appear that users are mostly accurate in estimating they spend less than ten minutes on the sites.

These figures again suggest low levels of continuing engagement with these open science projects. Half of visitors come to the sites only once and do not return; nor do they spend long periods of time on the sites.

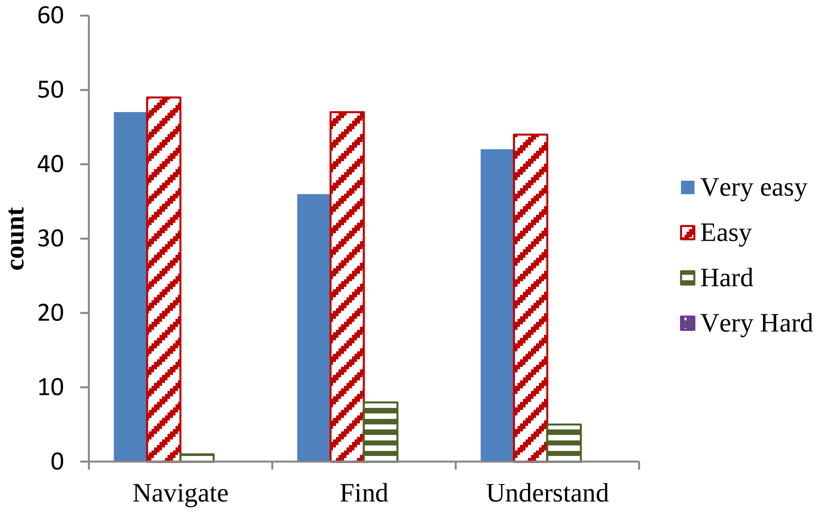
4.3.2 Resources and downloads

Very small numbers of respondents (19%, n=20) had downloaded resources from the websites. Of the resources downloaded, publications (n=14) were the most common; the other resources downloaded were images and photographs (n=2) and audio or video material (n=5). One respondent included 'research results' under 'other'; presumably this respondent viewed these as different from 'experimental data'.

Equally small numbers (18%, n=19) thought there were some kinds of resources missing from the website they had visited. Interestingly, although the numbers are low, some resources felt to be missing were present on the website concerned. For example, the AC site had experimental data and publications available (see Section 4.2.2 above); the DART site had a project blog, some information about researchers and some publications (see Section 4.2.3 above). CMOS had background information and brief biographies of researchers.

Failure to find resources could be a problem of language; that the respondent had a different understanding of the terms used (as noted above). It could be a problem of navigation – the respondent was unable to find such material on the site. However, the majority of respondents found the websites either very easy or easy to navigate, to find particular pages and to understand the material contained on the site (see Figure 3).

Figure 3 Ease of use of websites



Navigate – how easy have you found it to navigate around this website?
Find – how easy have you found it to find particular pages on this website?
Understand – how easy have you found it to understand the material presented on this website?

Thus, there seems to be no link between reported ease of navigation and whether users felt some resources were missing. That is, users who found the websites easy to navigate did not report more or fewer resources missing than users who found it harder to navigate. However, taking into consideration that half of the visitors were on the site for the first time and were typically spending fewer than ten minutes on the sites, failure to find resources could also be indicative of a lack of engagement with the sites.

4.3.3 Public engagement and participation

The final section of the survey sought to explore respondents' attitudes to public participation in research. However, as noted in Section 4.3.1 (above) the discussion of these data must be tempered by the fact that by this point in the survey (section 7) over half of respondents were not answering the questions. For example, as shown in Table 7, although a considerable majority of those who answered (86%, n=43) agreed that public participation in research was important, just over half of the total number of respondents (n=55) chose not to answer this section; an overall response of 41%. Although it is not possible to be certain, the pattern of response for this section varies little from the preceding and subsequent sections (see Figure 2), which suggests that a reasonably consistent group of people, which comprehended the relevance of this section of the survey, answered this group of questions,.

As shown in Table 7, a majority of those who responded considered public participation in research was important. Eighty-six per cent of those who answered chose this response, a figure which broadly agrees with major surveys such as the *Public Attitudes to Science* (UK) and *National Science and Engineering Indicators* (USA) series.[34]

Table 7 Opinions on public participation in research

		Frequency	%
Do you think it is important for the public to participate in research?	Yes	43	86
	No	1	2
	Not sure	6	12
	Total	50	100
	No answer	55	

The most common reasons respondents gave for the value of public participation in research (as shown in Figure 4) were contributory – that members of the public might have useful knowledge, reasons to take part or simply like to make a contribution to research.

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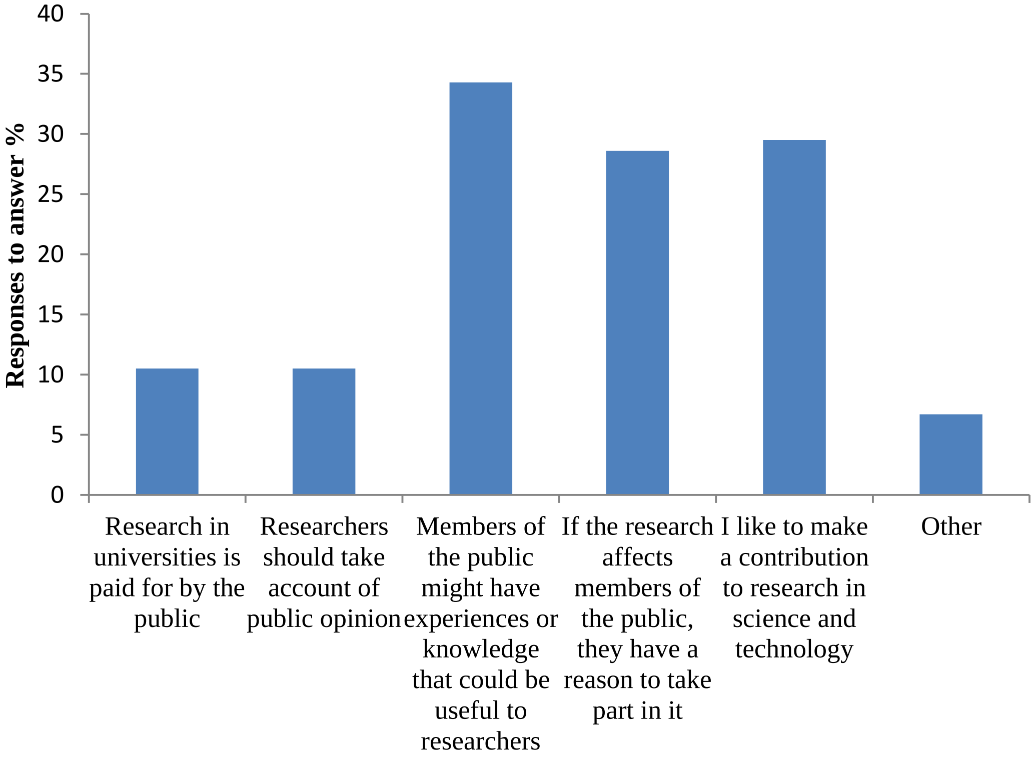
[34] Some of this set of questions were specifically included to enable comparisons with the PAS series. However, it must be noted that both their sampling technique (it questions a quota-sampled group of members of the public) and survey methodology are different (it uses both face to face surveys and workshop discussions to obtain data).

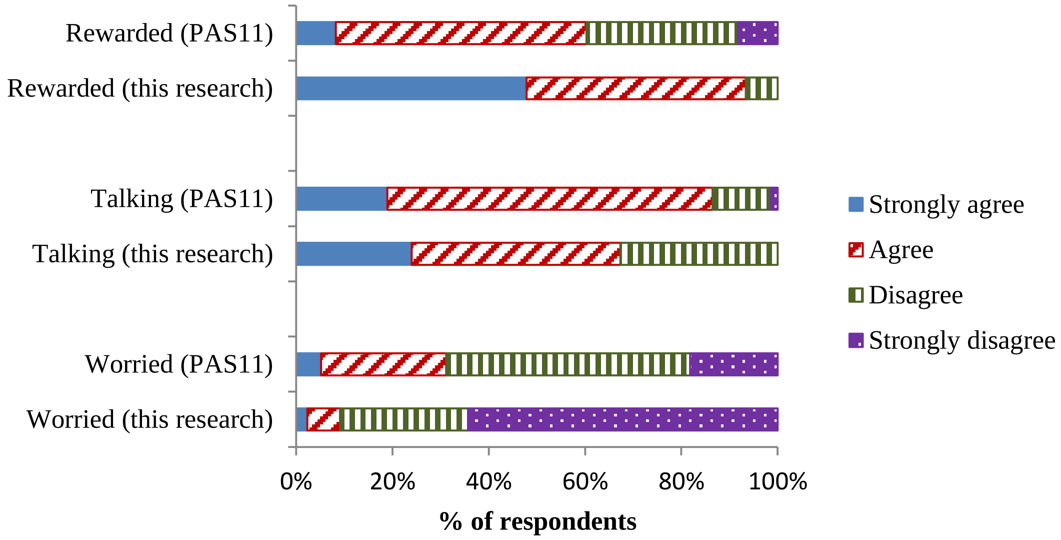
Figure 4 Reasons to support public participation in research



NB Respondents could select multiple responses: 3 people gave 1 response, 34 two or more responses and 63 gave no answer.

Respondents were supportive of scientists and considered they should be rewarded for public engagement activities (see Figure 5). They were largely unworried by knowing more about science, which suggests that respondents to this survey were particularly ‘science-philic’; something that might be expected of visitors to science-based websites, who were also, as noted in Section 4.3.1 (above) already interested in science and likely to have a science or research-based occupation. However, respondents to this survey were less likely to agree that scientists should spend more time talking about the social implications of their work than respondents to the PAS survey. The fact that these results were obtained from an online survey could have been a factor in this response.

Figure 5 Inter-survey comparisons



Rewarded: Scientists should be rewarded for communicating about their research to the public;

Talking: Scientists should spend more time than they currently do talking about the social implications of their work;

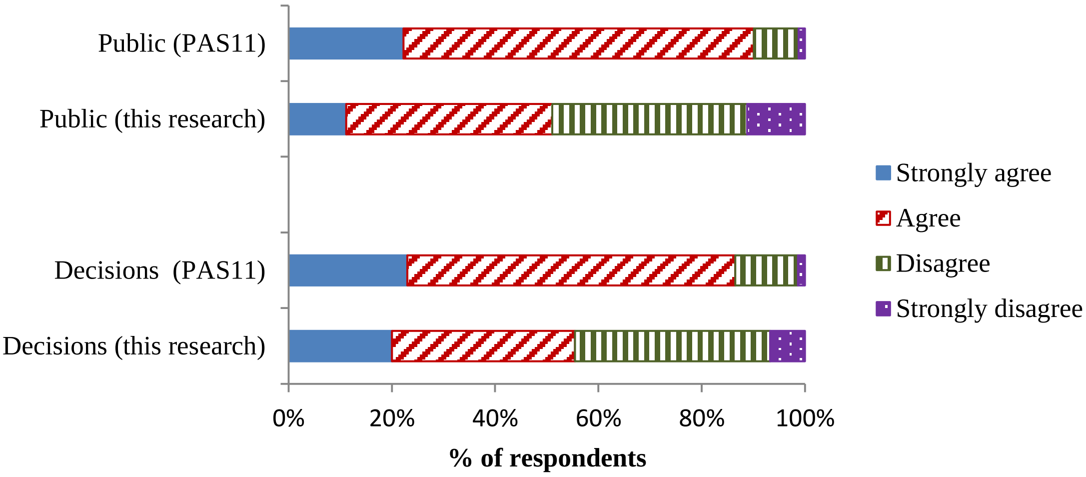
Worried: The more I know about science the more worried I am

Data from PAS11 Computer Tables (IpsosMori, 2011b) and this research

Respondents were fairly evenly balanced on the issue of public involvement in decision-making (see Figure 6) but with somewhat contradictory views. About half agreed or strongly agreed that public opinion concerning scientific and technological issues should be considered by governments, while just over half agreed or strongly agreed that decisions should be made by scientists, engineers and politicians and the public should be informed, rather than involved.

Perhaps bolstered by those who felt that decisions on scientific and technological issues should be made by scientists, engineers and politicians, respondents were broadly trusting of scientists.

Figure 6 Public opinion and decision-making



Public (PAS11): Governments should act in accordance with public concerns about science and technology

Public (this research): Public opinion should be considered when making decisions about science and technology

Decisions (PAS11): Experts and not the public should advise government (PAS11)

Decisions (this research): Decisions about science and technology should be made by scientists, engineers and politicians and the public should be informed

Data from PAS11 Computer Tables (IpsosMori, 2011b) and this research

Figure 7 shows that most respondents' (68% of n=46) level of trust in scientists was about the same as five years ago, with the proportion saying they trusted them much more than five years ago (10%) around five times the proportion that says it trusts them less (2%).

Figure 7 Change in trust in scientists

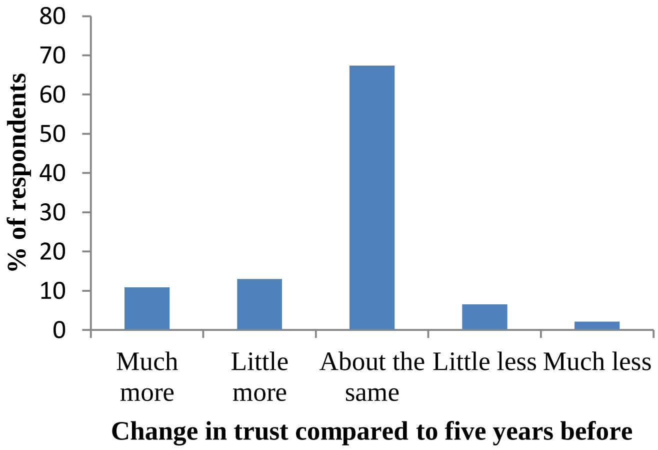
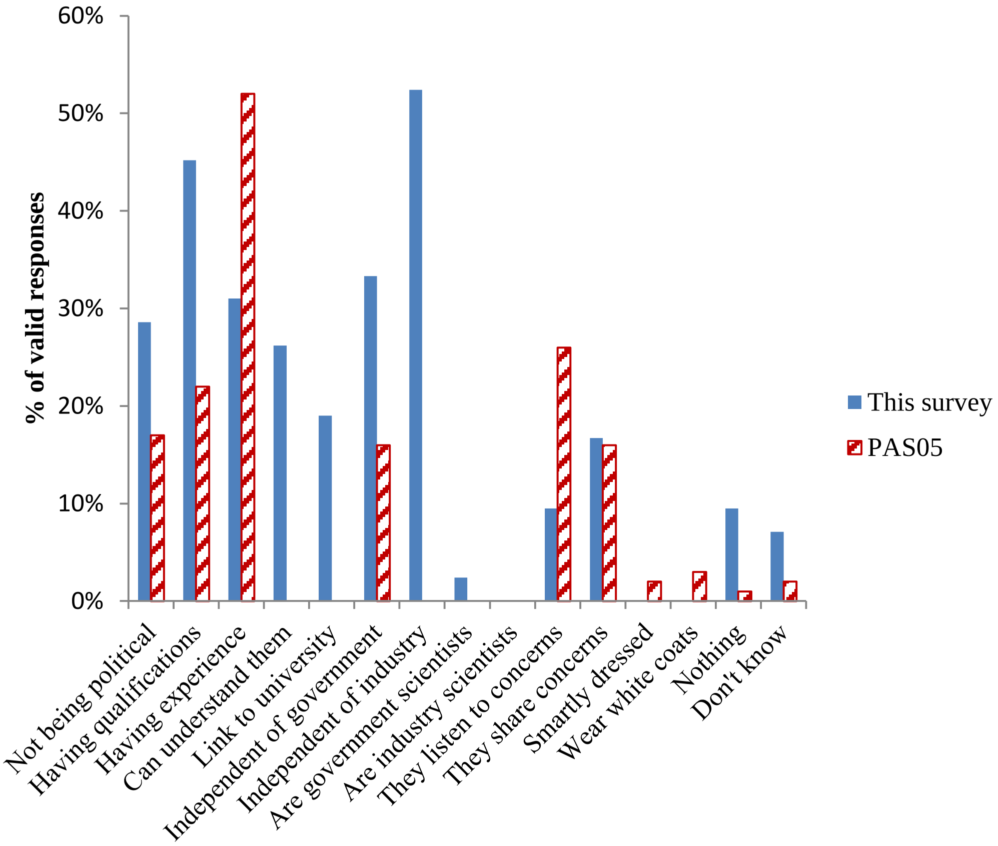


Figure 8 Factors determining trust in scientists



NB ‘Independence’ was a single factor in the PAS05 survey; this is shown alongside ‘independent of government’ in this figure. Some factors were not mentioned in PAS05, therefore ‘I can understand them’, ‘they have a link to a university’, ‘they are government scientists’, ‘they are independent scientists’ are missing data in this figure.

38% (n=40) of respondents gave up to three responses. A further 7% (n=7) were removed because respondents ticked more than three answers.

The most important factors in determining level of trust in scientists are shown in Figure 8. Of the response choices offered, respondents considered independence from business/industry to be the most important factor affecting their trust in scientists, followed by having academic qualifications. This is consistent with Critchley’s (2008) findings that public views of scientific research are profoundly affected by the context in which that work is conducted. Her study found the public is more likely to be supportive of controversial scientific research if it is conducted in publicly-funded universities, rather than private companies, partly because, in this situation, the scientists were thought more likely to be motivated by benevolence and that ‘public access to the benefits of University research was considered to be more likely’ (Critchley, 2008, p. 322).

Survey component summary

This section has discussed the results of a small-scale survey of visitors to four websites (three university-based projects and one special-interest website) to establish baseline data on the scientific and cultural background, motivations and opinions of visitors to open science websites.

The major point to note is that the response levels to the survey were low. For three sites (AC, CMOS and DART) respondents were in single figures. While these sites have low overall visitor numbers, so the respondent numbers could be expected to be small, none the less, even the considerably larger number of respondents from MLU was of similar proportions, compared to website visitor numbers, to the other sites.

Only around half of respondents were return visitors and most spent fewer than ten minutes on the sites. Furthermore, very small numbers of respondents had downloaded or made use of resources on the sites. However most respondents did not feel there were any resources missing, although some identified as missing resources that actually existed on the visited websites, which again may be indicative of a lack of engagement. These factors, taken together, suggest that levels of public engagement with open science sites are currently slight.

The drop-off rate for answering questions appeared rapid, with only around half of respondents answering the questions from section 3 onwards. As the questions from that point began to be concerned with engagement (for example, downloading resources) it is also possible that respondents were visiting the sites for reasons other than engagement. The most common reason given for visiting the surveyed sites was a general interest in the subject, which tends to suggest either that visitors were content with their degree of engagement or did not see their activity as engagement. Very few respondents were using the site to support their professional or personal research.

The sample sizes procured were too small to support far-reaching extrapolation. However, they do show some indicative trends. Visitors to open science websites are more likely to be male than the average Internet user and to be predominantly in the age group 25–44 (excluding the possibility that men are more likely than women to take part in a survey). They are also likely already to be moderately or very interested in science, again something which has been shown to be stronger in middle to older age groups (IpsosMORI, 2011; National Science Foundation, 2010) and work in scientific or technical jobs. They are likely to be part of a small – but potentially highly-engaged – group of active contributors within their online communities.

Respondents were supportive of public involvement in science and technology, indicating that members of the public could contribute to research through skills, experience, knowledge and interest. They were somewhat more pro-science than respondents to major surveys (RCUK/DIUS, 2008; IpsosMORI, 2011), agreeing more markedly that scientists should be rewarded for communicating about their research. They were considerably less worried by knowing more about science, which is perhaps to be expected of a group of people who deliberately sought to visit science-based websites.

Respondents to this survey expressed somewhat contradictory opinions regarding scientists’ and governmental dialogue with members of the public. Compared to the PAS surveys, they were less likely to agree that governments should take public opinion into account regarding decisions about science and technology issues but, on the other hand, more likely to agree that government decisions about science and technology should only be advised by scientists and engineers. However, the questions asked were not worded in exactly the same manner in this survey, so the figures can only be a general indication.

Although the full data for the PAS08 survey were not available, the published report noted that ‘experience and academic credentials were by far the most important factors that lead people to trust scientists and engineers’ (RCUK/DIUS, 2008, p. 6). Respondents to this survey rated independence from business/industry more highly than academic qualifications. Some of the factors are directly comparable to the 2005 *Science in Society* survey; there, ‘experience’ was the most highly-regarded factor (IpsosMori, 2005, p. 489) but this quality was rated fourth by respondents to this research.

As the PAS surveys have consistently shown, levels of trust in scientists are quite stable. In this survey, most respondents reported they trusted scientists ‘about the same’ as five years ago; this mirrors the PAS11 findings (68% about the same), (IpsosMORI, 2011, p. 44).

Chapter 5. Discussion

Open science has its roots in the enabling of collaboration among geographically separated groups of professional scientists. A major aim of this research was to investigate the implications of using open science's inherent accessibility to extend this to engagement between professional scientists and members of the public.

5.1 Themes identified

A number of themes related to this question have been identified in the results of this research. Open science is not yet a tightly-defined protocol; the considerable diversity of understandings of what 'openness' means is reflected in a considerable diversity of practice. This diversity of practice means that open science has the potential to support a range of modes for public engagement with science and indeed, for public participation in research. However, the development of wider participation in research raises concerns first, about how it can be facilitated and second, about the quality and quantity of the data and information that are generated by non-professional participants. Practising open science requires the instigation and sustaining of shared practices, whether among multi-site professional research groups or among professional-public research collaborations. Open science also raises issues of data ownership. Many agencies already have an interest in the outputs of research, for example researchers, funders, publishers and industry; extending the range of participants even further will increase the complexity of this issue. Finally, practising open science may require development of new tools and techniques, not only for researchers, who may need to develop and use new skills of communication but also for members of the public, who may need to develop skills of interpretation and analysis.

1 Open science is not yet a tightly-defined practice

As Grubb and Easterbrook's (2011) small-scale qualitative survey showed, even among scientists involved in varied open advocacy efforts, there was a low degree of consensus on the meaning of openness. In this research, this was particularly reflected in the case studies and interviews, which indicated that, even among researchers on the same project, there can be considerable diversity in understandings of what 'open science' means. In interviews, professional researchers offered a range of definitions of openness, extending from open access publication, to enabling open access to results, to complete transparency throughout the research process. Such diversity may be linked to the different circumstances in which open science is practised; for example whether practitioners work in groups or alone. Members of the public showed a similar diversity in their definitions, ranging from open science's ability to support simple one-way sender-receiver communication to full and dialogic professional-public collaboration. The potential for collaboration was also noted by professional researchers. The case studies offered support for this diversity of definition, showing considerable variety in how open science is understood by project members and therefore in how it is practised. This was particularly demonstrated by the DART open archaeology project, which was using a wide variety of different software tools to make information, evidence and data available. This variety was seen by the project champion as a means of supporting the project's members in their commitment to open practice, in that using tools well-suited to the task rendered undertaking that task less onerous.

The motivations underlying the choice to work in an open way are equally varied and affected by different circumstances; for example whether scientists are publicly or privately funded. Open science is in an experimental period of rapid evolution and diversification and natural selection has not yet removed the ‘organisms’ unsuited to the system. Greater agreement is likely to emerge as the field matures.

2 Open practice supports flexibility in modes for engagement

Open science can be a mode for embedded science communication; that is, communication which arises naturally from scientists’ normal work-related activities (Nielsen, 2009). Thus, open science accommodates a range of engagement modes, particularly since its practices are not yet fixed. As noted above, it can be a mode of communication for simple one-way transmission of information, through which scientists can convey or explain science to the public, and the public can access scientific information. However, the location of open science within ‘Web 2.0’ means it can also offer a mode for engagement that will be familiar to those who personify the ‘web’s culture of lateral, semi-structured free association’ (Leadbeater, n.d., p. 83); the community whose members have grown up using social media not only to consume – to search for information, share ideas, participate in debate – but importantly also to contribute, by re-purposing data and information and creating videos, blogs, websites, galleries and so on. This is the group characterised by Bruns (2009) as ‘produsers’: those willing to go beyond participation and become actors; active contributors as well as commentators. This suggests that open science need not fix on particular modes of engagement. This is important, in that it will allow those who practice open science to incorporate new tools and models as they arise, rather than being confined to existing communication instruments; something which is very likely to happen in the rapidly-changing, dynamic realm of Web 2.0.

The interviews and case studies showed that researchers both express and demonstrate a willingness to be open. Interviewees expressed the opinion that open science offered a potential route for transparency both of process and results. In practice, all the project websites observed for the case studies and those included in the survey, had made some information available, or had plans to do so, including contextual information about the project’s background, programme, researchers, and so on. Such types of information are of course, common on non-interactive websites. However, while offering only these types of information is not necessarily supportive of interactive engagement, it can none the less be supportive of a willingness to be open. From the downstream side, the survey showed that some respondents had downloaded publications and data for their own use, although the applicability of this conclusion is limited by the small numbers of survey respondents.

Interviewees recognised that the authenticity and completeness of the record that open science could provide would support both ethically transparent professional practice, and potentially help compliance with funders’ policies on open access to research outputs. Open science was also seen as being able to support scrutiny and review of research, both by professional and public audiences. However, the accessibility required to support wider scrutiny is noted as a potential problem. If material is published in subscription journals, private individuals, small companies or institutions in the developing world may not be able to afford the cost of access. To some extent, this can be overcome by open access publication, either the ‘gold’ route of publication in open access journals (which may include publication of full datasets) or the ‘green’ route of deposition in institutional or personal free-access archives. Universities, with their ‘capacity for creating and transmitting knowledge’ (Hart, et al., 2009, p. 19) are well-placed to be gate-openers for public access to university-created knowledge and providers of mechanisms for its transmission. However, while some disciplines have well-established norms for deposition of papers and other material in open archives, in others, there are cultural barriers that militate against such practices. In addition, as noted in Section 4.1.4 above, the commitment of researchers' time to tasks such as archiving causes some interviewees concerns; a point which was reflected in the case studies, where inequalities in availability of data and other resources were evident. Finally, although funding councils and journal publishers have begun to acknowledge the value of open access, including the generation, deposition and sharing of datasets and other research information (see Section 2.2 above), mechanisms for the reward and recognition of such non-traditional contributions are yet lacking.

3 Open science offers support for public participation in research

The survey showed that visitors to the project websites were strongly supportive of the general premise that public participation in research should be encouraged. While this result may have been biased by the fact the respondents were drawn from visitors to science-based websites, this opinion is reflected in other, more broadly-based public surveys, such as the UK *Public Attitudes to Science* series. However, visits to project websites were mostly very short, which website creators may consider should affect where information is placed for ready accessibility and how they can encourage visitors to stay on the website for longer. Survey respondents were also likely to have been drawn from the more active members of their communities and were therefore reflecting the views of a small but highly-engaged group. While this group may be influential in the development of a community, the existence of a much larger, silent, group cannot be ignored. Future open science sites will need to consider the requirements of different groups of users and – as some interviewees suggested – are likely to have to provide multiply-layered access, reflecting the complex layers of the research process.

Most visitors to the websites did not download material but where they did, publications and data were the most popular resources. Material was most commonly downloaded for reading and personal use. The survey respondents were unbalanced with respect to the general population (e.g. more likely to be male, in the middle age group and working in a scientific or technical occupation). This imbalance, combined with downloading behaviour, would suggest that visitors to open science websites are something of a 'niche' public, but one already interested in the details of the science and therefore likely to be willing to engage and participate more fully. Participation as a result of personal interest is perhaps best seen in projects concerned with medical conditions. Websites such as PatientsLikeMe have brought together people living with a variety of medical conditions to share their experiences and understanding. The data its members are willing to provide is being used in research and publications.[35] The UK Alzheimer's Society has a network of volunteers (people with dementia and those who care for them) which helps set research priorities, scrutinises research and monitors research projects funded by the society.[36]

However, data from the case studies showed that evidence of professional-public collaboration was limited; on the project websites, non-project members rarely left comments or interacted with project members. This inequality of contribution has been noted in since the early 1990s in almost all multi-user communities and online social networks (Nielsen, 2006). As noted by Bidwell (2009) there is evidence that researchers and community members do not always consider themselves peers, which may account for the reluctance of members of the public to comment on work on the websites. This contrasts with earlier arguments that professional expertise has

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[35] http://www.patientslikeme.com/research

[36] http://www.alzheimers.org.uk/site/scripts/documents_info.php?documentID=1109

been rendered redundant and that ‘everyone should be given an equal voice, irrespective of their title, knowledge, or intellectual or scholarly achievement’ (Keen, 2008, p. 43). However, if those who practice open science wish to enhance its potential to sustain public participation, further attention must be paid to the development of mechanisms that could support mutual respect and therefore fruitful engagement, dialogue and collaboration.

4 Wider participation raises concerns over the quality and quantity of information

Three major points emerged regarding the information made available by open science. First, interviewees were concerned that naïve users might be overwhelmed by the quantity of data likely to emerge from some projects. The case studies showed that all the projects had faced difficulties in dealing with large quantities of raw data, both in terms of quantity and completeness and also in terms of how to make the data available in a format that was readily accessible to public participants. The case studies offered a certain amount of unmediated data and information but there was a tension between getting the data out and getting it out in a form in which it is meaningful and usable. This tension is analogous to the tension between mediation and non-mediation in science communication activities, typically performed by communication specialists (Burns, et al., 2003) and framing or non-framing, as discussed by Nisbet and Mooney (2007) and Nisbet (2009).

Second, there were concerns about how non-professional consumers would be able to identify credible and trustworthy data. As Metzger (2007, p. 2078) noted, in the digital environment, where ‘nearly anyone can be an author [and] authority is no longer a prerequisite for content provision’, the research community’s conventional indicators, such as authorship and reputation, may neither be well-understood nor a sufficiently effective imprimateur. Interviewees and case study project members both noted that ideally, professionally-produced data should be richly contextualised and framed for public participants but how this might be achieved was less clear, especially as it might necessitate extra work both on the part of the researchers involved (see Theme 7, below) and on the part of the information consumers, who must develop methods of assessing credibility.

Third, there were concerns that the quality of information provided by public participants might not be of a high enough standard to be used alongside professionally-produced data; a point which one case study project had begun to address by considering how methodologies could be shared among all participants. Several existing Citizen Science projects have addressed the issue of data quality. For example, Worthington and colleagues (2011) in their Evolution MegaLab project (Silvertown, n.d.) which asked members of the public to gather data on the distribution of banded snails, used both pre-submission (asking participants to take a test of their identification skills and offering educative measures to improve skills) and post-submission (error-identification and data cleaning) measures to ensure community-generated data would be of a quality acceptable to the scientific community.

There is an important difference to be drawn between collaboration and democratisation. Open science does not necessarily mean that scientists lose their role or sacrifice their expertise; that science becomes subject to polls. A useful analogy may be drawn with ‘citizen journalism’, which has, since the late 1990s, revolutionised the ways we receive, gather, produce and disseminate news. Weblogs have made a potential news producer of every citizen, however:

> … while blogs add openness and critical debate to reporting, they have increased the amount of unverified information in the public domain. None the less, blogs give campaigners and the public the power to contribute to political discourse [and even possibly] to affect political events (Niblock, in press).

In journalism, the proliferation and acceptance of Web 2.0’s mechanisms means that members of the public can become both information-provider as well as information-seekers, with access to precisely the same sources as professional news reporters (Trench & Quinn, 2003). However, despite such changes, ‘professional news organisations still retain a very privileged place in framing and shaping the news agenda’ (Holliman, 2011, p. 2). The expertise of scientists is likely to mean that they will be awarded similar privileges while, as their journalistic colleagues are discovering, they are also being afforded access to the expertise of public collaborators and contributors, whose skills may enrich science.

5 Practising open science underscores the need to develop shared practices

Practising open science in multi-site research groups is likely to involve the instigation of shared practices, agreed and pursued by all members of the group. The case studies show there are disciplinary differences in approaches to openness – some disciplines have ethical practices which militate against making data openly available. Researchers also vary in their personal attitudes towards openness. As noted in Section 2.2.2, compliance with funders’ mandates for open access to research outputs is still nowhere near complete; if researchers are reticent about making the polished results of their work freely available, it is perhaps unsurprising they are even more reticent about sharing raw and tentative information.

However, the existing ‘strong shared praxis [of science] makes it well suited to collective intelligence’ (Nielsen, 2012, p. 80) and readily adaptable to socially mediated behaviours. There need to be shared principles of planning, vision, use of time, information flow patterns, tools to be used and practices to be followed, which for greater success – as shown by the case studies – would arise from the shared development of aims and objectives. Shared aims can reduce the stresses of changing resources, as new tools can be added as the need for them is perceived.

When collaboration is extended to non-professional participants, shared practice must likewise be extended. As noted above, some projects have sought to address concerns about the quality of data produced by members of the public by sharing methodologies and structures. This is demonstrated in the DART case study, which intends to create an open and evolving methodology library. However, shared practice goes beyond following a prescribed method and needs to include the recognition of local or experiential expertise. As both Trumbull, et al. (2000) and Brossard, et al. (2005) noted, where participants consider a standard methodology inappropriate, for example due to local environmental conditions, they may change it, potentially rendering their data unusable.

6 *Open practice raises issues of ownership*

There is clear potential for conflict between the adoption of free availability of information and companies' and institutions' need successfully to exploit intellectual property. Even where the science may not be such as can create profits, issues of ownership, including the many and varied ways in which use of data can be licensed or denied, exist. Scientists have expressed personal concerns that they may be 'scooped' when other scientists use published data before the original producer, although others contend that openness offers its own protection for priority and precedence (Wald, 2009). It is notable that no interviewees mentioned specific concerns over ownership of the research process – the participants involved in this research did not appear to consider this a major issue. This contrasts with earlier work, which identified that ‘involving the public inevitably means researchers have to give up some of their power [and] although many researchers have recognised that this shift is essential for projects to become genuinely collaborative, no one has reported finding it easy’ (Staley, 2009, p. 66). It may be that as co-creative public participation in research becomes a more widespread paradigm (as opposed to the more common contributory model) that researchers – and other participants – will have to grapple with the issue of power hierarchies.

Responses to the online survey show that visitors to open science sites considered independence from business/industry to be the most important factor affecting their trust in scientists, followed by having academic qualifications. This is consistent with Critchley’s (2008) findings that public views of scientific research are profoundly affected by the context in which that work is conducted. Given that open science exists through and depends on the largely unregulated arena of the Internet, this would suggest that future developers of open science sites should consider making clear that their research originates in a university or publicly-funded group. In the case study projects, the logos of the several universities participating in the DART project are on the front page; the Artificial Culture and Bloodhound@university projects have such information but not on the front page.

There are also problems arising from disciplinary ethics. While information-sharing is widely accepted in some disciplines, such as physics and mathematics, is it less common in others, such as the biological sciences. Some interviewees and members of case study projects mentioned concerns about personal privacy; disciplines such as medicine and the social sciences have norms that preclude the publication of personal information pertaining to research subjects. While such differences in ethos may cause strains within multi-disciplinary projects, they are also more widely reflective of deep-seated social mores concerning notions of personal privacy which could expose problems regarding data confidentiality that will not be easy to resolve.

7 Open science may require development of new tools and techniques

As noted earlier (see Section 2.2.4) science communication has long sought to reflect the dynamic, tentative and uncertain nature of research. In research science, the process is at least as important as the results:

> The creativity and invention [of research] comes in the process of laboratory work and demonstration and if we are to judge a scientist's artistry fully, it must be by watching him or her in the laboratory with its retorts, tubes and compounds, timing, weighing and testing; or in front of a monitor interpreting the brainwaves and scans of a willing subject. (Hamilton, 2003, p. 267)

Interviewees considered that open science has considerable potential to reveal the workings of science and scientists through its presentation of the complete record of research activity. However, as Borgman (2003, p. 165), suggested, making 'digital laboratories useful to multiple audiences requires simple analytical structures, more common vocabulary and user interfaces that demand minimal domain knowledge'. If researchers are to embrace the archiving of methods, research diaries and notebooks, results, data, publications – in other words, the many manifestations of the researchers' activities – the skills they will need to acquire may become an issue. Maintaining an archive, a website, a blog or an open notebook may require some researchers to learn new techniques (although others will already be perfectly comfortable with these activities). Numbers of scientists already write blogs about their research and engage in dialogue with readers through these blogs, for example the collections of researchers who blog together on sites such as *Scientific American*

Blogs and *ScienceBlogs*[37] or the use of a blog as part of a science communication strategy, such as the blog of Cancer Research UK.[38]

Participants need to commit dedicated time to their open science practice, which may be seen as time taken away from ‘real work’. However, such open practice could also provide the means by which scientists could maintain a respectable digital reputation; something which concerns significant numbers of scientists (Reich, 2011a).

Although all the projects in the case studies had faced difficulties in making information available, the survey showed that respondents spent more time on websites that had made more resources available. While this may reflect the obvious conclusion that the more there is to look at, the longer visitors will stay, it may also have implications for how researchers make resources available, where they are placed and how they are signposted. If users can’t find the resources they want, they will not linger and instead choose to visit other sites that offer greater depth of information. Interviewees commented that information providers will need to offer support to information consumers, perhaps by developing narratives or maps that contextualise the research.

However, while researchers may be required to develop the skills needed for mediating information, members of the public may need to develop new skills of gaining access, interpreting and understanding the structures of the digital ‘collaboratory’ (Wulf, 1993), although the greater availability of data may itself offer them both the opportunity to develop those new skills and the material on which they may practice them. These skills, and the fact they are expressed through the medium

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[37] http://blogs.scientificamerican.com; http://scienceblogs.com/

[38] http://scienceblog.cancerresearchuk.org

of the Internet, matter ‘not least because by allowing people to participate and share, it also gives them a route to recognition’ (Leadbeater, 2009, p. 229), so that, as interviewees expressed, the contributions of amateur scientists can reach the mainstream and be both valued and valuable.

The considerable growth in use of social media tools in recent years has brought potentially open science practices more readily within the reach of both scientists and members of the public: keeping blogs, commenting, using micro-blogging software, social citation software, video sharing, podcasting and so on, are steadily becoming more commonplace. Using readily available and popular tools means that rather than needing to develop new skills, existing skills can be re-purposed and existing tools integrated into traditional scientific work and communication patterns (Crotty, 2011).

5.1.1 Limits to the findings

The most profound limit to the quality of this research is that its configuration could be seen as prejudiced towards a positive view of open science and public engagement with science. For example, all the scientists interviewed were publicly-funded; on reflection, it would have been enlightening to have interviewed scientists from industry and the private sector, which would have enriched the discussion around such issues as access to research, intellectual property protection, data ownership and so on. Likewise, it would have been valuable if the author had succeeded in talking to interviewees likely to hold sceptical views. Many interviewees commented on possible negative aspects of open science and although other interviewees who, through their writings or reputation could be perceived as holding sceptical views were identified and approached, unfortunately, none replied.

This prejudice towards positive views was, to a degree, inevitable for the case study and survey components. Non-open projects are, by their nature, invisible until journal publication, and are therefore harder to identify and certainly harder to follow. Also, one objective of the research was to conduct case studies of ‘open’ projects to establish how openness is achieved in practice, which precluded studies of non-open projects. A similar point could be made with regard to the survey; the objective was to establish information on the motivations of visitors to open science project websites, rather than visitors to other kind of sites. However, it is acknowledged that the work would have been enriched by including a wider range of material.

5.1.2 Suggestions for future work

Based on the findings from this project there are four key areas of proposed future work that would be of great benefit to furthering knowledge within this area:

1. Arising from Section 4.1.1, and the case studies, research to address the questions of varying understanding of the meaning of openness and particularly how this is developed among participants in research projects that include the aim of being ‘open’. This work might address questions such as:

   > Within the context of a multi-disciplinary project, investigate how researchers define and resolve different understandings of the extent of openness, for example by developing shared practice or through developing experience and expertise. Such an approach could, for example, investigate the development of shared practice or experience and expertise within the group, leading to greater insights of inter-disciplinary perspectives.

2. Arising from Section 5.1.1, and the case studies, research to investigate attitudes to open science among a wider range of researchers, for example those working in private industry. Research could also be undertaken to investigate attitudes and understandings towards open science among researchers, writers and others identified as holding sceptical or negative views. This work might address questions such as:

   > Are there similarities and differences in attitudes to open science between publicly- and privately-funded researchers?

3. Arising from Sections 4.1.3, 4.1.5, and 4.3.2 above, research based alongside an active research project (ideally one co-created by professional researchers and members of the public) to establish the audience for open science, the optimal tools and strategies for public engagement via open science, how open science practices are or can be incorporated into everyday working arrangements and evaluate the effectiveness, reach and impact of different strategies. This might address questions such as:

    Within the context of an active research project, evaluate which tools and strategies are most effective in supporting open practice and public engagement activities by researchers and members of the public. Such research could extend to consider, for example, work to compare and contrast the effectiveness of online and face-to-face public engagement activities.

    Within the context of an active research project, investigate how open science practice can support public engagement and dialogue between researchers, non-professional participants and online audiences.

    Within the context of an active research project, investigate how open science can support public engagement with research outputs. Such an approach could, for example, investigate how members of the public interact with research outputs, what uses they make of them, attitudes of researchers to online input from members of the public and how shared practice develops between professional and non-professional researchers, leading to deeper insights into the nature of public engagement via open science.

4. Arising from Sections 2.3.4 above, 4.1.2 above and 4.2 above, research to bring together citizen science and open science, enabling professional researchers and members of the public to work together throughout the research process. This process would go from the identification of pertinent research questions to establishment of sound methodologies, validation of results, and publication, incorporating open science practices for dissemination and enabling of public engagement with the research and evaluating the impacts of the research and its methods. Work has already been initiated on extending participation in citizen science to a wider range of communities (Haklay, 2011); building on projects such as Haklay’s to identify or establish a suitable project, such research could, for example, address questions of why, how or if citizen scientists are able to incorporate open practice, such as:

    > Establish what tools and strategies best support dissemination, re-use and mutual sharing of research outputs by professional and non-professional participants in a research project.
    >
    > Consider the routes through which non-professional participants develop the interpretive and analytical skills to use the information and data made available through open science.

Chapter 6. Conclusion

The hypothesis investigated through this research is whether open science has the potential to support public and community engagement with science. By making use of innovative access technologies, based on Web 2.0 principles, open science has the potential to be a model for public engagement directly with science, offering public audiences unmediated access to research outputs and results while the projects concerned are actively in progress. However, understandings of what is meant by ‘open’ are not yet settled and the practice of open science is equally variable, so that researchers and projects currently operate along a continuum, from complete openness to selected archiving.

Open science can sustain collaboration among researchers in multi-site research groups, supporting honesty and transparency both between colleagues and in the relationship with the wider public. However, there are factors militating against open science practice: in particular, researchers have concerns about how these open science approaches will integrate with the currently-accepted norms and behaviours that at present support the maintenance of reputation, precedence, quality assurance and intellectual property. For members of the public, open science offers access to a greater range of evidence and can provide the context against which published information can be judged; when the raw dataset is made available, as are the methodologies by which the research was conducted, the published and polished conclusion can be compared and contrasted. However, members of the public may have to be ready to develop the skills needed to interpret and analyse raw data.

Making research outputs openly available means a new range of participants can be recruited; these may be members of the public but also could be professional audiences beyond the projects’ research field. Open science thus has the potential to support collaboration, if the necessary dialogue can be maintained, for example through the use of Web 2.0 and social media software, which are becoming increasingly common tools for scientific communication. However, engagement with active projects will entail adaptations by both scientists and members of the public; all the projects followed as case studies had experienced difficulties in making data and other information available. There is also more to accessibility than simple availability; there is agreement that research outputs will need to be annotated, classified and contextualised so that they become useable by wider audiences.

The quantity of data that could potentially be made available through open science may render interpretation and analysis difficult, especially for audiences unused to data normalisation processes. Projects may be required to offer contextualisation and mediation of what may be quite complex data, with consequent demands on researchers' time and skills. However, if these skills can be recognised and developed, for scientists, open science offers not only technical and research-related advantages, but also a new mode for science communication, in which engaging with audiences can become part of daily scientific work. Much of the activity that renders science 'open' is an extension of everyday work: the research diary becomes a blog, the laboratory becomes a social network, papers are collaboratively created, the public face of the project becomes a website, data are automatically collected and flow seamlessly on to a wiki and dialogue operates through comments and responses. For members of the public, openness offers a variety of routes for engagement, from simply following the progress of a project in which they are interested, engaging with scientists via discussion and comments, contributing their time and effort to data organisation, accessing resources they can take and re-use for their own interest, to collaboration throughout the scientific process, from research question, to research design, to experiment, to analysis.

The factors outlined above support the conclusion that the emerging trend towards open science has the potential to change the mediation of public conversation about science. The strengths of open science are that it capitalises on present trends in scientists' and members of the public's use of social media tools and thus has the potential to build communities within which scientists and members of the public, domain experts and experiential experts, can work together. For scientists, it offers a novel route for communicating the results of their work using the practices and tools which are already a part of their work, making science communication part of daily activity, rather than special events. It has the bi-directional advantage of offering both scientists and members of the public the benefits of both full transparency and complete veracity in the scientific record. Its weaknesses are that the information freely offered through open science is susceptible to misuse and, without rich contextualisation and narrative (both of the background and supporting material for the research as well its results) open to misunderstanding and misinterpretation.

There are other difficulties that must be overcome: first, a public used to the presentation of science through carefully considered, normalised and well-ordered conclusions may be confused, or even bored, by the mass of raw data that is the first output of many research projects. Second, requiring researchers to contribute data, writings, images and the other research outputs to open science websites and to respond to public comment (which may or may not be relevant), could add to scientists' workload or be seen as taking time away from their 'real' work. Finally, if the numbers of members of the public who participate in open science remain low, this could be demoralising for scientists and lead them to discontinue their efforts.

However, the societal mood of the moment (at least in Europe and North America) is well suited to the development of open science as a medium to support public engagement with science. There is a social and governmental move towards greater transparency and greater public influence in the decisions about the issues in science and technology which affect people’s lives. Currently, public trust in scientists is significant and members of the public support the concept of public participation in research. In their turn, scientists acknowledge their responsibilities to engage with the public and have expressed support for the idea that open science can provide a medium for this interaction. The maturation of ‘Web 2.0’, the group of Internet technologies for social production and networking, and the cultural norms which support their development, is making it possible for scientists and members of the public to engage in innovative and flexible ways.

In short, the paradigm of openness creates a confluence of aspiration, opportunity and method. The development of meaningful engagement, dialogue and collaboration through open science has considerable potential for science, scientists and members of the public.

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Chapter 8. Appendices

8.1 Appendix 1 Interviewee consent forms and information sheet

Anonymous:

Open Science Public Engagement

Human subjects research consent letter

I, (print name in full) ___________________ agree to participate in the research project being conducted by Ann Grand between January 2009 and December 2011

I understand that transcripts of recorded verbal communications and/or email communications with the researcher will be studied and excerpts may be quoted in a doctoral dissertation and in future papers, journal articles and books that may be written by the researcher.

I grant authorisation for the use of the above information, with the understanding that the information will remain confidential and will not be passed on to any other group, organisation or individual. I understand that my responses will be made anonymous and identifying information will neither be disclosed nor referred to in any way in any written or verbal context. I understand that printed transcripts will be secured in the researcher's university office and electronically stored responses in password-protected files and that recordings and transcripts of my conversations with the researcher will be destroyed no later than December 2012.

I understand that my participation is entirely voluntary and that I may withdraw from the study without explanation at any point up to and including July 2011.

Name:...

Address: ....

Signature: .... Date ....

Researcher’s signature .... Date.........................

Ann Grand
Science Communication Unit, Faculty of Life Sciences
University of the West of England
Coldharbour Lane
Bristol
BS16 1QY

+44(0) 117 328 3332

ann2.grand@uwe.ac.uk

Please keep a copy of this information for yourself and return a copy to the researcher.

Non-anonymous:

Open Science Public Engagement

Human subjects consent form – non-anonymous

I, (print name in full) ___________________ agree to participate in the research project being conducted by Ann Grand between January 2009 and December 2011

I confirm that Ms Grand has fully discussed the open and public nature of the research and I understand that this means my name and other identifying factors may be disclosed as part of the process of dissemination of information.

I understand that transcripts of recorded verbal communications and/or email communications with Ms Grand will be studied and excerpts may be quoted in a doctoral dissertation and in future papers, journal articles and books that may be written by her.

I understand that my participation is entirely voluntary and that I may withdraw from the study without explanation at any point up to and including July 2011.

I grant authorisation for the use of the above information. I understand that printed transcripts will be secured in the researcher's university office and electronically stored responses in password-protected files and that recordings and transcripts of my conversations with the researcher will be destroyed no later than December 2012.

Name:...

Address: ....

Signature: .... Date ....

Researcher’s signature .... Date.........................

Ann Grand
Science Communication Unit, Faculty of Life Sciences
University of the West of England
Coldharbour Lane
Bristol
BS16 1QY

+44(0) 117 328 3332

ann2.grand@uwe.ac.uk

Please keep a copy of this information for yourself and return a copy to the researcher.

Information Sheet: Open Science Public Engagement

The Project: The aim of this project is to investigate - using a case study approach - ways that Open Science and public engagement can be mutually beneficial and explore the potential for a framework where the two can be integrated to create a symbiotic framework for interaction between professional scientists, amateur experts and the public.

Project Timeline:

January 2009 – December 2011

Contact details:

Ann Grand
Science Communication Unit, Faculty of Life Sciences
University of the West of England
Coldharbour Lane
Bristol
BS16 1QY

+44(0) 117 328 3332
ann2.grand@uwe.ac.uk

Thank you for your help with this project. Should you decide you wish to *withdraw* your contribution from the project or see a *report* of the project's findings, please contact the researcher before July 2011.

8.2 Appendix 2 Interview schedules

Scientists

1. What does ‘public engagement’ mean to you?
2. Do you think it is important to engage directly with people (other than colleagues and other scientists) about your research? Why – or why not?
3. How easy do you find it (or think you might find it) to explain your work to non-experts? To experts in other fields? To lay enthusiasts?
4. Would you say that you take part in public engagement activities? Could you give me some examples?
    a. If they say they do PE activities:
        i. How much of your time would you estimate you devote to them?
        ii. What kinds of groups of people do you engage with (examples if necessary – school pupils, university students, journalists, members of the general public)?
        iii. Why do you take part in these activities?
        iv. Do you find there are any things that get in the way of you taking part in PE activities?
    b. If they say they don’t:
        i. What things get in the way of you taking part in PE activities?
5. How understandable do you think your work is to a) lay science enthusiasts and b) the general public? What are the barriers to comprehension?
6. Have you heard about the ‘Open Science’ approach? What does the term mean to you?
7. Do you think your research could be carried out using an open science approach?
8. How do you see open science developing in the next five / ten years?
9. In the group of people you work with, what technologies are used to support communication and collaboration (for example, electronic lab notebooks, email, wiki, common document repository)?
10. How do / would you feel about opening up your work to public scrutiny – for example, blogging personal speculations, ideas or talking about new or unexpected results – so that people can follow what it is really like to do research?
11. If you could design your ideal Open Science interface, what would be the two things you would most like it to have?
12. Are there any more things you would like to add before we end the interview?

NB An extreme definition of Open Science might be: an approach to doing science in which the whole of an ongoing scientific investigation and its data are made freely available as the work happens. Along the ‘continuum of openness’[39] occur such things as data sharing, open access, institutional repositories, wikis, blogs, open notebook science.

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[39] JISC Open Science at Webscale, (Lyons, 2009)

Other collaborators

1. Could I start by asking you to tell me something about your interest in science?
2. Are there any scientific topics you are particularly interested in?
3. How much of an expert do you consider yourself to be in a specific field of science? In science generally?
4. Do you actively discuss scientific ideas? How often? Where – online forums, talks, informal events?
5. In discussions, would you say you are usually a disseminator or a recipient of information and ideas? Why?
6. Do you read science-based magazines, such as *New Scientist* or *Scientific American*?
7. Do you read scientific journals, papers or similar research publications or visit websites concerned with research?
8. Have you heard about 'Open Science'? What does the term mean to you?
9. Would you personally be interested in following the development of a research project?
10. What would your ideal research website look like?
11. Are there any more things you would like to add before we end the interview?

Question for people in PE

12. Could you give me a potted description of (the activity)?
    i. How much of your time would you estimate you devote to it?
    ii. What kinds of groups of people do you engage with (school pupils, university students, journalists, members of the general public)?

Examples for q2

physics, astronomy and cosmology, biology and natural science, molecular biology and biotechnology, health and medicine, chemistry and materials science, scientific ethics, psychology and neuroscience, sociology, computer science and artificial intelligence, mathematics, the philosophy of science, complexity theory, cybernetics, adaptive systems...

8.3 Appendix 3 Coding frame

				References
Open Science				
	Difficulties			
		OS - difficulties for non-scientists		5
		OS - difficulties for scientists		
			abuse of data - scooping, etc.	5
			commercial and legal problems	9
			governments	2
			lack of funding	2
			lack of shared language	7
			lack of shared understanding	9
			lack of skills	6
			lack of time	8
			maintaining quality	7
			need for change in attitude	8
			ownership (e.g. of data)	7
			privacy issues	3
			publication issues	7
			unwillingness	4
			vagueness of definition	1
	Features			
		authenticity		10
		availability		5
		bringing together		7
		capturing the record		10
		clarity		9
		definitions of open		32
		expertises		6
		layers		4
		scrutiny		9
		sharing failure		3
	Methods and tools			
		collaborative discussion		7
		community		12
		crowdsourcing		4
		difficulties with tools		22
		media		1
		need for selection		2
		non-web tools		3
		open access - repositories		6
		piloting		4
		shared objects		2
		shared standards		5
		support		3
		theoretical techniques		7
		Web 2.0 (blogs, etc)		25
			open notebook	5

				References
	Motivations			
		specific for non-scientists		8
		specific for scientists		
			changes work pattern	3
			collaboration	5
			communication	5
			competition	3
			connexions	4
			dissemination of research	5
			efficiencies	9
			ethics and rightness	9
			funders' policies	6
			how voluntary	2
			inducements	6
			inevitability	2
			public demand for information	4
Public Engagement				
	definitions of PE			2
	dialogue			7
	direction of engagement			7
	models - deficit			0
	mutual learning			1
	problems with			
		problems for public		1
		problems for scientists		6
			public's expectations	2
			take-up by scientists	1
			why do PE	2
Space between OS&PE				
	access			13
	need for context			16
	PE as tool for scientists			8
	publics			13
	too much data			6
	what would be ideal			26

8.4 Appendix 4 Case study selection criteria

	My contention is that this involves:	As suggested by:
Public engagement	Participation by both public and experts	(McCallie, et al., 2009) (Poliakoff & Webb, 2007) (PSP, 2006)
	Transfer of information / understanding / opinion (could be one-directional e.g. expert → public or public → expert or could be bi-directional expert ↔ public)	(ACU, 2002) (DIUS, 2008) (expert → public) (COPUS, 2001)(expert → public)
	Mutual learning	(McCallie, et al., 2009)
	Multiple perspectives	(McCallie, et al., 2009)
Open Science	Raw data available	(Science Commons, n.d.)
	Full project description (hypothesis, methods, aims, work programme)	(OpenWetWare, 2009)
	A permanent record of activity	(myExperiment, 2011) (Poynder, 2008)
	Electronic lab notebook /wiki	(Waldrop, 2008b)
	Public accessibility	(Poynder, 2008)
	Access to project-derived software (cf Open Source)	(Open Source, n.d.)
Open Science with Public engagement	Public accessibility	(Poynder, 2008) (Jensen & Holliman, 2009)
	Full text publications	(Suber, 2004)
	High public visibility (tagging, etc.)	
	Project context information (background information, funding, history, glossary)	
	Encouragement for public to contribute to project (for example via blog comments, wiki development, email direct to researchers, web voting, forum)	(Nature, 2009) (McCallie, et al., 2009)
	Dialogic activities (lectures, journalism, etc.)	(House of Lords, 2000) (RCUK/DIUS, 2008)

8.5 Appendix 5 Website urls

Case studies

Bloodhound@university
http://bloodhoundssc.uwe.ac.uk/RenderPages/RenderHomePage.aspx

The Detection of Archaeological residues using Remote sensing Techniques (DART)
http://dartproject.info/WPBlog/

The Emergence of Artificial Culture in Robot Societies (AC)
http://sites.google.com/site/artcultproject/

Survey

Complex Systems Modelling and Simulation infrastructure (CoSMoS)
http://www.cosmos-research.org/

Machines Like Us (MLU)
http://machineslikeus.com/

Others (see Section 3.3.1)

BBC Amateur Scientist
http://www.bbc.co.uk/radio4/features/sywtbas/2010/

Evolution Megalab
http://evolutionmegalab.org/

FoldIt
http://fold.it/portal

Galaxy Zoo
http://www.galaxyzoo.org/

Open Dinosaur Project
http://opendino.wordpress.com/about/

Encyclopædia of Life
http://www.eol.org/

DIYbio
http://diybio.org/

myExperiment
http://www.myexperiment.org/

UsefulChem (wiki)
http://usefulchem.wikispaces.com/

Open Research Online
http://oro.open.ac.uk/

Open Science Project
http://www.openscience.org/blog/?page_id=44

OpenWetWare
http://openwetware.org/wiki/Main_Page

British Geological Survey
http://www.bgs.ac.uk/research/home.html

Perimeter Institute
http://pirsa.org

Pulse
http://www.pulse-project.org/

8.6 Appendix 6 Survey questionnaire

Science on the web

1. Background to this survey

This survey forms part of a PhD research project being conducted at the University of the West of England, Bristol, UK. Any information gathered will be used only for the purposes of the research.

We are very grateful for your help and involvement. The information gathered from this survey will form an important contribution to the research.

If you do not wish to answer a particular question, please just leave the answer blank.

If you have any questions connected with the survey or would like more information, please email the researcher on ann.grand@live.uwe.ac.uk

We anticipate the survey will take approximately ten minutes to complete.

To take part in this survey, you must be over 18 years of age.
    1. I confirm that I am over 18 years of age.

2. Science on the web

"Website" in the following questions refers to the site you were visiting when you were asked to take part in this survey.

1. How easy have you found it   Very easy Easy Hard Very hard
    To navigate around this website?
    To find particular pages on this website?
    To understand the material presented on this website?

2. Is this your first visit to the site?   Yes/no

3. If this is not your first visit, approximately how many times have you visited the site?

3. Resources on the website

1. Have you downloaded any resources from the website?
    experimental data?   Yes No Does not exist on the website
    publications?
    other resources?

If you have downloaded 'other' resources, could you say what they were?

2. If you have downloaded some resources, how do you intend to use them? (Tick as many as apply.)
    to read now   to read later   to use in my professional research
    to use in my personal research   to share with others   to use for teaching
    Other (please specify)

3. Are there resources missing from the website that you would like to have seen there? (Tick as many as apply.)

no
background information about the project
information about the researchers
information about the project's funding
experimental data
publications from the project
ability to contact the researchers
project blog
Other (please specify)

4. Reasons for visiting this website

1. How did you first find this website?

search engine
a friend told me about it
a colleague told me about it
I followed a link from another website
I followed a link from a blog
I am a member of the project team to which the website relates
Other (please specify)

2. Why did you choose to visit this website? (Tick as many as apply.)

I'm a member of the project team
I’m an academic looking for information for research
I'm browsing
I’m a teacher looking for information for my students
I'm particularly interested in its subject matter
No particular reason
I'm looking for information for my personal research
I'm a student looking for information to support my work
I'm generally interested in science
Other (please specify)

3. For this visit, how long would you estimate you have spent on the site? (Not including the time spent completing this questionnaire.)

Less than 10 minutes
10 to 30 minutes
More than 30 minutes

4. Will you return to this website to see how research is progressing?

definitely
possibly
no

5. Improving the website

1. Do you have any suggestions for ways in which the website could be improved? If so, please outline them here.

6. Other websites

1. Have you visited any other websites that encourage public participation in research? (Tick as many as apply.)

Galaxy Zoo (www.galaxyzoo.org)
Open Science Project (www.openscience.org)
Open Source Initiative (www.opensource.org)
FoldIt (http://fold.it/portal)
Open Dinosaur Project (http://opendino.wordpress.com)
InnoCentive (www2.innocentive.com/)
Other (please specify)

2. If you have visited any websites that encourage public participation in research, why do you choose to do so?

- enjoyment
- general interest
- Other (please specify)
- they have useful information
- enthusiasm for the subject

---

7. Public participation in research

1. Do you think it is important for the public to participate in research?

- yes (automatically taken to 2)
- no (automatically taken to 3)
- not sure (automatically taken to Section 8)

2. I think public participation in research is important because (tick as many as apply)

- Research in universities is paid for by the public.
- Researchers should take account of public opinion.
- Members of the public might have experiences or knowledge that could be useful to researchers.
- If the research affects members of the public, they have a reason to take part in it.
- I like to make a contribution to research in science and technology.
- Other (please specify)

3. I don't think it's important for the public to participate in research because (tick as many as apply).

- Researchers are the people best qualified to do the research.
- I don't have the skills I think are needed for research.
- I'm not clever enough to understand science and technology
- Scientists don't talk enough about research, so I don't know what's happening.
- Other (please specify)

---

8. Science and society

1. What is your opinion on these statements?

	Strongly agree	Agree	Disagree	Strongly disagree
Decisions about science and technology should be made by scientists, engineers and politicians and the public should be informed about those decisions				
Scientists should be rewarded for communicating about their research to the public				
Public opinion should be considered when making decisions about science and technology				
The more I know about science, the more worried I am				
Scientists should spend more time than they currently do talking about the social implications of their work				
Scientists are the people best qualified to explain the impacts of scientific and technological developments				

2. Which THREE of the following do you think are the most important in determining whether you would trust a scientist?

- They are independent of government
- Having academic qualifications
- They are employed by business/industry
- They are wearing white coats/lab coats
- They are smartly dressed
- They are government scientists
- They are independent of business/industry
- They are linked to a university
- I can understand what they are saying
- Nothing
- They share my concerns
- Don’t know
- Not being political
- They listen to my concerns
- Being experienced

3. Would you say you personally trust scientists more or less than you did five years ago?

- Trust them much more
- Trust them a little more
- About the same
- Trust them a little less
- Trust them much less
- Don’t know

---

9. Background information

1. Are you Female? Male?

2. Which age category do you fit into? 18–24 25–44 45–59 over 60

3. Where do you live?
UK
Europe
North America
South America
Middle East
Australia/New Zealand
Asia/Pacific
Africa

4. Which of these descriptions best suits you? (Tick as many as apply.)

- I am not interested in science at all
- I am moderately interested in science
- I am very interested in science
- I work in a scientific or technical job
- I am a professional researcher
- Other (please specify)

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10. Do you have more you want to say?

Another strand of the research for this project is the use of interviews to discuss the issues in greater depth. Interviews can be carried over the phone (typically lasting about 30 minutes) or conducted via email. Would you be willing to be interviewed? If so, please leave either your email address or a phone number on which you can be contacted.

1. My email address is:
2. My phone number is:
3. My time zone is:

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13. Your answers

You may ask for your contributions to be withdrawn from the research before the end of July 2011. To make this possible, please enter a 4-character code of your choice in the box below. If you decide to withdraw, email this code to ann.grand@live.uwe.ac.uk with the subject line 'withdraw data'.
1. My code is:

Thank you for taking part in this survey and contributing to the research.

By clicking the SUBMIT button below, you give your consent for any answers you have given to be included in the research.