SCIENTISTS’ COMMUNICATION WITH THE GENERAL PUBLIC
─ AN AUSTRALIAN SURVEY

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DECLARATION

This thesis contains no material that has been accepted for the award of any other degree or diploma in any university. To the best of the author's knowledge and belief it contains no material previously published or written by another person, except where reference is made in the text.

Suzette D. Searle

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ABSTRACT

This thesis describes the communication activities and views of Australia's scientists around their communication with the general public. This exploratory research is based upon a national Internet survey of 1,521 Australian scientists who worked across public and private sectors for eight different types of employers and in seven science disciplines. The scientists were aged between 21 and 67+ years and the survey population was representative of the sex-age distribution of scientists in Australia in 2006.

This study sought to find out if scientists in Australia agreed that they had a responsibility to communicate with the general public, how personally important it was to them, and if there were any benefits for them from doing so. A significant finding of this research is that a large number of scientists have positive feelings about themselves, their communication and their work, as a benefit of communicating with the general public.

Whether communicating with the general public was a part of their job, or otherwise recognised or rewarded, and what scientists did to communicate with the general public is also explored. Hindrances to their communication and areas for improvement are identified. The influence of scientists' sex, age, discipline and employer upon their communication activities and views is analysed. Recommendations for improvement of communication practice are made.

Keywords: scientist, science communication, Australia, survey, age, sex, discipline, employer, generation

CHAPTER 1. INTRODUCTION

Nothing in science has any value to society if it is not communicated, and scientists are beginning to learn their social obligations.

(Roe, 1953, p. 17)

Background to the Study

'Dialogue' had become a buzzword in government, political, scientific and science communication circles in Australia when I began my PhD in early 2005. It was associated with a rhetorical trend toward greater public involvement in decision/policy making about science-related issues. Few within my scientific and communication circles within the Commonwealth Scientific and Industrial Research Organisation (CSIRO), however, knew what a 'dialogue' event or process was between scientists and non-scientists, let alone how to organise one that would have a successful outcome, whatever that meant. I wanted to know what a dialogue was; how to organise one and how to get the best outcomes for all involved. By the end of the year I had a useful grasp of dialogue definitions, practices, processes and events. I was also intrigued and inspired by the writings of advocates for dialogue (Bohm, 2004; Bohm, Factor, & Garrett, 1991; Emery, 1989; Roberts, 2002; Yankelovich, 2001) about what could be achieved. An important element of the kinds of dialogue they described was participants' examination of their own and others' spoken and unspoken beliefs and assumptions (Bohm, et al., 1991). I wondered what was known about scientists' assumptions and beliefs about themselves and their scientific knowledge. I knew that as a scientist with CSIRO for 17 years, I had never questioned myself quite in this way. What self-awareness did other scientists take with them to dialogues with non-scientists? It also occurred to me that irrespective of which of many dialogue processes were selected to bring scientists and non-scientists together to discuss science and technology issues, the scientists would be the common element to all. Therefore, holding up a mirror to their beliefs and assumptions would inform and benefit those scientists seeking a more effective communication with the general public.

This was confirmed when I took part in an international (with a strong European focus) workshop in Dresden organised by Citizen Participation in Science and Technology in mid-2006. Informal discussions with other participants confirmed that little research had focussed on scientists to help them in whatever dialogue (or ‘participatory’ or ‘engagement’) process was to be used. Most of the research focus had been on what the public think about science, scientific issues and scientists, or on the participatory processes, particularly to discuss emerging technologies such as biotechnology and nanotechnology.

I also came to appreciate through conversations and presentations at the workshop that the concerns about and practices of science communication differed between countries, and that national studies of scientists were rare.

Back in Australia I established that not only had there been minimal research describing Australian scientists in dialogue processes, but very little had in fact, described any aspects of scientists’ communication with the public. What had been done often focussed on scientists’ communication via the media. Maybe Australia’s scientists were communicating often and well, out of range of the media’s microphones or cameras. Perhaps, as such communication is rarely recorded and compiled these scientists were not given credit by scientific and political leaders, who may just have assumed that scientists needed to do more. Given this lack of basic information about scientists’ communication with the public in Australia, I decided to start at the very beginning by exploring all the ways that Australia’s scientists communicated with the general or lay public.

Many Australian scientists have arguably yet to experience the full force of public opinion about their science and therefore may underestimate the importance of the general public in their communication. This is because in Australia there have yet to be ‘crises of confidence’ in science or the governance of science, as have occurred elsewhere such as in the United Kingdom (House of Lords, 2000, p. Section 1.1). As a result there has been less concern among Australian scientists about what ‘the general public’ thinks of them and their science. It was at this stage of scientists’ indifference to the public’s views that this research aimed to document their views and activities.

Please note that the terms ‘general public’, ‘general public(s)’ and ‘society’ will be used interchangeably in this and the other background chapters as a short-

hand for the many general publics that exist (Leshner, 2005b) and change with changing scientific issues.

The Problem

According to a number of Australia's eminent scientists and political and scientific leaders in science, there is a serious problem between scientists and the general public. These leaders call for improved communication between 'science and society' (Batterham, 2000; Carr, 2008a; Higgins, 2007; B. Marshall, 2006). Their demands for better communication are part of an international trend in such rhetoric that has gathered urgency over the last 10 years.

The nature of these exhortations, however, differs between countries. In Australia and the United States of America for example, they appear to encourage scientists to share their knowledge to inform public debate and decision-making. In Denmark and the United Kingdom, however, there is an additional emphasis on a two-way communication that captures the benefits of citizen participation in decision-making about science and technology. In the United Kingdom, research and practice in science communication between 'science and society' has been enhanced by well-funded research and policy initiatives (AAAS, 2000; HEFCE & RCUK, 2006; House of Lords, 2000; N. Pitrelli, 2003; Turney, 2006).

Much of the academic research around communication between 'science and society' has focussed on the audiences and their understanding of, or interest in science[1]; or on developing and improving participatory processes that bring scientists and non-scientists together to discuss science and technology issues. Little research has been conducted to better understand the views, beliefs, attitudes, assumptions and experiences that scientists bring to their communication with others, as pointed out by MORI (2001) and Pitrelli, Brunelli and Murelli (2006). Internationally, studies that placed scientists and

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[1] There is no universal definition or description of science In this study, the word 'science' is most often used to mean the same as 'scientific knowledge'. Where it is used as a synonym for those organisations that conduct or control scientific research, or the whole enterprise involved in the production of scientific knowledge, the difference will be obvious.

their communication with the public under the microscope are few (MORI, 2001b; Vetenskap & Allmanhet, 2003). Such studies have focussed either on scientists working within a particular field (often emerging technologies such as biotechnology, genetically modified organisms (GMOs), cloning, nanotechnologies (Burchell, 2005)) or within a particular sector (such as scientists and engineers within universities (Nielsen, Kjaer, & Dahlgaard, 2007; People Science and Policy Ltd., 2006)) or scientists at a particular event. Other studies have specifically dealt with scientists' views of and experiences with the media, such as the 2007 Australian survey which focussed on barriers to discussing work with journalists (Australian Science Media Centre & Australian Science Communicators, 2007; Gascoigne & Metcalfe, 1997; Hartz & Chappell, 1997). In Australia, very little has been done to describe scientists' views and activities around their communication with the general public. Surveys of scientists in other countries were conducted after this current study and are discussed in Chapter 8.

My research moves beyond the mainly anecdotal reports available in Australia and provides empirical, baseline behavioural and attitudinal data about scientists' communication with the general public.

Research Questions

This research provides empirical baseline data to inform communication between 'science and society' in Australia to guide those who wish to bring about the positive changes in science communication called for by scientific and political leaders. It aims to inform science communicators, scientists and their employers, and those who make science communication policy and to identify areas for improvement to facilitate such communication. To achieve these aims, the following five research questions were addressed:

1. Do scientists think that it is their responsibility to communicate with the general public?

2. Do scientists believe that there are any benefits for them from communicating with the general public?

3. Is communication with the general public personally important to scientists?

4. What do scientists currently do to communicate with the general public?

5. Does anything hinder scientists from communicating in the way they would like with the general public?

6. Are there areas for improvement to facilitate communication between scientists and the general public?

Overview of the Method

This thesis describes and discusses exploratory research based on a nation-wide Internet survey completed in 2007 by 1,521 scientists, aged from 21 to over 67, who worked across public and private sectors for eight different types of employers and in seven science disciplines.

Scientists in Australia were invited to participate through an email sent via their employers or professional associations. A link in the email took them to an online questionnaire with 61 closed and open questions about themselves, their activities and their views around their communication with the general public. Questions also explored scientists' workplace cultures with specific regard to communication with the public, along with the form and frequency of their communication activities over the previous 12 months. Scientists' views on their responsibilities to communicate and the benefits and personal importance of and the hindrances to their communication were sought through requests for comment and open-ended questions. Factors that would help them most to communicate with the public are described and analysed. Demographic influences on their communication practice are also investigated.

Significance and Scope

This is the first Australian study of its kind providing large-scale, quantitative and qualitative cross-sectional data that described scientists' views and activities around communication with the general public. It advances knowledge of science communication in Australia by providing evidence of Australia's scientists' views and behaviours. Previously, in the absence of such data, Australian practitioners and academics had little choice but to draw upon research about scientists in other countries, little knowing if it were relevant to

the Australian situation. This national, cross-sectional survey was designed to enable subsequent time-series data integration.

This study is significant for communication practice and policy. The findings from this research will inform those involved in science communication (scientists, their employers, science communicators and funders of science), the media and science education and scientific research, to improve such communication.

This baseline knowledge will help policy-makers and other decision-makers to monitor changes in scientists' views and behaviour as different scientific issues and concerns about the governance and communication of science arise. It will inform the evaluation of the impact of policies and programs that are intended to improve communication between scientists and the rest of society.

Publication of the survey results will give a direct voice to Australia's scientists about their experiences with and opinions of communicating with the general public.

This research will also enable general international comparisons with research findings from other scientifically developed countries.

Thesis Structure

Chapters 2, 3, 4 and 5 broadly describe the culture of science and scientists' communication in modern western democracies as it has evolved over the last three decades. Chapter 2 focuses on the calls by scientific and political leaders, scientists and other commentators for better science communication between science and society over the last 25 years or so (1985 ─2008). It critically examines who is calling for scientists to change their communication with the general public and why.

Chapter 3 considers science as a culture (with many subcultures) and how, within that context, the reality of science in the 21st century differs from the more idealistic views that inspired the rhetoric of scientific and political leaders, highlighted in Chapter 2. It then outlines the features of this culture that are common elements across the international science community, such as its competitiveness, specialisation, male domination by number and seniority, and

the declining prestige as a profession, over the last quarter of a century. This chapter concludes with a focus on Australia: a description of its scientists, the organisation and funding of science, and recent national science communication initiatives.

Chapter 4 focuses on the research that describes scientists' communication with the general public, beginning with a description of scientists' communication in Australia. It examines the rules of the science profession that guide scientists' communication, and scientists' failure to communicate well. Research findings about scientists' communication with the public are then reviewed with reference to risks and obstacles.

Chapter 5 focuses on scientists' motivations for communicating with the public and other influences upon their communication. Scientists' communication with their peers and the general public (one-way and two-way) is then discussed, and research that has identified what would help them to communicate is reviewed.

In Chapter 6 the methods and analyses are outlined, the questionnaire is described and justifications for each are presented. The efficacy of the Internet–based questionnaire is also discussed as are problems attached to comparing it with other national surveys.

Chapter 7 presents the survey results that address the six research questions for this study, and ends with an examination of the effects of scientists' sex, age, discipline and employer type on their communication activity and views.

Chapter 8 presents a brief summary of the survey findings and places the research results from this study of Australia's scientists in an international context. It discusses the findings with reference to the research questions. The relationships between scientists' communication activity and their work culture, views and characteristics are also discussed.

'Conclusions and Recommendations' are presented in Chapter 9, the final chapter. Limitations of this study are considered and recommendations for scientists' communication practice and further research are made.

The next chapter describes national and international calls for scientists to communicate beyond their scientific peers to the general public and describes the changing relationships between 'science and society' over the last 25 years.

CHAPTER 2. CALLS FOR SCIENTISTS TO COMMUNICATE WITH THE GENERAL PUBLIC

Science and communication are two sides of the same coin.
If a great discovery is not communicated, then it is essentially lost, and, with it, the funding that paid for the research is essentially wasted.

(Anonymous Australian scientist in the current study 2007)

Introduction

This chapter describes the calls by eminent scientists, leaders of international science organisations and scientific academies, and political leaders for better communication between scientists and the general public. It focuses upon these public requests in the first decade of the 21st century. Earlier statements are included, however, to illustrate the decades it is taking for scientists' communication with the general public to become an acceptable part of their scientific and workplace culture.

The material in this chapter demonstrates the belief that sharing scientific information widely is important and that exhortations for scientists to communicate have become commonplace. They have been made by the most senior of the world's scientific bureaucrats, and the most eminent of the world's scientists. Their calls also reflect and advocate a changing relationship between scientists and the general public that includes a two-way communication between 'science and society'. These messages have been heard by some, and over the last decade responses have included research into different aspects of communication, and training initiatives to improve scientists' communication, especially amongst younger scientists. These responses also reflect increased public demand for more, and more effective, communication with scientists.

The following literature review is written in broadly chronological order within each section to give a sense of how the views of researchers and leaders of science have changed over decades.

The Importance of Scientific Information to Society

Over the last 10─25 years in Australia and other scientifically-advanced countries, many social reformers, political leaders, presidents of professional scientific associations, philosophers and senior scientists have recognised and publicly emphasised the importance of scientific knowledge. There were, however, those few who recognised much earlier how important 'natural knowledge' was to become. During the Second World War, for example, Sir William Henry Bragg, then President of the Royal Society of London, stated that, 'It is not universally nor even sufficiently understood how important natural knowledge has become' noting also that experimental science had 'assumed a commanding influence on all our affairs' (Bragg, 1941, p. 26). Bragg had the vision and the courage to suggest that scientists justify themselves and the value of their knowledge to those in power and he urged scientists to personally communicate with those in government who were 'charged with duties to the nation' (Bragg, 1941, p. 27). In 1977 van der Vink also emphasised the need for scientists to be politically 'savvy':

> In the next generation, we will need not only scientists who are experts in subspecialties, but also those with a broad understanding of science and a basic literacy in economics, international affairs, and policy-making. In the end, our greatest threat may not be the scientific illiteracy of the public, but the political illiteracy of scientists (van der Vink, 1997, p. 1175).

Many scientists arguably ignored Bragg and van der Vink's suggestions, as American social science researcher and public opinion analyst, Yankelovich observed in 1984. 'Scientists have been slow to leave the protective isolation of the laboratory and to involve themselves in the public policy' (Yankelovich, 1984 online).

Now, according to many, science and technology are integral to every aspect of modern life. Science writer and twice Pulitzer Prize winner, Jon Franklin, said 'If science was ever a thing apart, a special way of living and of seeing things, that time is past. Today, science is the vital principle of our civilization' (Franklin, 1997).

Decades later in the United Kingdom, however, there were still those in the scientific establishment who were trying to shuck non-communicative and secretive scientists out of their 'shells' for public consumption (Miller, 2001) as evidenced by the 1985 publication by The Royal Society: *The Public Understanding of Science*. This report is commonly called the *Bodmer Report* after the chair of the working group, Sir Walter Bodmer. In this influential document, the target of scientists' communication, at least in the United Kingdom, had grown larger, extending beyond those 'charged with duties to the nation' to the lay public. The call had become 'urgent' and heralded a significant commitment to increasing the public understanding of science for the next 15 years or so in that country.

The *Bodmer Report* urged all scientists to communicate broadly with society, and to develop a better rapport with the Parliament, the Civil Service, industry and the media. It also noted the paradox of 'scientist's mistrust, lack of understanding and often unwillingness and inability to communicate adequately with the journalist' and 'the importance of a good rapport between scientist and journalist if science is to be properly and adequately represented in the media' (Bodmer, 1985, p. 24).

It has now become a truism for world leaders to highlight the 'commanding influence' of science or the technological developments that science has made possible (Mathieu & Rossi, 1979). Statements of the importance of science to society have become commonplace, as is illustrated by senior executives in the United Nations. Pái Pataki, Chairman, Executive Board, United Nations Educational Scientific and Cultural Organisation (UNESCO) at the 'World Conference on Science for the Twenty-first Century: a New Commitment', warned, however, of the power and the danger of scientific and technological developments:

> We are gradually gauging the extent to which scientific and technological developments are empowering humankind with the power to act upon the planet and the universe, on the very processes of life. We realise that this power may set off irreversible chain reactions. (Pai, 1999, p. 22)

Annan, Secretary-General of the United Nations (1997-2006), on the other hand, wrote about the problem-solving ability of science:

> Science has contributed immensely to human progress and to the development of modern society. The application of scientific knowledge continues to furnish powerful means for solving many of the challenges facing humanity, from food security to diseases such as AIDS, from pollution to the proliferation of weapons. Recent advances in information technology, genetics, and biotechnology hold extraordinary prospects for individual well-being and that of humankind as a whole. (Annan, 2004, p. 925)

He also spoke about the need for every nation's public to 'engage in a candid dialogue about the benefits and risks of new technologies, such as genetically engineered organisms or nanotechnology, so that informed decisions can be made about their introduction into our lives' (Annan, 2003, p. 1485).

Obama, a month before becoming President of the United States of America (USA), spoke of science as holding the key to our survival as a planet:

> Whether it's the science to slow global warming; the technology to protect our troops and confront bioterror and weapons of mass destruction; the research to find life-saving cures; or the innovations to remake our industries and create 21st Century jobs — today, more than ever before, science holds the key to our survival as a planet and our security and prosperity as a nation. (Obama, 2008, online)

Australian Nobel Prize winner and Fellow of the Australian Academy of Science, Professor Barry Marshall conveyed a sense of urgency when he proclaimed that:

> Our best scientists and medical researchers must seize the opportunity to speak directly to the Australian people and to engage the media at every level; from scientific journals to talkback radio (B. Marshall, 2006).

Two years later, Australia's Minister for Innovation, Industry, Science and Research, Senator the Hon. Kim Carr, spoke about the importance of scientific advice: 'Australians look to our scientists and researchers to contribute to our

economic, social and environmental well-being and to expand our horizons of knowledge' (Carr, 2008a). 'Australia needs the best scientific advice it can get to tackle the many issues we face as a nation' (Carr, 2008b). Clearly, scientific knowledge is seen as critical for humanity's continued survival by many of its leaders.

According to Pitrelli (2003), the 1985 *Bodmer Report* legitimised science communication and was a catalyst in the United Kingdom for research activity and communication initiatives over the next 20 years. It led to the establishment of the Committee on the Public Understanding of Science (CoPUS), a tripartite organisation with representatives from the Royal Society, the British Association for the Advancement of Science, and the Royal Institution. It also led to the launch of the journal, *Public Understanding of Science,* in 1992.

It is interesting to note therefore, the progress made in the 26 years since the report's publication. According to Jensen for example, 'Officially, researchers and academic institutions alike have accepted the importance of public engagement. However, it is not clear whether these generous intentions translate into effective popularisation actions from individual scientists or career recognition from the institutions for these actions' (Jensen, 2011, p. 26). The implications of this statement with reference to communication by individual scientists are further explored in the next two chapters, and in the results of this study.

New and Changing Relationships Between Scientists and the General Public

'People don't listen to scientists any more.'

Jean Salençon, President, French Academy of Sciences, 2009

Figure 1. 'The end is near'

Australian cartoonist Ron Tandberg in '*The Age'* newspaper 24 Feb. 2011, online

As early as 1977, Goodell wrote about 'the uneasy relationship between science and the public [that was] changing, as technological ills have increasingly plagued society'(Goodell, 1977). 'These changes in turn have put pressure on science to update its antiquated concepts of how much to tell the public, when, and how.... In short, dramatic changes in science and in communication are forcing changes in science communication, and, in the process, in the kind of scientist who gets communicated' (p. 6). The calls by scientific and political

leaders for scientists to communicate have emphasised the importance of communication to help both scientists and society through these changes. By explicitly demanding changes in the practice of communication by scientists, they imply that scientists should re-examine their assumptions about themselves and the general public. For example, Yankelovich observed that, 'In scientific circles, it is always assumed that the public and society at large must catch up with science and technology…Little is said about what science must learn about the public' (Yankelovich, 1984, online). There have been a few far-sighted scientists who did say just that, however. Once again it was Bragg who stated seven decades ago that scientists should understand more than just their science; they should understand more about the people that they met if they wanted the best chance of bringing about the changes scientists desired (Bragg, 1941, p. 27).

It would seem that the changes scientists may have desired, spoken about by Bragg, are increasingly subject to changes desired by the public. For example, Goodell (1977) wrote that the public expected to participate in determining the directions of science:

> Science has produced communications technologies that have democratised learning and experience; now the public demands a democratisation of science. The public expects to participate, and indeed must participate, in determining the directions of science. (p. 8)

Yankelovich believed that the issue was 'not to make scientists into more skilful "communicators"'. 'The challenge goes deeper than that. It is a matter of changing the structural relationship between the science community and the larger society' (Yankelovich, 1984, online). He suggested that science had negotiated an unwritten 'social contract' with society that ensured a creative separateness from involvement with goals, values and institutions other than its own.' He believed, however, that, 'the creative isolation that [left] the scientist free to pursue the goals of science irrespective of the consequences' however, was responsible for 'a dangerous gap between the technological sophistication of our tools ─weapons, industrial processes, analytical procedures ─ and our social ability to manage them' (Yankelovich, 1984, online).

Yankelovich then warned that unless science as an institution seized the initiative to change 'its unwritten contract with the rest of us', science 'would be either absent as an effective influence' on the decisions to determine our survival or 'reduced to the presentation of technical testimony that trivialises the role of science'.

A year later in the United Kingdom, the influential report, *The Public Understanding of Science* also linked the need for scientists' communication with the lay public to being accountable to the public taxpayer:

> …scientists as a whole must recognize that they have a serious responsibility to speak to the lay public. Scientists are also democratically accountable to those who support scientific training and research through public taxation. If the public is not told about the scientific research it supports, it is unlikely to worry if the level of support is reduced. (Bodmer, 1985, p. 24)

A decade later, these predictions became reality – the public was losing interest in funding science. Rowland, President of the American Association of the Advancement of Science (AAAS) in 1993, and winner of the Nobel Prize in Chemistry in 1995, wrote:

> We are also finding, usually with dismay, that the society which surrounds us and which has supported us quite generously in the past seems less than fully appreciative of what we see as our tremendous successes. So much so, in fact, that they are considering reducing, or have already reduced, the resources which are made available to us. (Rowland, 1993, p. 1575)

Three years later, Greenwood (1996) wrote in a *Nature* editorial, titled *Desperately Seeking Friends*, about the declining influence of scientists in society, and scientists' anxiety about their public and political support:

> ...many would argue that scientists, more than members of any other profession, are creating the future. One would think, then, that scientists would have a lot of friends and feel a sense of public appreciation not enjoyed by many other professions. (p. 933)

He described the ‘palpable anxiety’ felt by scientists because ‘our friends are few and their loyalty uncertain….Politicians tell us that science has no defined constituency and that scientists and their societies are naïve, self-important, and frequently ineffective ─ harsh criticisms that most scientists find offensive but have few ways to counter’ (ibid., p. 933).

In the following few short sentences, Greenwood succinctly described the difficult times that scientists were experiencing in the 1990s, which continue to this day:

> This is a tough time to many scientists. The money is getting increasingly tighter, and the nation as a whole shows alarming anti-intellectualism, most notable recently in the revival of efforts to ban the teaching of evolution or to insist that ‘creation science’ be given equal time in [classrooms]….Furthermore, the demand for efficiency and accountability in the use of public funds is constantly increasing. It is not hard to understand scientists’ growing sense of apprehension and uncertainty. (ibid., p. 933)

Greenwood argued for scientists to ‘change their ways’ and, instead of resisting, get involved in public outreach because no one else was going to do it: ‘We're busy, we claim. Can't someone else do the public outreach? Can't someone else fix our educational system or get the mindless auditors and regulators out of our business? Probably not’ (ibid., p. 933).

The following year, in 1997, Lubchenco, then President of the AAAS, also urged scientists to change their ways. She suggested that scientists consider a new social contract for themselves in response to ‘urgent and unprecedented environmental and social changes’ as they enter the century of the environment’ (Lubchenco, 1998, p. 491). She appealed to scientists in all disciplines for ‘faster and more effective transmission of new and existing knowledge to policy and decision makers and better communication of this knowledge to the public’ (ibid., p. 491).

Lubchenco stated that the roles of science ─ to discover, communicate, and use knowledge and training the next generation of scientists ─ had not changed, but that the needs of society for scientific knowledge had been altered dramatically.

‘Scientific knowledge is needed to inform policy and management decisions by helping society to understand the consequences of different choices’. She believed that, ‘Science should be leading the dialogue on scientific priorities, new institutional arrangements, and improve mechanisms to disseminate and utilise knowledge more quickly’ (p. 496).

It is interesting to note Lubchenco’s almost interchangeable use of words in this paper to describe communication: ‘inform’, ‘educating’, ‘transmission of knowledge’, ‘dissemination of knowledge’ and ‘dialogue’. With the exception of ‘dialogue’ they imply one-way communication.

In the same year, senior US physicist, Juan G. Roederer, then a US Presidential adviser, described the new relationship between science and society. Expanding upon Greenwood’s *Nature* editorial (1996), Roederer observed that the view of scientists held by politicians was not flattering. Roederer wrote: ‘Indeed, we are witnessing an alarming erosion of public trust and political support of science and knowledge-generating institutions…’(Roederer, 1998, p. 2). In asking rhetorical questions, he described science as a belief system and cultural activity that was losing active support under public and political scrutiny:

> …Science is no longer being considered a truly cultural activity by a large fraction of the population, and many politicians consider that "finding out why nature behaves the way it does" is nothing more than a government-financed "hobby" of scientists! (ibid., pp. 1-2)

Roederer (1998) pointed the finger at his fellow scientists as contributing to this declining regard for scientific knowledge, saying that scientists were ‘naive and socially ineffective’ and ‘generally bad communicators with the public, the media and the politicians’. He also said that scientists’ self-importance had severely limited their effectiveness and participation in national decision-making because ‘…we often find it a waste of our time, or unrewarding, to make the extra effort to explain our work in generally understandable terms to the public, to learn how to communicate effectively with the media and the politicians…’ (ibid., p. 2).

It is interesting to note that the former Director-General of UNESCO, Federico Mayor, also called for a new relationship between science and society that

involved 'bridging the knowledge gap through capacity-building and knowledge transfer knowledge transfer' (Mayor, 1999, p. 27). Sir Aaron Klug, President of the Royal Society from 1995 — 2000, went beyond the concept of knowledge transfer, or one-way communication, to write about dialogue in 2001. He pragmatically observed that good channels of communication were needed with non-experts because science and scientists were ultimately answerable to society: 'Science is, necessarily, run by scientists but it is ultimately society that allows science to go ahead…' particularly if scientists wanted to extend the boundaries of their licence to operate 'into new areas of research such as embryonic stem cells or new research methods, such as GM plants and animals' (2001, p. 172).

The importance of public attitudes towards research that was permitted and funded was also acknowledged by the UK Select Committee on Science and Technology in a report (2000). It recognised that 'in a democracy, public attitudes condition both a statutory framework and public research spending — though their direct impact on United Kingdom public spending is much less than in the USA' (House of Lords, 2000 1.14). This UK report echoed Greenwood's observation in 1996 of anxiety amongst scientists in the USA. It stated that scientists were feeling 'deep anxiety' because of 'public unease, mistrust and occasional outright hostility' at that time (House of Lords, 2000 1.1).

In 2003, Yankelovich reiterated the comments he had made twenty years earlier about the disparity 'between the sophistication of our science and the relatively primitive state of our social and political relationships'. He stated that it had grown 'ever larger and more dangerous, to an extent that now poses a serious threat to our future' (Yankelovich, 2003, online).

Alan Leshner[2], who became the Chief Executive of the AAAS in 2001, gave an overview of the changing and declining relationship between science and society in the United States (and elsewhere) several years after Lubchenco's (1998) call for change in the social contract of science. Leshner stated that the 'relationship

[2] AAAS Chief Executive Officer and executive publisher of *Science*

between science and society [was] undergoing significant stress' and that there had been a ' disaffection and shift in attitudes' by some members of the public around certain lines of scientific research such as therapeutic cloning and stem cell research, sexual behaviour, HIV/AIDS, and drug abuse and the teaching of non-science-based 'intelligent design theory' alongside evolution in science classrooms (Leshner, 2005a).

Leshner predicted 'a more difficult and intrusive relationship between science and society' than science had enjoyed in the recent past and observed that, 'as science encroached more closely on heavily value-laden issues', members of the public were 'claiming a stronger role in both the regulation of science and the shaping of the research agenda'. He suggested that 'the values [moral and religious] dimension [was] here to stay, certainly for a while', and that although 'for many scientists, any such overlay of values on the conduct of science [was] anathema to our core principles and our historic success', 'simply protesting the incursion of value considerations into the conduct and use of science' was not effective. He then offered advice to any scientists who may protest the changes to the status quo: 'try some diplomacy and discussion and see how that goes for a change' (Leshner, 2005a, p. 815).

This increasingly difficult relationship was also recognised by Carrada (2006) who suggested that:

> …occasions for friction between science and society continue to multiply due to the influence of new technologies, the choices new advances force us to make or the impact new knowledge has on the beliefs and values at the base of identities, culture and ways of thinking…(p. 13)

He also observed shifts in power between the scientific community, government departments and society about who decided scientists' work, noting that this was more frequently the 'result of a complex negotiation with a number of social groups: national and local politicians, private companies and their associations, lobbies or special interest groups, "moral authorities" and the media' (ibid., p. 13).

These statements acknowledge some negative reactions from the public(s) to science and scientific knowledge that range from indifference to rejection to

attack. For example, Olsen, marine biologist and filmmaker warned in his book, *Don't be such a scientist*, that an 'entire antiscience movement has emerged that truly does threaten our quality of life….Major groups are now arguing against certain childhood vaccinations on the basis of fears grounded not in scientific data but in anecdotes and innuendo' (2009, pp. 8-9). He stressed that communication of scientific knowledge was crucial 'in the struggle to make science relevant' (p. 9).

Rejeski, Director, Science and Technology Innovation Program at the Woodrow Wilson Centre for Scholars, made similar observations a year later about the rapidly changing 'nature of science', 'its potential disruptive impact' and the need for public engagement through 'broad public discourse and debate' (2010, p. vi). Rejeski stated that there was an accompanying need for changes in the governance of science that emphasised public engagement at the changing 'interface between scientists, between the public and private sectors and between the public sector and the public it serves' (p. vi).

From Education to Dialogue to Engagement

The ways in which scientists have been asked to communicate with the general public have varied and continue to vary from a one-way transmission or dissemination of scientific information to a two-way exchange or sharing of knowledge or a dialogue; from an explanation of how science itself works (Marburger, 2005) to an advocacy for the practice and values of science.

Earlier public calls were generally all about a one-way communication or education of the public to improve its decision-making and/or support for science. In 1976 for example, Birch, then President of the Australian Academy of Science, said: 'In order to make valid decisions as to the uses of science, decisions which rest on a social consensus, the community should be educated in scientific thinking and in an appreciation of what science can and cannot do' (Birch, 1976) .

In 1997, Lane also appeared to be thinking about education and one-way communication: ‘When a newsworthy discovery is made or about to be published, NSF [National Science Foundation[3]] would like to join with you to get the message out’ (Lane, 1997, online). Lane’s request to his peers to ‘get the message out’ was prompted by declining taxpayer funding for American science and engineering: ‘Today, public support must be earned. We can no longer expect it in the form of a blank check and an undefined agenda. This is entirely appropriate’. Lane then suggested that to earn this support, scientists would have to communicate ‘more broadly, more frequently and more effectively’[4]. Two years later, however, Lane (then assistant to the President for Science and Technology, and director of the White House Office of Science and Technology Policy*)* made it very clear that he was talking about two-way communication as part of the expanded role of scientists:

> In this new civic capacity, scientists and engineers step beyond their campuses, laboratories, and institutes and into the center of their communities to engage in active dialogue with their fellow citizens….
>
> …To engage in dialogue is to listen as well as to speak. While there is great need for the public to have a better understanding of science, and we should promote this in every way possible, there is as great a need for scientists to have a better understanding of the public (Lane, 1999).

A year later, Iaccarino, Assistant Director-General for Natural Sciences, UNESCO, was emphatic that the scientific community must change and ‘must learn to dialogue with society in order to obtain the means of tackling effectively today’s pressing social and environmental problems’ (Iaccarino, 1999, p. 6).

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[3] The National Science Foundation supports and funds the underpinnings for all research disciplines, and the connections between and among research disciplines.

[4] In doing so, Lane also described the way science funding used to be in the middle of the 19 century – unquestioned: ‘Some experienced researchers now look back nostalgically to the decades after World War II, when taxpayer support of science was almost unquestioned and an agenda for science was rarely discussed’ (Lane, 1997, online).

In Australia, Gascoigne and Metcalfe had earlier observed, however, that some bodies of scientific research 'have found two-way communication a painful process' (Gascoigne & Metcalfe, 1994, p. 397).

Over the last decade, researchers concerned with philosophy, sociology, political science, democracy, governance, communication, dialogue, cross-cultural studies, risk management, environmental management and sustainable development have converged on the development and implementation of citizen participatory processes. These include deliberative (reflective and decision-making) processes in particular, and more recently, the use of these to address science and technology issues. The adoption and integration of these citizen participation processes into policies and practices, however, is patchy, and varies from country to country.

By 2005 in the United Kingdom, both government and non-government organisations had invested heavily to improve the relationships between the publics and the scientific communities. These relationships had undergone 'significant stress' during the 1980s and 1990s over Britain's governance of science. Examples given in the House of Lords report (2000) included the 'fiasco' surrounding the bovine spongiform encephalopathy (BSE) or 'mad cow disease' outbreak in 1986, and the 'public uproar about GM crops and foods' (Sections 1.1., 1.2, 5.1). The report noted that the lack of public confidence in science and the '…increasing interest, and a small but growing body of experience, in scientific and official circles, in moving beyond simply giving information. Engaging the wider public in dialogue about what science could and should be doing was a theme advanced by many of our witnesses' (Section 1.18). The report then reviewed techniques either designed to improve policy-makers' understanding of the attitudes and values of the public by engaging with a more honest representative sample, or public consultation exercises, designed to engage directly with as many as possible of the public at large (House of Lords, 2000 Section 5.4). The rhetoric of 'dialogue' had entered the 'scientific and official circles' of science and technology in the United Kingdom. Within five years the word 'dialogue' was to become an almost meaningless buzzword, interchangeable with 'debate' and 'engagement' by many commenting about science and technology issues.

Over the next few years there was a number of influential government (e.g. Parliamentary Office of Science and Technology), academic (e.g. The Royal Society) and non-government (e.g. Wellcome Trust) publications which drew upon new social research and advocated dialogue in science and technology in the United Kingdom. By 2002 the need for scientists' to communicate beyond their peers in science had been well and truly embraced by the leaders of the AAAS – the 'world's largest general scientific society'. It was made very clear that to implement its new mission statement and goals, the Association would be calling on members to help it better serve society; 'not only in academe but also in schools, public media, and the halls of government' (Leshner, 2002).

The Association published nine new goals; three of which directly related to communication:

> Enhance communication among scientists, engineers and the public
> Provide a voice for science on societal issues
> Increase public engagement with science and technology. (AAAS, 2002, online)

These represented a change in the relationships between AAAS scientists and the public with regard to increased two-way communication. The previous AAAS mission, for example, had included goals that were about one-way education and advocacy of science: 'To increase public understanding and appreciation of the importance and promise of the methods of science in human progress' (ibid, online). Leshner, in 2003, commented on the need for scientists to change from the promotion of science, and education of the public, to a dialogue with the public about science:

> …But simply trying to educate the public about specific science-based issues is not working.…We need to move beyond what too often has been seen as a paternalistic stance. We need to engage the public in a more open and honest bidirectional dialogue about science and technology and their products, including not only their benefits but also their limits, perils, and pitfalls. We need to respect the public's perspective and concerns even when we do not fully share them, and we

> need to develop a partnership that can respond to them (Leshner, 2003a, p. 977).

Three years later Leshner wrote that, ‘We also need to find ways to move science forward while adapting to their [members of the public] legitimate concerns’ (2006, p. B 20). He noted that public engagement between science and society was a recent approach in the United States and that, ‘It is not yet clear whether the public-engagement approach will significantly reduce the tension that is weakening science’s relationship with society’ (Leshner, 2006, p. B 20).

Welp, de la Vega-Leinert, Stoll-Kleemann and Jaeger (2006) wrote more positively about the benefits for scientific research of ‘science-based stakeholder dialogues’[5]. According to the authors, these dialogues ‘were partly driven by researchers themselves, but also to a great extent by funding agencies and the general public’s demand for greater accountability in science’ (ibid., p. 174). They believed that, from a research point of view, there were at least four reasons for science-based dialogues:

> 1. Stakeholders can play an important role in identifying socially relevant and scientifically challenging research questions
>
> 2. Scientists need a ‘reality check’ for the research they are doing. Dialogue with stakeholders can provide such a check
>
> 3. The social science research on global change faces limits to scientific reasoning and requires the incorporation of ethical considerations
>
> 4. Tests need to have access to data and knowledge that otherwise would remain unknown or at least very difficult to access. (2006, pp. 171-172)

Wynne observed, in the same year, a ‘mainstream international commitment by scientific and policy institutions using science to encourage and cultivate two-

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5 They defined such dialogues as ‘structured communication processes linking scientists with societal actors, such as representatives of companies, NGOs, governments, and the wider public’. They claimed these dialogues were driven by the practical need to link scientific inquiry with different knowledge bases and to take into account value and risk judgements of individuals and groups’ (Welp et al. 2006 p. 174).

way “public engagement with science” as a means of alleviating this crisis of public mistrust[6]’ (Wynne, 2006, p. 212). For example, in 2007, the AAAS committed to moving beyond traditional education of the public toward opportunities for dialogue with the public saying that the organisation should be ‘building upon and moving beyond traditional public understanding efforts, toward more comprehensive public-dialogue opportunities’ (AAAS, 2009). Calls for dialogue and engagement between science and society have implicitly, and sometimes explicitly, suggested a two-way communication that involves listening and learning on the part of scientists as well as the sharing of their research results.

Some have suggested that dialogue is not enough ─ it has to move upstream ─ because those who participate in engagement ‘need to know that their participation will affect the policies and processes under discussion. They want assurance that trajectories of change and innovation will take meaningful account of their views’:

> For the past twenty years, in response to a perceived ‘crisis of trust’, scientists have been slowly inching their way towards involving the public in their work. They looked first to education as the answer, and more recently to processes of dialogue and participation. But these efforts, while admirable, have not yet proved sufficient. (Wilsdon & Willis, 2004, p. 16)

In 2004 and 2005, social scientists within an influential UK-based think tank and public interest consultancy firm (DEMOS) climbed up a few rungs of Arnstein’s ladder of citizen participation (Arnstein, 1969) when they called for not only better communication between scientists and society, but public participation in all stages of the R&D[7] process (Wilsdon & Willis, 2004; Wilsdon, Wynne, & Stilgoe, 2005). They made a case for ‘upstream’ public engagement in science

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6 There is no general, indiscriminate public mistrust or rejection of ‘science’; indeed, there is lots of enthusiasm for it – but this is discriminating enthusiasm, even if the discrimination is of course fallible (Department of Innovation Industry Science and Research, 2010, p. 75).

7 Research and Development (R&D)

and technology which meant that ‘a process of *ongoing* deliberation and social assessment, that embeds dialogue between scientists, stakeholders and lay publics within all stages of the R&D’ should start ‘at a point where research trajectories are still open and undetermined’ (Wilsdon, et al., 2005, p. 38). They suggested that the next phase, beyond giving the public a voice in science policy and decision-making, is to appreciate ‘the codes, values and norms that govern scientific practice, but which are far harder to access and change’ (ibid., p. 19). This need for understanding of the culture of science is a critical driver of this thesis.

Others have reservations, however, about the achievability or the wisdom of promising increased public involvement with science (through agenda setting and decision-making). For example, in a European-Commission funded report of six countries (Austria, Belgium, France, Portugal, Sweden and the United Kingdom), there was a telling statement regarding the many gaps between the rhetoric calling for ‘more participatory and interactive aspects in science-technology-society relations’ and reality of scientific citizenship where ‘the deficit model and linear communication are present in the public arena is stronger than ever’ (Felt, 2003, pp. 671-672).

There are those, such as Phillips who believe ‘that the ideal of communication among equals, inherent in much dialogue theory, is not only an impossible ideal but also a dangerous one: by creating an illusion of a dominance-free space, it can work to mask power relations and diverging knowledge interests (Phillips, 2011, p. 87).

Although the idea of upstream engagement of the public in science policy and decision-making moves well beyond the current political rhetoric and communication practice in Australia as is discussed later in this chapter, there has been recognition nationally and internationally that better communication between science and society is needed. In the Antipodes, however, it appears that the science establishment in New Zealand has been much more proactive than in Australia regarding rhetoric, research and programs to encourage more dialogue between science communities and their public(s.)

New Zealand

The New Zealand Ministry of Research, Science and Technology (MoRST) observed that New Zealanders' concerns about science research were associated with 'the rapid development of biotechnology, increasing commercialisation of research and the need for confidentiality from our research organisations':

> These issues are linked to trust and to values. People perceive that science research is taking place without adequate public awareness and debate. They feel that some research is taking place in areas where people feel uncomfortable as it conflicts with values they hold as important. (New Zealand Ministry of Research Science and Technology, 2009, online)

As a result, the Ministry had wanted to engage communities in discussion over science and technology (S&T) related issues 'that are, or may become, a cause of tension between science and society' and spent $NZ450,000 per year between 2002 and 2004 on trial programmes to engage communities in discussion over science and technology related issues (ibid., online).

New Zealand researchers have also defined what they mean by 'dialogue', and explored and experimented with processes which could lead to dialogue and involve the public in science and technology decision-making (Allen, Du Plessis, Kilvington, Tipene-Matua, & Winstanley, 2003; Cronin & Jackson, 2004; Hipkins, Stockwell, Bolstad, & Baker, 2002; Roper & Weaver, 2004). The Royal Society of New Zealand also publicly embraced concepts of 'dialogue', and 'public engagement'. In the Society's 2002 policy paper, it stated that: 'Science organisations must be enabled to provide scientists with encouragement, training and incentives to engage more regularly and effectively with the non-specialist public'. More specifically it asserted that, 'It is now essential to fund and train the S&T community in dialogue processes to engage in debate as part of society'; and, paraphrasing the UK study (MORI, 2001b), wrote that 'Scientists must be able, as well as willing, communicators' (Royal Society of New Zealand, 2002 website).

Also in 2002, MoRST published a commissioned report that provided insights into what the New Zealand public knew, thought and felt about science. The

report’s authors stated that they had gone beyond previous research focussed on the promotion of a positive image of science to the public, to focus on communication, and the goal of informing the development of ‘two-way dialogue of specialists and non-specialists’ (Hipkins, et al., 2002, p. 5). In the Royal Society of New Zealand’s 2005 Annual Report, its vision for 2005-2009 included the belief that ‘researchers and technologists must be responsible to society and that we should maintain an open dialogue about the issues arising from science and technology’ (Royal Society of New Zealand, 2005, online). In this last decade it appears that dialogue has clearly been part of New Zealand’s scientific, political and governmental landscape.

In Australia, leaders have been more likely to call for scientists to ‘transfer’ their knowledge or engage in public ‘debates’ than engage in a two-way communication or a dialogue.

Australia

Australia’s leaders in science have been slower to embrace the recent international trend in rhetoric about the practice of dialogue and engagement in science and technology. In fact, the high-level public rhetoric in Australia has been more about the promotion of science and a one-way dissemination of information by scientists, or more recently their participation in public ‘debate’ or their ‘freedom to speak’. The following shows how the political rhetoric in Australia about scientists’ communication has reflected international trends over the last 20 years.

In Australia in 1993, the then Minister for Science, Small Business and Customs, Senator Schacht, said in his speech at launch of the Australian Science Festival, that researchers had to explain and sell themselves, ‘particularly [to] the finance sector’:

> I want the science community, the researchers, to get out and explain themselves to other parts of the community, particularly the finance sector, to make them more comfortable in dealing with science and technology issues. They've got to go out and sell themselves... If they don't, Australia is not going to prosper. (Schacht, 1993, online)

In his *Final Report* (Nov. 2000), Australia's then Chief Scientist, wrote that, 'a new social contract between science and society must be created' (Batterham, 2000), directly 'channelling' Lubchenco (President of the AAAS) three years before. The simple strategy he proposed, however, was 'More communication between researchers and the public, including schools'. His two recommendations regarding scientists' communication were:

> funding and encouraging researchers to communicate with the public — especially with local schools, institutions and to non-government organisations. Direct contact is the best approach;
>
> and
>
> encouraging debate, with the government seeking and tabling the best scientific advice available on issues of community concern for public discussion;…'. (Batterham, 2000, p. 58)

The rhetoric of 'knowledge transfer', popular with the government a few years ago, began to include the concept of 'engagement' as can be found in a 2006 report by PhillipsKPA Pty Ltd to the Australian Government Department of Education, Science and Training (DEST). The authors said that their desktop research has led them 'to conclude that the emerging preferred language internationally is "engagement"'. They also stated, 'Some Australian stakeholders expressed a strong preference for the language of 'engagement' because of concerns that 'knowledge transfer' infers a 'one-way flow of knowledge, versus a two-way negotiated flow of knowledge for mutual benefit which is usually stressed as a key feature of engagement'. The authors suggested therefore that DEST consider the 'benefits and risks associated with different terminologies before settling on a final language for the purposes of policy development' (PhillipsKPA Pty Ltd, 2006, p. v.).

At that time, this concept of two-way communication was fleetingly referred to by the Minister for Education, Science and Training, the Hon. Julie Bishop MP, at the beginning of her speech to launch the 'Knowledge Transfer' report in June 2006. At first Bishop used both expressions; 'knowledge transfer' and 'community engagement' interchangeably. Bishop then focussed entirely on

'knowledge transfer' for the rest of her speech which she defined as 'the process of engaging with business, government or community to generate, acquire, apply and make accessible knowledge for quantifiable economic benefit for the community' (Bishop, 2006, online). Bishop reflected the government view at that time, that science was a tool for growing the economy.

In the same year, in response to accusations of gagging scientists in the Commonwealth Scientific and Industrial Research Organisation (CSIRO)[8], the Chief Executive Officer of CSIRO launched the organisation's new public comment policy. He stated that: 'Scientists are CSIRO's frontline communicators, and we trust them to discuss their science, even in potentially controversial areas' (Garrett, 2006).

There are eminent scientists who have encouraged Australia's scientists to publicly contribute their knowledge to inform decision-making about complex, science-intensive issues. For example, Marshall, talking about the stem cell debate, urged that, 'We must be available to help educate policy makers and politicians, and ensure that scientific truths are injected into the often emotional and volatile debates that are held (B. Marshall, 2006, online). Marshall also urged scientists to work closely with the media to help the public develop an informed view: 'Because when the media is able to deliver scientific information in a clear, concise and accurate way, the public is given the key to unlock the science and understand any scientific debate' (B. Marshall, 2006, online).

Scientific organisations, such as the prestigious Australian Academy of Science (AAS), in the context of gene technologies for plants, have also stated that: 'There is a need for more effective dialogue between scientists and the mainstream environmental movements to establish common ground and identify areas for future research. The Academy supports a strong and robust public debate as an important component of the introduction of any significantly new technology into society' (Higgins, 2007, online).

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[8] CSIRO was described by Marceau et al. (2004) as, 'the biggest single employer of scientific researchers in the country'.

In Australia, a change in government in 2007 led to a change in the political rhetoric, if not the reality, regarding scientists' communication. The then new and current Innovation, Industry, Science and Research Minister, Senator Kim Carr, focussed on scientists' contribution to 'debate' as the basis for informed decision-making, and protection of scientists' right to speak out: 'This is the time for our scientists and researchers to lift up their voices. They have important things to say' (Carr, 2008g). Carr was determined to address concerns about political interference with government organisations, such the Australian Research Council (ARC) , the CSIRO and the National Museum of Australia (Carr, 2008a, online). He said he wanted to liberate 'the voices of science' in Australia's public research agencies and protect 'their right to speak out and to represent their research or discoveries' using charters. These were signed in November 2008 with four public research institutions (Carr, 2008g, online):

> It is not good enough to allow scientists and other researchers to comment on matters of public interest but then to quarantine them from contentious issues. As is often the case, it is in matters of contention and sharp debate that their knowledge and expertise is most valuable. (Carr, 2008a, online)

Unfortunately the Science Minister's call for the protection of a scientist's right to speak out and the subsequent signing of charters with major public research agencies[9] (Carr, 2008a, 2008b, 2008c, 2008e) may have raised false expectations about what can be communicated by scientists who are first and foremost government employees. One of the general principles of the charters states that as government employees, 'They should not advocate, defend or publicly debate the merits of government or opposition policies (including policies of previous Commonwealth governments, or State or local or foreign governments) (Carr, 2008h, online)'. The charters did, however, state how researchers were able to contribute to policy-making: 'Researchers can contribute to policy-making by

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[9] Australian Institute of Aboriginal and Torres Straight Islander Studies (AIATSIS)
Australian Inistitute of Marine Science (AIMS)
Australian Nuclear Science and Technology Organisation (ANSTO)
Commonwealth Scientific and Industrial Research Organisation (CSIRO)

adding to the store of information and analysis governments can draw on' (Carr, 2008h, online).

Claims in the media that CSIRO climate change scientists have been gagged (ABC, 2009b; Beeby, 2009a, 2009b) continued after these charters were signed.

Government scientists are still either confused or defiant about what and how they can contribute to the public decision-making and problem-solving on issues to which their scientific knowledge can contribute, without inadvertently commenting on government policy. Australia's first female Chief Scientist, Professor Penny Sackett spoke about the need to end this detrimental confusion. Referring to the importance of scientists engaging around climate change, she stated that they needed to be:

> clear about when they are talking about science and when they are talking about policy, and that line needs to be very clear so there is no confusion. I think in this country, and in other countries around the world, that line has been blurred to the detriment of both science and those in government charged with those who elect them for making policy decisions. First and foremost, I would like to see a clean, clear and continual reminder of the division between what is science and what is policy. (Sackett, 2011a, online)

Sackett also stated that she was concerned that policy and politics were distracting the general population from discussing and questioning the message about climate change (ibid.). In summary, it would seem that Australia's scientific and political leaders well appreciate the importance of scientific knowledge to the intellectual life, economic prosperity and public decision-making of Australians, and publicly exhort scientists to share that knowledge, as long as it does not impinge on the shifting sands of government policy-making.

Critique on issues

It is notable that these international calls for better communication presented in this chapter are often addressed to 'scientists' 'researchers' or the 'scientific community' or to the generic 'science' which arguably also includes the organisations and institutions that employ scientists. There is rare recognition in

this public rhetoric, however, of the diversity of scientists, sciences and science organisations in Australia within those broad descriptors that may affect scientists' ability to comply.

It is also of value to note that underlying this rhetoric is the widely-accepted view that communication, and therefore science communication, 'works': that it is believed to have 'the capacity to change people's attitudes and behaviour in any desired direction'. Australian researchers, Sless and Shrensky, disagreed with this view in 2001 stating that what research results there are, show: 'Weak or no correlation between media messages and public behaviour; unpredictable results; little or no changes in behaviour due to public information campaigns; and so on' (Sless & Shrensky, 2001, p. 99). Despite this evidence, they also stated that, 'Most communication practitioners do not know about these findings, and those that do don't believe them' (ibid., p. 99).

Six years later Dr Peter Pockley, winner of the 2010 Australian Academy of Science medal for his contribution to science in the public domain, observed that, 'The openly stated aim [of organisations] has been to garner greater public understanding, but the underlying goal is to gain political traction for increased support to bring Australia up to the norms of competitive nations'. He too concluded that, 'The reality, though, is a lack of evidence that an increase in the PR for science has had any effect at all' (Pockley, 2007, p. 28).

Maybe these elusive effects of media campaigns and PR are there, but either undocumented or the evidence is difficult to collect or analyse? For example, speaking specifically about the impact of public engagement in technology appraisal, Australian researchers, Katz, Solomon, Mee and Lovell (2009) stated that it, 'is difficult to assess' (p. 535).

There are at least three assumptions that invariably accompany public calls to scientists to communicate: that they do not communicate well or sufficiently; that scientists exist as a homogeneous professional group that is able to respond to these calls; and that communication by scientists will lead to greater public support for science. The third assumption has been addressed by other researchers such as Sless and Shrensky (2001) and is not the subject of this study. Scientists' communication frequency and the homogeneity of scientists' views and actions are the subjects of this thesis.

Chapter Summary

Numerous public statements by eminent scientists, bureaucrats and politicians indicate that there are serious problems with communication between science and the rest of society. These public entreaties explain why communication of scientific knowledge is important, and reflect and advance expectations of a changing relationship between science and society. These not only call for more communication and more effective communication; they also acknowledge the need for a different communication. The isolated voices throughout the 20th century of insightful scientists and researchers, calling for more direct communication between scientists and the public, have been joined by a choir of the world's leaders in science and politics over the last decade.

Numerous statements by scientific leaders from organisations such as UNESCO, The Royal Society, the AAAS, and political leaders in the USA and Australia, demonstrate the rising importance of scientific knowledge to our quality of life. They also point out that scientists need to communicate beyond their peers to a public that ultimately controls their funding and directs their research. International and national leaders are now more likely to call for scientists to engage in a 'dialogue with' rather than an 'education of' the public. This chapter ended with a focus on Australia and the statements by its leaders and eminent scientists that illustrate another trend in public rhetoric: that scientific knowledge needs to be communicated to inform and help, rather than dictate to, the publics' decision-making and problem-solving. Interestingly, however, political control, over whether publicly-funded scientists can speak at all about their scientific results and the implications of their findings, mocks these sentiments. It would seem that if the government of the day decides that scientists' comments infringe in any way upon its often fluid policy-making ─ then scientists do not have the 'freedom to speak'.

The views of social science researchers and leading scientists, along with the findings of government reports from the UK and Australia, are evidence of a widespread recognition that society's relationship with scientists has changed and that scientists' communication with people outside their specialized field is expected to improve in response.

While it is clear that leaders within the global scientific community believe that the future of science needs better communication between 'science and society', this communication has been slow to enter the cultural practice of science. This begs the question: Are there other factors that override these ideals for better communication? These factors are explored in Chapters 3 and 4.

The next chapter describes science as an international culture that is prescribed and enforced by its members. It then outlines the changes to the conduct of science over the last three decades, including the increased importance of public opinion on the funding, conduct and direction of science. It concludes with a description of science and scientists in Australia.

CHAPTER 3. THE CULTURE OF SCIENCE

Introduction

This chapter introduces science as a culture that shapes scientists' communication with the general public. It then describes common features or cultural similarities across the international science community such as its competitive nature, the importance of peer recognition, the increasing segregation of science into numerous specialisations (disciplines, and fields of research) and its sexist, male domination. Differences between employment sectors are also discussed.

The changes in this culture of science, the publics' perception of science, and the relationship between scientists and society over the last four decades are also described. A subtext of this description is how the reality of this culture in the 21st century differs from the more idealistic descriptions expressed in the rhetoric of scientific and political leaders that were discussed in Chapter 2. This chapter concludes with a description of science in Australia (organisation, sector differences, the importance of government funding and the effects of short-term employment contracts, contestable funds, commercialisation and collaboration on the communication of science). Australia's scientists ─ their number and distribution across sectors by discipline are also characterised ─ as part of an aging and gender-biased scientific workforce that is facing serious shortages. The final section presents evidence of the problems with a career in science in Australia that affect the recruitment, morale and retention of scientists. All these factors affect scientists' communication with the general public, which is discussed in detail in Chapter 4.

A Definition of Science

According to John Ziman, an English physicist who wrote frequently about the philosophy and social dimensions of science, 'what science does, is generate knowledge' (2000, p.5). What science is, however, is a little more complicated

to define and describe out of context. As Chalmers, author of *What is this thing called Science*? wrote: ‘There is no general account of science and scientific method to be had that applies to all sciences at all historical stages in the development’ (Chalmers, 1999, p. 247). Hull, narrowing ‘science’ down to western and westernised societies, described it as, ‘one of the major ways that people in western and westernised societies today establish their beliefs, but it is neither the only way nor merely the way that they do so’ (Hull, 1988, p. 26). Lane considered that science was a ‘way of knowing about nature (including humans and human-made devices), methodologies, and engineered systems’ (Lane, 1999, online).

Many, such as Popper (1972), Feyerabend (1993), Kuhn (1999) and Chalmers (1999) have written about the philosophy of science. Ziman (2000) and Nowotny (2001) described science in terms of its nature and organisation and relationships with the rest of society. There are also ethnographic descriptions of those who do science – the scientists – written, for example, by (Charlesworth, Farrell, Stokes, & Turnbull, 1989; Latour, 1987; Merton, 1973; Whitley, 2000).

Irwin and Wynne (1996) represented science in an all-embracing way as a ‘collection of institutions, areas of specialised knowledge and theoretical interpretations whose forms and boundaries are open to negotiation with other social institutions and forms of knowledge’ (Irwin & Wynne, 1996, p. 8). Ziman also portrayed science as a social institution, of which ‘academic science’ was the ideal type (Ziman, 2000, p. 83).

Unlike others, Ziman separated academic science and industrial science (Ziman, 1998), as well science and engineering, and science and technology. He proposed, for example, that ‘Technology is science in application: science in action is research’ (Ziman, 2000, p. 14). Others combined them or saw them as part of the same continuum. Australia’s science minister defined science as not only including the physical sciences, but the humanities and social sciences as well. ‘When I say science I mean knowledge in all its forms’ (Carr, 2008d).

It is ‘science as a culture’ that is of most relevance to the current study of scientists’ communication with the general public.

Science as a Culture

Science is recognised and described as a culture. ‘Scientists belong to a community that has its own values, traditions and goals …that are transmitted and reinforced by its members’ (Ziman, 2000, p. 398). Studies from the fields of history and sociology, by authors such as Merton (1973), Kuhn (1996), Gregory and Miller (1998) and Becher and Trowler (2001), have also described science as a culture in both its romanticised and actual practice. The American sociologist, Robert Merton, for example, proposed a model of the culture of science that was based on the ideal norms of communism, universalism, disinterestedness and organised scepticism (CUDOS) (Merton, 1973). Since then, many have written about scientists’ commitment or lack of it to these Mertonian norms. Kuhn, for example, in *The Structure of Scientific Revolutions* described how the established scientific community did not follow the Mertonian norms because it strongly resisted new assumptions (achievements or paradigms and theories) that ‘subvert[ed] the existing tradition of scientific practice’ (Kuhn, 1996).

Other researchers and commentators, such as Cole (1973), Long (1995), Evetts (1996), Zuckerman (1988), Fox (2001) and Ledin (2007) specifically commented on the lack of Merton’s ‘universalism’[10] within science. The lack of universalism has also been referred to in recent international and national statistical reports (Foley, 2005; National Science Board, 2008, 2010; National Science Foundation (Division of Science Resources Statistics), 2003, 2004; UNESCO, 2007). Ziman, on the other hand, defended Merton’s analysis, believing that, although it was ‘highly idealized, and ‘rejected by most present-day sociologists’:

> it still provide[d] the best theoretical framework for an understanding of how … well-established practices [i.e. peer review, respect for priority of discovery, comprehensive citation of the literature,

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[10]‘Universalism’ - the ideal that claims to truth are evaluated in terms of universal or impersonal criteria, and not on the basis of race, class, gender, religion, or nationality.

> meritocratic preferment on the basis of research performance] interact to produce the sort of knowledge that we recognize as peculiarly "scientific". (Ziman, 1998, p. 1813)

In 1959 the British novelist Charles Percy Snow, who had also been a scientist, spoke about the breakdown of communication between literary intellectuals and scientists – or the 'two cultures' of the 'intellectual life of the whole of western society' (Snow, 1998, p. 3). He described the members of the scientific culture as having 'common attitudes, common standards and patterns of behaviour, common approaches and assumptions'. Snow stated that the scientific culture 'cuts across other mental patterns, such as those of religion or politics or class' (Snow, 1998, p. 9).

Today commentators and researchers continue to refer to Snow's 'two cultures' ─ but they also speak and write about the increasing cultural diversity within science that is due, for example, to the increasing number of scientific disciplines. They also write about science's communication problems with the rest of society, not just those with a background in the humanities (van Dijck, 2003; Ziman, 2000).

The discussion about two cultures continues in Australia, as does the desire to end the 'false divide' between the arts and science (Metcalfe, Riedlinger, Pisarski, & Gardiner, 2006; van Dijck, 2003). This was illustrated in 2009 in a government report where it was declared that: 'Better understanding of the connections and commonalities between science and the arts is also required to maximise Australian's collaborative creative potential' (Department of Innovation Industry Science and Research, 2009, p. 48)

Aikenhead noted that 'Scientists share a well defined system of meaning and symbols with which they interact socially. This system was institutionalized in Western Europe in the 17th century, and it became predominantly a white, male, middle-class, Western system of meaning and symbols' (Aikenhead, 1996, p. 8).

Aikenhead also listed the cultural features (or public facades) of 'Western science' described in the literature as being: 'mechanistic, materialistic, masculine, reductionist, mathematically idealized, pragmatic, empirical, exploitive, elitist, ideological, inquisitive, objective, impersonal, rational,

universal, decontextualized, communal, violent, value-free, and embracing disinterestedness, suspension of belief, and parsimony'(Aikenhead, 1996, p. 9). Many of Aikenhead's items are subsets of science as a research-led culture in academia. His long list did not, however, include 'competitive', another cultural characteristic of science, which is explored in the next section.

A competitive culture

Science is highly competitive and this is a critical aspect of the culture of science that influences scientists' communication. Scientists compete for recognition in the form of citation of their work, awards, job offers, promotions, interpersonal approval, invitations to meetings, appointments to professional committees, prestigious appointments and other honours (J. R. Cole & Cole, 1973; Goodell, 1977). Goodell observed as early as 1977 that, 'As the number of scientists increases, while the number of jobs decreases, competition becomes more and more intense, more personal, more frightening' (Goodell, 1977, pp. 89-90). Becher and Trowler (2001) added that 'more commercial competitive pressures are becoming increasingly important in scientific disciplines'. The authors seemed to imply that increasing specialisation was a response to competition too:

> Rivals seek to surpass each other in the quality and significance of the work, in the esteem in which they are held by professional colleagues, and in the honours that are bestowed on them; they may vie for the same jobs, but they seldom engage in battle over the very same area of intellectual territory. (Becher & Trowler, 2001, p. 118)

Disciplines compete for graduates too. In Australia, Marceau, Turpin and Woolley (2004) reported on disciplinary differences in the system of rewards and opportunities:

> The attractiveness of the system of rewards and opportunities available to science and technology research graduates varies considerably between fields of study [in 2002], with physical and life sciences and chemistry amongst the lowest paid fields of study along with civil engineering and visual/performing arts. (p. 12)

The following section reviews the literature that describes how scientists reward and punish each other within this competitive culture.

The importance of peer recognition

Scientists are rewarded through awards, appointments and peer recognition (Becher & Trowler, 2001, p. 118) and a number of studies have described these. For example, an American study of 120 American university physicists by Cole and Cole found that the quality of scientists output (research publication) was recognised through the receipt of 'honorific awards, membership in honorific societies, appointment to top-ranking academic departments, and having one's research known in the national community of physicists' (S. Cole & Cole, 1967, p. 390; Mahoney, 1976). Cole and Cole describe the latter as 'a recognition through reputation that is usually achieved by first publishing scientific work and then having such work favourably evaluated by colleagues e.g. cited by others' (J. R. Cole & Cole, 1973, p. 58).

Peer recognition influences all aspects of a scientist's research career. Cole and Cole (1967) found, however, that this reward system for academic physicists 'plays favourites'. 'There are indications that the sheer quantity of publications is more likely to be used as a criterion of promotion in the less prestigious departments, and that quality research is more often rewarded when it is produced by physicists in high ranking departments' (p. 390). Zuckerman (1970) also observed this bias in rewards for American scientists, with a high correlation between assessed contributions to science and investigators' scientific standing' rather than 'the distribution of talent in the scientific community'. 'Rewards and facilities for research are concentrated among relatively few investigators and organizations'. She stated that this bias was accepted by scientists as 'just and correct' even though 'this stratification of rewards and research facilities was 'at odds with the egalitarian ethos of science' (p. 235).

Mahoney also spoke about the stratification of the scientific community and the 'very apparent elitism' that is found within science within any sub-group of scientists, especially when it compares itself with another sub-group of scientists (Mahoney, 1976, p. 74).

Peer approval also protects and supports scientists against non-scientific critics. Ehrlich described the importance of peer approval during a radio interview in 2009 when he was asked, 'How do you deal with being reviled? How did you deal with being attacked so energetically for so long?' In reply Ehrlich spoke about the value to scientists of other scientists' approval, and how support and recognition from his mentors, peers and the scientific community had helped him deal with criticism from non-scientists:

> It's very easy and that is, I'm a typical scientist in that scientists value the opinion of other scientists. …I've gotten virtually every honour the scientific community can give me and that gives me what scientists want – approval from the peers. Not approval from idiots… (Ehrlich, 2009, online)

There is another separation between scientists that is a feature of the reductionist culture of science; the specialisation that scientists pursue to claim their unique contribution to the world's scientific knowledge.

Specialisation

Science is segregated into numerous disciplines and fields of research, each with their own and differing subculture under the umbrella of science (Becher & Trowler, 2001; Kingsley, 2008a). Becher and Trowler pointed out, however, that the concept of an academic discipline is not altogether straightforward, being subject to both historical and geographical variation over time (2001, p. 41). Ziman also commented on this variation in disciplinary definitions between countries and universities: 'Academic disciplines are surprisingly real, even though they often differentiated very arbitrarily….few recognized disciplines are really 'compact'. That these were established by historical accident can vary somewhat from university to university and from country to country' (Ziman, 2000, p. 47) .

Ziman observed that scientists were 'notoriously blinkered to features of experience that lie outside the frame of their specialised interests'. But he also pointed out that 'Much of the power of science comes from the specialised training of observers. Like a musical conductor or a wine taster, a

palaeontologist or ethologist learns to be sensitive to very small differences within a very narrow perceptual frame' (Ziman, 2000, p. 86). Milestone (2001) also observed that specialisation is necessary for a scientist to ensure a leading edge in a field which was an important criterion to obtain funding (p. 132).

This segregation creates and reinforces communication differences and difficulties between scientists and non-scientists alike. More than fifty years ago, the narrowness of scientists' knowledge honed to develop expertise within a single discipline or field of research was recognised by physicist J. Robert Oppenheimer (1953):

> We [scientists] are, of course, an ignorant lot; even the best of us knows how to do only a very few things well; and of what is available in knowledge of fact, whether of science or of history, only the smallest part is in any one man's knowing. (p. 89)

Hartz and Chappell (1997) commented on the increasing profusion of narrower and narrower fields: 'Not only are many scientists and engineers isolated, unskilled communicators, they also tend increasingly to specialize in fields that are simultaneously growing narrower in scope and greater in number' (p. 22). Ziman (2000) also noted the resulting mind-boggling fragmentation of the scientific literature into different disciplines. He described how academic disciplines are recognised as separate domains of organised teaching and research, and that these cut across institutional boundaries and affect many scientists' behaviour and expectations (pp. 47, 113).

These disciplinary differences create barriers to scientists' communication that include jargon ('Every science has its own language' (Oppenheimer, 1953, p. 79)) and other shorthand written and spoken communication characteristics that allow those within the same disciplines to communicate efficiently. At the same time, however, it make them unintelligible to scientists outside their fields and to the average person (S. Cole & Cole, 1967).

Both the fragmentation of science into disciplines and the central importance of disciplinary culture affect scientists' communication between disciplines and with the general public.

A Male-Dominated, Sexist Culture

There is much recent evidence of the continuing dominance of men and of discrimination against women in the culture and practice of science to the present day (Burelli, 2008; Erdelen, 2007; Fox, 2001; Ledin, Bornmann, Gannon, & Wallon, 2007; Long & Fox, 1995; National Science Foundation (Division of Science Resources Statistics), 2004; Rosser, 2004; United Nations Educational Scientific and Cultural Organisation (UNESCO), 2007). These studies illustrate a general structural bias in science against women.

In 2003, it was stated that women scientists and engineers employed in academia were disadvantaged compared with men in similar careers: 'Women faculty earn less, are promoted less frequently to senior academic ranks, and publish less frequently than their male counterparts' (National Science Foundation (Division of Science Resources Statistics), 2003, p. 1).

Rosser called for no less than an institutional change in American universities: 'The low numbers of women and stereotyping, overt discrimination and harassment and decreased funding issues were policy/practice areas ready to change'. She found that, 'More than 70 per cent (75/105 responses) said that balancing work with family responsibilities (children, elderly relatives, etc.) was a significant issue facing women scientists as they plan their careers' (Rosser, 2004, p. 35). Retaining women scientists has been more difficult than recruiting them into science degrees and professions.

In the same year, a study in the United States using data from nationally representative sample of recipients of doctorates in science (natural and social sciences) and engineering (engineering fields include chemical engineering, electrical engineering, and other engineering fields) examined gender differences for four critical outcomes that reflect successful movement along the post-secondary academic career path: tenure-track replacement, earning tenure, promotion to the rank of associate professor, and promotion to the rank of full professor. The study 'provided evidence that gender differences in the influence of family variables ─ marital status and family size ─ are related to women's chances for career success' and that women are less likely to be employed in tenure-track positions …and less likely than men to be promoted to senior ranks'

(National Science Foundation (Division of Science Resources Statistics), 2004, pp. 3, 15).

In Australia, studies reveal the same patterns of gender imbalances in science disciplines and discrimination against women. Although in 1998 Borthwick and Murphy, noted that, 'Australia ranks among the world's top countries for female share [46%] of first degree university graduates in science and engineering' (p. 5) and women are more common in the undergraduate degrees, they were still under-represented in postgraduate degrees. Marceau, Turpin and Woolley (2004) identified factors that contributed to a gender bias towards males amongst those studying for PhDs. These included 'traditional male dominance in science research', the 'course preferences of elite female students on entry to university' and the 'time for the increased numbers of female undergraduates to 'filter through' to the upper levels of research training'. Interestingly this study also showed a relatively greater distribution of women under thirty years compared to any older age grouping, drawing attention to a possible change in the relative number of women in science and technology in Australia over the next two decades, if these women stay in science (Marceau, et al., 2004, pp. 10, 14).

A year later, Foley (2005) wrote about the paucity and lower status of women in science in Australia. Foley quoted Australian Bureau of Statistics figures that only 24% of physics Ph.D. graduates and 23% of physics undergraduates were women. Furthermore, female physicists mostly [held] lower positions than their male counterparts (Foley, 2005, p. 43) and this situation appears to be characteristic of science in general.

In 2009 the President of the Federation of Australian Scientific and Technological Societies (FASTS), Ken Baldwin, commenting on the release of a report called *Women in Science in Australia: Maximising Productivity, Diversity and Innovation*, said that it 'finds the progress of women in science in the past 15 years has stalled'. He went on to say that, 'Despite impressive improvement in participation of women in science at undergraduate and postgraduate levels, retention of women at senior levels in science and technology remains poor'. The report found 'persistent structural barriers to women in senior positions in science and technology'. The results of this discrimination were that in Australia:

> Female scientists are clustered at the lower levels of responsibility, even in disciplines where they are well represented, such as biological sciences
>
> In nearly every category female professional scientists are earning less than their male counterparts
>
> Significant numbers continue to report discrimination and harassment
>
> Women have lower levels of recognition in measures of scientific excellence or esteem. (FASTS, 2009, online)

Other examples of recent discriminatory practices against women in the United States and Sweden, related to selection, hiring and promotion procedures, and the distribution of resources, peer review and assessment of scientific excellence, were given in a 2008 European Commission report. The report noted that, 'Gender bias is the often unintentional and implicit differentiation between men and women situating one sex in a hierarchical position to the other.

> It revealed that, 'In the first-ever analysis of peer-review scores for postdoctoral fellowship applications in Sweden, it was found that female applicants had to be 2.5 times more productive than the average male applicant to receive the same score' (Caprile et al., 2008, p. 17).

Servon and Visser (2010, p. 5) concluded that, 'women continue to feel hindered by the masculine culture of the [science, engineering and technology] sectors' on the basis of quantitative and qualitative data obtained from over 2,493 survey respondents and 28 focus groups of women in SET fields in the United States. They found that 'women across the SET sectors report experiencing a variety of demeaning and predatory behaviours in the workplace including: experiencing sexual harassment, being viewed as less capable, a perceived bias in performance evaluation and receiving unwanted attention due to appearance.

The evidence is overwhelming that women continue to be discriminated against within the scientific community – they are paid less, recognised and rewarded less, promoted less, are less likely to be given tenure, and are retained less at

senior levels, despite the fact that relatively more women are entering science at undergraduate and postgraduate levels.

Male domination of senior positions

Men also dominate senior positions in research and development and there are numerous accounts and international reports within the last fifteen years that not only describe the imbalance in the number of women in senior positions in science, but also call for this to change. The reasons given for the low number of women in senior positions go beyond the generally younger age of women in science. In 1995 for example, an Australian survey that included focus groups with scientists and engineers found that most felt that there were relatively more women in the lower levels of science and 'Most agree that women scientists faced obstacles to career advancement' (Department of Industry Science and Tourism, 1996, p. 19; Woolcott Research Pty Ltd., 1995).

The Gender Advisory Board of the United Nations Commission on Science and Technology for Development attributed the lower number of women in senior positions to the fact that, not only were women in science and technology fewer in number and generally younger than men, but they were constrained and concentrated at the lower ranking levels of science system by a 'glass ceiling' caused in part by 'work-life balance; gendered patterns and approaches to productivity; and performance measurement and promotion criteria' (Huyer, 2006, p. 6).

In 2007 the male domination of science by their number, seniority and receipt of recognition and awards was further described by Erdelen (Assistant Director-General for Natural Sciences (UNESCO)). He stated that the latest data published by the UNESCO Institute for Statistics revealed that 'science and technology are still dominated by men' (Erdelen, 2007, p. 1). Most recently, US researchers Servon and Visser (2010), reported that their research based on a large data base[11] 'has found that women continue to be significantly under-

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[11] 2,493 survey respondents and 28 focus groups

represented in higher levels of management in the SET sector and experience lower retention rates than their male colleagues' (p. 1).

Despite the overwhelming evidence that women are discriminated against in science; the associated calls for this to change and the numerous initiatives to attract and retain more women, this cultural bias within science continues to be very slow to change.

Employment sector differences

The cultures and associated practices and expectations of science differ between employment sectors. Much has been written for example, about the cultural differences between universities and industry; the divide between 'academic science' and 'industrial science', or academia and business and government (Gregory, 2009; Heaney, Williams, & Mazauric, 1996; People Science and Policy Ltd., 2005; Ziman, 2002).

Heaney, Williams and Mazauric (1996) described the 'desirable and necessary' cultural differences such as research motivation, communication practice and funding sources, as influences upon how and what scientists in academia and industry in the United States communicate. They portrayed academic scientists as being motivated by curiosity and relying largely upon government and foundation grants, and industrial scientists as being more goal-driven and reliant upon internal funding from the company, which ultimately comes out of the company's profits (ibid., p. 66). The authors identified a critical difference in funding trends in the mid-1990s, and this has arguably continued in many western democracies to the present day. While government funding for academic research has been declining, 'industrial profits have been rising over the past few years' (ibid., p. 68).

They described very different public communication practices for academic and industrial scientists. Academics, for example, must make their knowledge public to be successful. 'Achieving tenure and winning grants depends largely on published evidence of productivity and the establishment of a good reputation in the scientific community. This view was reiterated by People Science and Policy who described British academia as a 'research-led culture' where an academic career is very dependent on research publications' and the 'drive to get research

funding' is generated from the is 'from on high, the top of the university' (People Science and Policy Ltd., 2005, p. 7).

This necessitates open discussion of scientific work with other scientists'. Industrial scientists, on the other hand, need to keep their knowledge private, 'to protect the company's investments in newly acquired knowledge or data'(ibid., p. 67).

Ziman described 'industrial science' as having the same knowledge base as academic science but being sociologically distinct, with many contrasts. 'One is that industrial scientists do not, in general, "own" their research in the sense of undertaking projects of their own choosing and being free to publish their results entirely on their own initiative' (Ziman, 2002, p. 398). He also described industrial science as contravening the Mertonian norms [the modified version of communalism, universalism, disinterestedness, originality, scepticism] at almost every point (Ziman, 2000, p. 78).

Interestingly though, Heaney at al. (1996, p. 66) clearly stated that although both academic and industrial cultures had changed significantly in the past decade, they had not necessarily become more similar. Both Ziman (2000) and Nowotny et al. (2001) were to disagree. They observed the beginning of a merging of academic and industrial science, and described it using terms such as 'post academic science' and 'Mode-2 science' respectively.

Ziman described 'post-academic science' as a hybrid culture that 'outwardly preserves many academic practices and is still partially located in "academia"'. He described the effects on science in universities that have been wrought, however, by changes in funding sources and duration:

> Universities and research institutes are no longer deemed to be devoted entirely to the pursuit of knowledge 'for its own sake'. They are encouraged to seek industrial funding for commissioned research, and to exploit to the full any patentable discoveries made by their academic staffs ─ especially when there is a smell of commercial profit in the wind. (Ziman, 1998, p. 1814)

Nowotny, Scott and Gibbons (2001, p. vii) described the increased importance of the potential applications that had moved knowledge production away from

the classical disciplinary organisaton of knowledge production to a context-sensitive science that they called a 'mode-2 knowledge production'.

The following section reviews further how the culture, or more accurately subcultures, of science have changed over time as the cultures of academia and business have begun to merge.

Changes in the culture of science

Competition, commercialisation and changes in funding sources have changed what kind of science is conducted and by whom (National Science Board, 1998; Nowotny, et al., 2001; Whitley, 2000; Ziman, 2000). Ziman described this change as no less than a redefinition science at every level: 'In less than a generation we have witnessed a radical, irreversible, world-wide transformation in the way that science is organised, managed and performed' (Ziman, 2000, p. 67). The fact that scientific research had become 'more expensive and directly dependent on public and corporate funding' has also meant changes in the kind of research that is done toward practical, problem-solving research that has 'demonstrable practical utility' (Ziman, 2002, p. 398).

Nowotny, Scott, and Gibbons (2001) described a changing relationship in the latter decades of the 20th century that was characterised by a large heterogeneity in the organisational structures involved, the temporary character of the research groups, and the transdisciplinarity of the approaches. Ziman describes post-academic science as largely the work of teams of scientists, often networked over a number of different institutions (Ziman 2000). Others described scientific research as more of a hybrid between 'basic' (pure, curiosity driven, university-based) and 'applied' (use- or mission-driven, industry-based) (International Council for Science, 2005, p. 13).

There are ongoing tensions between the cultures of universities and businesses when they are expected to collaborate to commercialise research findings. In recent years these tensions have been discussed as barriers to the progress of science and technology or the 'innovation system'. Turpin and Deville (1995) , wrote about the pressures on publicly funded research institutes in most countries 'to become more financially independent, to be more commercial in

their operation, to be more accountable, and to adopt more business-like principles and practices' (p. 142).

The international review, *Science and Society: Rights and Responsibilities* in 2005 warned that these changes to scientific practice which included 'an increasing presence of the private sector, as well as increased collaboration' carried 'possible risks to academic freedom and research ethics' (International Council for Science, 2005, p. 14).

Increasing competition for public funds was linked to research that was becoming more costly to conduct according to the US report of the Government-University-Industry Research Roundtable[12] in 1997. 'Traditional academic research is growing more competitive as federal funding fails to match growth in the number of grant applicants and in the costs of modern research. Industry is relying more on a base of academic research'.

The Roundtable report also described how industry sponsorship was restricting and controlling scientists' communication:

> …Industry's links with academe have grown stronger and more pervasive in the past decade. The private sector in many industries has come to rely on academic researchers for long-range research that it once did in-house. Industrial sponsors of academic research typically restrict publication of research results and apply other controls on information. (The Government-University-Industry Research Roundtable, 1997)

Along the same lines, Gregory (2009) predicted that the 'growing proportions of scientists in business rather than in academia and the relatively low participation of commercial scientists in the traditional communications of the scientific community' would divide scientists further, because communication in business

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[12] The Government-University-Industry Research Roundtable was created in the mid-1960s. It provides a forum for dialogue on science and technology issues among top government, university, and industry leaders, and is sponsored by the National Academies of Sciences and Engineering and the Institute of Medicine.

is ‘more about competition and self-interest than they are about Etonian universalism and communism’ (p. 15).

Ultimately the changes in the culture of science over the last few decades have also affected what is and is not communicated with the general public as will be discussed in detail in Chapter 4.

The increasing importance of public opinion

The increasing importance of public opinion to the conduct of science is another changing aspect in the culture of science. Associated concerns about a declining public support for scientific research have prompted social research about the public’s views of science, science issues and scientists, and involvement in the governance of research and technological change[13]. This research has been funded by governments, universities, charities and industry.

This focus on what the public thinks and understands about science has dominated communication research in the last 15 years. As a result there are a number of regional, country and state reports from focus groups, interviews, and, large-scale, surveys, of the publics’ views about science (European Commission, 2001, 2005a, 2007; MORI, 1999b, 2005a; National Science Foundation Board, 2008, 2010; People Science and Policy Ltd., 2008; Quantum Market Research, 2009).

Specific studies of public opinions around issues which have science elements, such as gene technology, include Cormick and Ding (2005) and MORI (199a, 1999b).

It is interesting to note that although direct government engagement with the public on science and technology issues in Australia is generally restricted to consultation by government departments and agencies, there was a time when there were calls for a more powerful involvement of the public in science in Australia. One of them was a decade ago in the 1998 *Health and Medical*

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[13] e.g. through processes such as consensus conferences, citizens’ panels, workshops and public meetings.

Research Strategic Review - The Virtuous Cycle - Working together for health and medical research (or the Wills Report). While the recommendations for communication unsurprisingly involve informing the public and promoting public understanding and appreciation of medical and health research, it also included involving 'the community in setting the agenda for priority-driven research' and involving the community in the research process. The report did not state, however, what was meant by 'involvement' (Wills, 1998, p. A11.10).

Science in Australia

This section looks more closely at science in Australia. The organisation and characteristics (such as contestable funds and pressures to commercialisation research and collaborate across public and private sectors) that mould the culture of science in this country are outlined first.

Description and organisation

In Australia, the range of organisations involved in science and innovation across the public and private sectors, and across national, State and Territory jurisdictions include '39 universities, State and Territory government research, innovation and science agencies, and more than 60 major research facilities, managed mainly by universities and government research agencies. There are private, non-profit bodies (including 29 independent medical research institutes) and some large, and thousands of small, private companies in all industries'(Department of Education Science and Training, 2003, p. 1).

Australia's science industry, as distinct from the whole scientific enterprise, was defined as providing the scientific equipment and laboratory services used in scientific measurement for customers in engineering, food processing, medical and health, pathology, R&D and education (Department of Industry Tourism and Resources & Department of Education Science and Training, 2005, p. 27).

There are more than 5,000 companies[14] and other enterprises in the science industry that manufacture scientific equipment, import and distribute scientific equipment as well as provide laboratory and technical services (ibid., p. 72).

Bitmead (1997) pointed out that the generally small to medium size of firms in Australia had implications for the in-house research facilities that they could afford and the researchers that they could employ (p. 79). Marceau, Turpin and Woolley (2004) for example, described the small company size in biotechnology within the private sector in Australia, and the resulting 'heavy' reliance upon the research scientists within the public sector 'for the science on which their products depend' (pp. 11-12). This must be the case for many of the more than 75% of Australia's science companies which had less than 10 employees and a turnover of less than A$50 million (Department of Industry Tourism and Resources & Department of Education Science and Training, 2005, pp. 25, 72).

Marceau (2007b) described Australia's 'complex system of public sector science research' and stated that this meant that 'there is competition for scientists and for resources among public sector institutions, especially in emerging fields' (Marceau, 2007b, p. 314).

Industry in Australia is the single biggest spender [as opposed to source of funds] on research according to Marceau et al. (2004). The number of industry sectors undertaking research, however, is very limited; the scale of research activity is small and reducing; and overall the proportion of funding for research spent by industry is lower in Australia than the OECD[15] average (Marceau, et al., 2004, p. 3). Industry remained the biggest spender according to figures in 2008 from the Australian Bureau of Statistics. These showed that business accounted for 57% of the total expenditure; higher education was the next highest with

[15] Organisation for Economic Co-operation and Development (OECD)

about 28%; and Government (both Commonwealth and State/Territory) were 14%[16] (ABS, 2008c).

Sector differences

Australian Government-commissioned reports since the 1990s have clearly recognised problems arising from the cultural differences between academic and business institutions. For example, one reported that a focus group of Australian engineers and scientists in 1995 'perceived two key barriers to the advancement of science and technology in Australia: the corporate culture of middle management and business versus scientific goals' (Department of Industry Science and Tourism, 1996, p. 25).

In 2004 an article posted on a website by the government organisation Science Industry Australia (Inc.) claimed that: 'Much of the strength of the Australian science industry today is directly traceable to the successful commercialisation of government-funded basic research going back as far as the 50s and 60s' (Science Industry Australia Inc., 2004).

This may have been so, but there are indications that such successful commercialisation may be the exception rather than the rule. Ten years later, another Australian government report, *Measure by Measure*, stated that:

> …Anecdotal evidence from the [science] industry indicates that interactions between researchers and companies can be complex and frustrating to both parties. As one company commented: '*Our experience is that the majority of researchers are not genuinely interested in cooperation with commercial operations. The exceptions have been very successful*'….[original italics]. (Department of Industry Tourism and Resources & Department of Education Science and Training, 2005, p. 42)

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[16] 8112.0 – Research and Experimental Development, All Sector Summary, Australia, 2006-2007.

Conversely, it was also recorded that research organisations reported that science industry companies had said upon being offered intellectual property that ‘none of the intellectual property was close enough to their portfolio interests, or that the intellectual property was not sufficiently developed to be of interest’ (Department of Industry Tourism and Resources & Department of Education Science and Training, 2005, p. 42). In the following year, the Australian Government House of Representatives Standing Committee on Science and Innovation made a number of statements about the general lack of well-developed business and entrepreneurial skills among academics and researchers working in the public sector. This was related to the ‘culture of academia and the lack of real incentives for researchers in the public sector to commercialise their research activities’ (House of Representatives Standing Committee on Science and Innovation, 2006, p. 85). The Committee also gave a number of reasons[17] for the apparent lack of business and entrepreneurial skills amongst most university researchers such as ‘a perceived lack of information regarding commercialisation practices and procedures’, and ‘the culture of the researchers, in particular the perception that by commercialising “you’re selling out”’ (ibid., p. 85). The Committee also commented on researchers’ lack of motivation to commercialise their work because ‘they see little real incentive or reward to undertake the commercialisation of their work’ and ‘there is no real peer or professional advancement currently associated with commercialisation involvement’ (ibid., p. 85).

The Committee wrote that there was ‘the need to encourage a more fundamental cultural and attitudinal change’ because some public sector researchers had a negative perception of commercialisation (House of Representatives Standing Committee on Science and Innovation, 2006, p. 86). A lack of academics’ interest in commercialisation was also stated one year later by the Australian Government Productivity Commission. The Commission had a different approach to the Committee however, and warned that cultural change in

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[17] Information provided by DEST [Department of Education Science and Training] (House of Representatives Standing Committee on Science and Innovation, 2006, p. 85).

universities to facilitate commercialisation of knowledge for financial gain posed risks to community well-being and to the core role of universities. It also posed risks to ‘some of the motivations for science career choices’ of some researchers ‘who can be more motivated by curiosity and research excellence than commercial opportunities’ (Productivity Commission, 2007, pp. xx-xxi).

The importance of government funding

In Australia, the public funding of R&D through government agencies is very important, with the federal government playing the most prominent role (Department of Education Science and Training, 2003, p. 1). As stated by Bitmead (1997), ‘Universities in Australia have been dependent on government funding since their inception’ (p. 78). The major government funding bodies are the Australian Research Council (ARC), the National Health and Medical Research Council (NHMRC) and the Cooperative Research Centres (CRCs). According to the Productivity Commission (2007), ‘The bulk of such public funding (about five dollars in every six) is provided to universities or public sector agencies’ (pp. xx-xxi). Australia’s professional societies and learned academies[18] also receive Commonwealth funding for ‘the transfer of outcomes of research and innovation within Australia and in maintaining contact with the latest international developments’. Government grants were used to ‘assist the academies to promote research and scholarship and pursue activities in the national interest, including the provision of independent advice to the government’ (Department of Education Science and Training, 2003, p. 269).

The Commission stated that, ‘about 40% of total Australian Government financial support for science and innovation’ funds higher education research. Universities receive block funding direct from the Australian Government …and they are also the primary recipient …of the competitive funding programs administered by the ARC and NHMRC (Productivity Commission, 2007, p.

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[18] The Australian Academy of Science, the Australian Academy of Technological Sciences and Engineering, the Academy of the Social Sciences in Australia, the Australian Academy of the Humanities, and the National Academies Forum.

xxix). Research tax concessions are provided by the government as well (Cutler, 2008, p. 8).

Decline in Commonwealth science funding

Commonwealth funding for science and innovation has been declining for decades as science has not been a funding priority for a succession of federal governments since the 1970s. This is despite the political rhetoric, and the repetitive, but largely ignored government–commissioned reports that call for increased funding and cultural change. Garrett-Jones (2007a) pithily observed that, 'Despite some worthwhile structural reforms, science and innovation policy in Australia does not occupy centre stage: not in strategic planning, not in resource allocation and not in the minds of business, public and politicians' (p. 38). In early 2008, Carr drew attention to Australia's relatively low expenditure on R&D compared to other OECD countries:

> 'We should all be proud that Australia produces about 3 per cent of the world's scientific papers with just 0.3 per cent of the world's population. We should be less proud that our total expenditure on research and development as a share of GDP was just 78 per cent of the OECD average in 2004-05'. (Carr, 2008d; online)

The decline in public funding for science, that has caused 'endless restructuring and cutbacks in resources' of public sector science, was also linked to the decline in university staff and students in the natural sciences by Marceau (2007b). The biomedical sciences were, however, a disciplinary exception because 'national priority status [had] been given to research in this field for some time' (pp. 314-315).

Further evidence of the relative decline in Australia's Commonwealth funding for its science and innovation was provided in the '*Venturous Australia Report*' (Cutler Report):

> Public support for research and development (whether private or public) has declined over the past fifteen years, from a high of 0.76 percent of GDP in 1993 to a low of 0.58 percent in 2007'....'Public

expenditure on education has slipped below the OECD average'.
(Cutler, 2008, p. 2)

The report tracked the decline of public investment in research from '1995 with university funding for research falling further behind the full-cost of conducting that research and government research agencies such as the CSIRO suffering successive funding cutbacks' (ibid., pp. 13-14).

A 2009 government report, *Powering ideas: An innovation agenda for the 21st century*, influenced by the Cutler Report, stated that: 'Commonwealth spending on the science and innovation has fallen 22 per cent as a share of GDP since 1993─94. Business spending on research and development collapsed in the late 1990s, and while it has grown since then, we still lag many of the countries we compete with' (Department of Innovation Industry Science and Research, 2009, p. 2). Australia spends two per cent of GDP on research and development, falling behind Austria, Denmark, Germany, Iceland, Switzerland, Taiwan and the United States which spend more than 2.5% (Department of Innovation Industry Science and Research, 2009, pp. 2-3).

While the Commonwealth remains the dominant provider of funding for research granting projects[19] and its funding has decreased, State and Territory government funding for R&D has been increasing since the late 1990s; mainly because they have been investing in infrastructure for emerging technologies such as biotechnology, and information and communications technology (ICT) (The Allen Consulting Group Pty Ltd, 2003, pp. vii, x, 86). In Australia, 'the long standing practice' had been a State and Territory government focus on agricultural research, environmental research and public health research (generally in public hospitals) (ibid., p. 71).

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[19] 'The Commonwealth government provides 38 per cent' while 'State and Territory governments provide about 8 per cent of R&D funds' according to a report in 2002 by the Australian Bureau of Statistics (HEFCE & RCUK, 2006).

The declining availability of public funds for R&D in Australia has contributed to organisations and institutions seeking funds elsewhere; cutting costs and employing a more flexible (short-term) workforce.

Short-term contracts, contestable funds, commercialisation

The work experience of scientists in Australia is increasingly characterised by short-term employment contracts, dependence upon contestable funds for research, and the pressures to commercialise research findings. This has been explored by a small number of surveys of scientists' perceptions of and attitudes to workforce issues, and described in government-commissioned reviews.

Many of these focus on researchers in the medical and health sciences such as the Wills Report (1998). It found that scientific progress was impeded by the increasing number of contract staff, and their limited career development and funding opportunities. A 1999 survey in of 266 biomedical researchers that found that biomedical research in Australia was characterized by poor job security, low salaries and a gloomy outlook (Australian Society for Medical Research, 1999).

Three years later, in a more general study of Australian universities, Anderson, Johnson and Lawrence (2002) described 'decline in the relative status, salaries, prestige and general attractiveness of employment as an academic'. They also tellingly reported that many Australian academics said 'they would not recommend an academic career to anyone' (2002, p. ii).

A national telephone poll of 501 active health and medical researchers conducted by Research Australia in 2003, found that funding and infrastructure support remained, overwhelmingly, the greatest concern for researchers (Shewan, Glatz, Bennett, & Coats, 2005, p. 610).

It is perhaps unsurprising then, that longer term research funding was also found to be a continuing and pressing cause for concern for 84% of the scientists who participated in an online web survey of 520 scientists in 2003. The survey was designed to track the career paths of scientists and identify the nature, extent and mechanisms of contribution to innovation in Australia (Marceau & Turpin, 2007a; Marceau, et al., 2004; Turpin, Garrett-Jones, & Diment, 2005, p. 17).

Given the communication focus of this current study, it is worth noting that, that after concerns about 'access to longer term research funding' and the 'emphasis on applied funding over basic research', 'the third strongest issue concerned a lack of public understanding of S&T[20] (34 per cent)' (Turpin, et al., 2005, p. 17). Arguably, however, this third issue may also be linked in scientists' minds to the possibility of increased funding through public support if the public had a better understanding of science and technology.

Marceau, Turpin and Woolley (2004) wrote about the effects of shifts in Australian government policies and funding for research that commonly involved increased contestability for funds and the commercialisation of research result. They summarised these effects as 'position uncertainty, low pay and short term project dependence' (ibid., pp. 2-3). They also commented on policy makers' increased control over the funding and direction of research in Australia in recent years (ibid., p. 30) .

In 2008 it was reported that an online survey of 379 ASMR[21] members conducted in 2006 found that, 'Employment insecurity and lack of funding are a cause of considerable anxiety among Australian health and medical researchers'. The authors pointed out that, 'This may have important implications for the recruitment and retention of researchers' (Kavallaris et al., 2008, p. 520).

The Cutler Report stated that the lack of full funding of research through competitive grants programs such as the Australian Research Council (ARC) and performance-based block grants was undermining both teaching and research in Australia's universities. This was because universities had to invest in their own research from other revenue streams, 'most particularly from the teaching of full fee paying overseas students' to make up the shortfall and this had consequences (Cutler, 2008, p. xii).

[20] Science and Technology

21 The Australian Society for Medical Research (ASMR) is the peak professional society representing Australian health and medical research.

Collaboration

The pressure on Australian 'universities in the 1990s to supplement their federal grants with external funding led to an increase in the approaches of universities to industry seeking collaboration' (Bitmead, 1997, p. 71). For example, the Cooperative Research Centre (CRC) program, established in 1990, 'signalled the first major commitment by the [federal] government to foster and facilitate interactions between universities and industry'(ibid., p. 75). Bitmead observed that, 'the CRC program has been the government's biggest commitment to its continued support of science and technology in Australia and this program has been maintained [to the present day] despite a change in government' (ibid., p. 79).

Within Australia's 'well-developed but comparably small science, technology and engineering base' and the environment of decreased government funding for research, the importance of Australian scientists' collaboration with scientists internationally, to access '98% of the world's science and technology', was recognised (Department of Education Science and Training, 2003, p. 269).

Sectoral differences in levels of national and international collaboration have also been identified:

> Bibliometric data indicate that those sectors with the highest levels of basic research — medical research institutes, universities and CSIRO[22] — are the sectors with the highest levels of international collaboration.
>
> Further, hospitals and medical research institutes, with their high concentration on research in the medical and health sciences, have the highest proportions of institutional collaboration. (ibid., p. 270)

Upstill and Spurling (2007) commented on the pros and cons of increased collaborative research for CSIRO. A positive was that growth in collaborative

[22] Commonwealth Scientific and Industrial Research Organisation

research indicated the 'increased relevance and commercial impact of CSIRO research'. A negative was that 'collaborative research can pose its difficulties when commercial and scientific goals are not convergent' and they warned that, 'Vigilance is needed in managing collaboration arrangements so that they do not impinge on scientific integrity and independence' (Upstill & Spurling, 2007, p. 121). This increased collaboration by government and university scientists with industry has also impinged on scientists' freedom to communicate as will be discussed in Chapter 4.

Interestingly, within an international context, collaboration does not appear to be a strong feature of science in Australia. According to its Science Minister in 2008, 'Australia was ranked last out of twenty-six OECD countries for research collaboration between industry and universities, and second last for research collaboration between industry and public research organisations' (Carr, 2008d).

A Description of Australia's Scientists

This section examines scientists in Australia in terms of their number and distribution across public and private sectors, and as an aging, gender-biased workforce. Evidence of current and expected shortage of scientists in particular fields is presented as are the causes of these shortages, such as declining public funding, short-term employment contracts and low salaries.

The very few national surveys and studies of scientists in Australia have often described the working experiences and career prospects of researchers (Australian Society for Medical Research, 1999; Marceau, et al., 2004; Rouse, 2000; Shewan, et al., 2005). For example, Shewan et al. (2005) found that 'Researchers are predominantly motivated by the excitement of discovery, rather than salary, community recognition or the potential for personal wealth from the commercialization of their discoveries. Publications are viewed as a more important research outcome than the patenting of research findings or creation of new businesses' (p. 610).

How many scientists in Australia?

The importance of and variation between different definitions of 'scientist' was briefly discussed earlier in this chapter. For this study, the Australian Bureau of

Statistics (ABS) definitions were used (these are presented in Appendix 5.6), along with the ABS Occupation figures from the 2006 Census of Population and Housing to account for the number of scientists in Australia. According to this latest Australian Census, there were 67,665 self-identified employed scientists living in Australia in 2006 out of a total national population of 19,855,288 (all ages) (ABS, 2006b).

There are also different ways of accounting for the 'number' of scientists, as individuals (as above), or in person years of effort (PYE)[23]. The latter has an advantage in accounting for people who work part-time, such as medical and health scientists. In terms of person years of effort (PYE), Australia's scientists numbered 87,269 in R&D 2006-2007 (ABS, 2006c).

The distribution of scientists across sectors by discipline

As previously stated, the public sector (Federal, State/Territory and Local Government; education and military) is a very important employer of scientists in Australia. A study published in 2004 showed that research degree graduates 'do not enter the private sector in greater numbers' and that 'what happens in the public sector is absolutely critical for the careers of Australian scientists[24] in virtually every discipline' (Marceau, et al., 2004, p. 11). Overwhelmingly science graduates with master or PhD degrees, in agriculture, chemistry, physics, life sciences, computing science and medicine entered the public sector when they entered the labour market. The government sector was the major employer of computing science graduates with 'over half the proportion of computer scientists' entering the government sector (ibid., p. 12). The

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[23] Person years of effort (PYE) - One person year of effort is equal to a full time employee whose time is wholly devoted to R&D for a whole year. Employees are defined as persons who worked for a private or public employer, and received pay for the reference period in the form of wages, salaries, or a commission while also receiving a retainer, tips, piece rates or payment in kind. Persons who operated their own incorporated business, with or without hiring employees, are also included as employees (ABS, 2008c)

[24] The Australian Expert Group in Industry Studies (AEGIS) study defined researchers as 'professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems and also in the management of the projects concerned' (OECD 2002, 93). (ABS, 2010, online)

Commonwealth Government and the State Governments[25] were also recognised as major employers of life sciences and agriculture graduates.

Only one in five researchers found their first job in the private sector. Geology graduates with master or PhD degrees were exceptions, 33% entering the private sector in any significant numbers after graduating (2002, the latest date available). Geologists were found to be employed evenly ‘across education, government and private sectors’ and the authors believed that this reflected ‘the broad economic importance of the mining industry in Australia’ (ibid., pp. 11-12).

Marceau, Turpin and Woolley (2004) also reported that, ‘Researchers trained in agriculture, chemistry, life sciences and physical sciences are more likely to move into science professional occupations than other occupations’ and that ‘these occupations are likely to be in either the education or government sectors’ (ibid, p. 12) .

Most of Australia’s science and engineering graduates, however, do not work in R&D. ‘They contribute to the economy by performing a range of professional and semi-professional roles, in primary industry, manufacturing and processing, and services. Many scientists are engaged in teaching, testing, monitoring and other non-research oriented professional work’ (Borthwick & Murphy, 1998, p. 2).

An aging workforce

In Australia the ‘science and engineering workforce is expected to age over the coming years’ (Productivity Commission, 2007, p. 250). The Commission’s report noted, however, that the ‘age structure varies by university, with GO8 universities[26] generally having a younger staffing profile’ and ‘in an ageing academic workforce, science academics are relatively young’. Commenting

[25] It should be noted that the term ‘Government’ also includes the CSIRO. It is likely that the CSIRO is especially important in the life sciences and agriculture, less so in IT (Marceau, et al., 2004, p. 5)

[26] The Group of Eight (GO8) has been operating as an informal network of vice-chancellors of eight Australian universities since 1994 and was formally incorporated in September 1999.

specifically on science academics, the Commission said that, ‘Proportionally more science academics are aged under 30 and fewer aged 50 and over than any other discipline’ (p. 250).

A gender-biased workforce

The patterns of gender bias internationally in science are also a part of the Australian science culture. For example, Marceau, Turpin and Woolley reported on the bias in gender composition in the natural and physical sciences towards women in undergraduate and honours degrees, and towards men in postgraduate degrees (2004, p. 9). The low proportion of women progressing to, and remaining in, a research career, especially in academia and science, technology, engineering and mathematics (STEM) areas[56'] ,was also described with concern in 2008 by the Parliamentary House Standing Committee on Industry Science and Innovation. The Committee admitted that they did ‘not know a lot about those decision-making processes, nor indeed the incentives or disincentives for those women to remain in the productive academic workforce’ but could ‘speculate about issues such as child care, work-friendly workplaces et cetera’ (The Parliament of the Commonwealth of Australia, 2008, p. 118). They then quoted submissions from the Australian Academy of Science (AAS), the Walter and Eliza Hall Institute of Medical Research (WEHIMR) and the University of South Australia (UniSA) about the high attrition rate of female academics in their later 20s and 30s and the lack of support for women during their child-bearing and child-rearing years (The Parliament of the Commonwealth of Australia, 2008, p. 119).

Many Australian Government-commissioned studies over the last decade have reiterated the importance of science to the ‘triple bottom line’ of Australians’ economic, environmental and social wellbeing (Cutler, 2008; Department of Innovation Industry Science and Research, 2009; Marceau, et al., 2004; Wolfendale et al., 1995). Against this background, however, they have also expressed concerns, not only about the lack of women in science, but also about the declining number of scientists with the skills needed now in Australia.

Shortage of scientists

In 2004 Marceau, Turpin and Woolley reported on the decline in the number of students entering science, at both the secondary school and university level in Australia. In 2007, Tom Spurling (then President of FASTS) spoke about the decline in interest in becoming a scientist; 'The Government's audit of science and engineering skills found Australia faces a shortage of 20,000 scientists by 2012' (Spurling, 2007).

In education, for example, the shortages of staff in universities for science research in Australia are becoming acute: 'our staff-student ratios are become increasingly unfavourable for teaching and research staff, the personnel available for research in any discipline are becoming stretched and find that research is the first area of endeavour that has to give way to crowded teaching timetables' (Marceau, et al., 2004, pp. 1-2). Marceau et al. (2004) explained that this was because 'grants remain extremely hard to get, especially by the young, and students in science have been few for many years, leading to few new staff opportunities in university/teaching research jobs as these positions are based on student numbers' (ibid., pp. 1-2).

Speaking specifically about shortages in the science industry, it was stated in *Measure for Measure* that, 'Anecdotal evidence and surveys of the science industry indicate that it is experiencing a shortage of trained and qualified people, particularly laboratory technicians, technical trade, chemists, mechanical and software engineers, sales and management staff'. These skills shortages were the results of 'the growth in demand for skilled staff, the relatively low profile of the industry as a career option, and the limited number of industry specific training courses for prospective staff' (Department of Industry Tourism and Resources & Department of Education Science and Training, 2005, p. 61).

In 2006, the *Audit of Science, Engineering and Technology Skills* found that the proportion of domestic student numbers in science, engineering and technology, across all education and training sectors, was either static or declining over the previous decade. 'This was particularly apparent for enabling sciences, which include advanced intermediate mathematics, physics and chemistry' (Department of Education Science and Training, p. x). It was difficult to recruit

scientists in the engineering disciplines, and in sciences such as Earth sciences, Chemistry, Spatial information sciences and Entomology, needed for the resources sector, defence needs and infrastructure development and renewal. People with high-level mathematical and statistical skills were needed ‘now and into the future’ in the finance and other sectors (Department of Education Science and Training, 2006, p. xi).

The Audit predicted a decline in the number of people working in science, engineering and technology (SET) resulting from a number of demographic changes, such as an aging of the SET workforce, a decline in the number of school leavers from 2010 onwards as a result of demographic change, and the low community profile of SET (Department of Education Science and Training, 2006, p. 49). Some of the Audit’s findings about Australia’s declining science workforce in Australia were dramatically summarised by Australia’s science minister in 2008:

> Australia has only eight PhDs per thousand in the workforce, compared to eleven in the United States, twenty in Germany and twenty-eight in Switzerland.
>
> And if we don’t act now, things will get worse. The 2006 Audit of Science, Engineering and Technology Skills concluded that Australia was heading for a cumulative shortfall of 19,000 scientists and 51,000 engineers and engineering trades people by 2013.
>
> After growing by 9 per cent a year in the eighties and early nineties, the number of students starting research degrees has flat-lined over the last decade. (Carr, 2008d, online)

The shortage of scientists is expected to increase as fewer students choose to study for and enter an insecure and underpaid workforces as professional scientists, and others choose to leave it because of its family unfriendly culture, or retire. In 2007 the Australian Government Productivity Commission also highlighted stresses on the science and innovation system in Australia such as the ‘emerging pressures in the academic and teaching scientific workforces, stemming from ageing and ongoing workplace inflexibilities’ (Productivity Commission, 2007, p. xxxii). Employment uncertainty and low salaries are not

attracting or retaining scientists according to a number of researchers and government initiated studies over the last couple of decades.

Problems with a career in science

It is not just scientists' numbers that are declining. The Productivity Commission reported on scientists' declining morale as a reflection of 'scientists' concerns about poor career pathways, excessive use of short-term contract employment and a burgeoning non-research workload'. It stated that this falling job satisfaction had 'potential consequences for productivity and future recruitment' (Productivity Commission, 2007, p. xxiv).

The seeds for these problems were sown decades ago. According to Blakey, a former Chief of the CSIRO Division of Building Research, the plethora of short-term (less than three year) contracts for science researchers had resulted from government science collaboration with industry because: 'With very few exceptions Australian industries are not in a position to make long-term commitments…' (Blakely, 1997, online).

Borthwick and Murphy described the difficulty for young scientists in Australia to establish a 'foothold in the scientific profession', particularly for those in research: 'An abundance of anecdotal evidence points to problems of low salaries and short term contracts which prevent young scientist from gaining job security and research continuity within Australia' (Borthwick & Murphy, 1998, p. 18).

In the same year a review[27] of health and medical research described the relatively low salary levels of researchers compared to full medical professors 'given the skills, training and possible alternative careers'. The failings of the grant system was also described: 'Lack of job security is a major issue for researchers who have to live with grant durations of rarely more than three years and uncertainty of renewal of a new grant. Researchers are often advised about

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[27] *'Health and Medical Research Strategic Review - The Virtuous Cycle - Working together for health and medical research'.*

the success or failure of a grant application only one or two months before an existing grant terminates' (Wills, 1998, p. 27 Discussion document). Employment uncertainty, 'the lack of a clear career structure and uncertain career prospects for contract staff are becoming more characteristic of life as a scientist in 'Australia, the UK and the USA'. These 'are major barriers to the recruitment and retention of high-quality research staff, and this in turn impacts negatively on research performance' (Bennet, Nicholson, & Gunn, 2005, p. 66).

Marceau and Turpin (2007a) observed how difficult it was for scientists, 'especially in the early stages of a research career' …'as most positions are short term and untenured' (ibid., p. 129). Salary was another issue: 'Scientists' positions are not among the best paid in Australia, which is perhaps not unusual in OECD countries, but the combination of position uncertainty and low pay must make many think twice about embarking on a career in scientific research' (ibid., p. 23):

> The short nature of many contracts, up to several, not just the first one, now offered both within universities and the CSIRO suggested a career in science research looks less attractive in relation [to] growing family obligations, the huge increases in the cost of housing and the salaries offered in competing sectors, notably finance where high-level mathematical skills are much better rewarded. (ibid., p. 30)

Lack of opportunities for mid-career researchers and the challenge of complying to an ever-growing body of regulatory requirements were other major issues for Australian researchers, along with insufficient investment in infrastructure and resources (staff, supplies, etc.) to build research capacity at an internationally competitive level (Department of Education Science and Training, 2006, p. 9)

The Productivity Commission suggested that scientists' job satisfaction could be increased through longer-term funding certainty; carefully designed performance assessment processes that rewarded higher performing institutions, research teams and individuals …and a level of academic freedom…'. The Commission also suggested the minimisation of non-research workloads; a suggestion that conflicts with calls for scientists to communicate with the general public (Productivity Commission, 2007, p. xxiv).

There is no shortage of awareness of the problems facing science and scientists in Australia. How successive Australian governments since the 1990s have responded to these problems with initiatives that have included science communication programs is outlined next.

National Science Communication Initiatives in Australia

There have been a number of Australian government initiatives over the last 20 years, and reviews of those initiatives, to understand and raise public awareness of science and technology through formal education and less formal avenues. These include publications by the Bureau of Industry Economics, (1995), Department of Innovation Industry Science and Research (2010), Gascoigne and Metcalfe (2001b), Rennie and Goodrum (2007) and Woolcott Research Pty Ltd. (1995).

In 1989 the Australian government established a national program to increase the public understanding 'of the important roles played by science, technology and innovation in all aspects of our life, and particularly in economic and social development': the Science and Technology Awareness Program (STAP) (Gascoigne & Metcalfe, 2001b). Two years later in 2001, under 'Backing Australia's Ability', STAP was replaced by the National Innovation Awareness Strategy (NIAS), a body with similar responsibilities (ABS, 2006c, p. 69). Part of the five-year, $35 million NIAS strategy was the science awareness component called Science Connections Programme (SCOPE) which promoted the benefits that science, engineering and innovation brought to 'Australia's continuing economic and social well-being' (ibid., p. 69). SCOPE aimed to establish the connection between continuing studies in science, mathematics and engineering beyond the compulsory years of schooling and associated career options (ABS, 2008c). This program was subsequently judged as 'successful in effectively reaching a number of target audiences which included youth, the general community, businesses, politicians and scientists' (ABS, 2006c, p. 69).

Rhetoric in government circles has continued about the need for better communication with the general public. For example, the Science, Engineering and Technology Skills Audit Steering Committee called for a building of Australia's science, research and innovation capacity for the future that included

better communication with the general public. The Audit Committee noted the need for workers in science, engineering and technology to have project management skills and improved communication as cross-disciplinary research increased (Department of Education Science and Training, 2006, p. 9). This need for better communication was in the context of promoting science, engineering and technology as a career among students, parents, industry and the community (ibid., p. 50).

In their background review for *Australian School Science Education National Action Plan 2008 – 2012*, Rennie and Goodrum (2007) described Australian Government programs designed to raise Australians' awareness of science and technology and ultimately engage the community with science and technology. This included the 'notable' Cooperative Research Centre (CRC) Programme: 'The CRCs are partnerships between universities, government institutions and industries focussed on Australian mining, agriculture, manufacturing, the environment and medicine' (ibid., p. 27). They also highlighted the importance of the two national organisations, CSIRO Education, and Questacon – The National Science and Technology Centre (Rennie & Goodrum, 2007, p. 27). Significantly however, the authors wrote that 'while interest in promoting community engagement in science continues, research findings about their effectiveness are rare and mostly equivocal' (Rennie & Goodrum, 2007, pp. 27, 29).

It is only relatively recently, since 2007, that Australia's two major research funding agencies (ARC and NHMRC) have stated that they aimed to improve the public availability of research results (Productivity Commission, 2007, pp. 232-233). Currently 'The ARC strongly encourages publication in publicly accessible outlets and the depositing of data and any publications arising from a Project in an appropriate subject and/or institutional repository.' The ARC provides up to 2 per cent of the total ARC funding awarded to a project, for publication and dissemination of project outputs and outreach activity' (Australian Research Council, 2010, p. 8). The NHMRC seems less committed; as it 'encourages researchers to consider [author's emphasis] the benefits of depositing their data and any publications arising from a research project in an appropriate subject and/or institutional repository' (NHMRC, 2011, online).

The Science for Australia's Future policy which replaces the ‘often fragmented nature of current initiatives’ in Australia, was agreed to in December 2009 by Federal, State and Territory Innovation Ministers. To underpin this, a national framework of principles for the funding of science communication, *Inspiring Australia: a national strategy for engagement with the sciences* was devised (Department of Innovation Industry Science and Research, 2010). It drew upon the contributions of 230 of the ‘Who’s Who’ of science and science communication in Australia through group discussions, workshop discussions and one-on-one conversations, and 22 written submissions. This strategy aimed ‘to build a strong, open relationship between science and society, underpinned by effective communication of science and its benefits’ (Department of Innovation Industry Science and Research, 2010). Funding for this new program was committed in 2010 (Department of Finance and Deregulation, 2010; Tune, 2010) [28], and began in July 2011 for three years. It included $2.4 million for a: new national hub for science and technology communication that ‘will coordinate the efforts of Australia’s research agencies, media outlets, universities, academies, professional bodies, the business sector, state-based science centres and museums and community-based organisations’ (Carr, 2011).

The *Inspiring Australia* report commented that many of Australia’s scientists ‘find it difficult to explain their work and its value to the general public’; it is not a performance expectation for most scientists ‘that they communicate science to audiences beyond their peers’, and ‘many scientists are not trained in media or general communication skills’. ‘Nor are there quick access online media training opportunities or similar resources to assist scientists to develop these skills’ (Department of Innovation Industry Science and Research, 2010, p. 67). This report succinctly described the attitude of science-based organisations in Australia toward science communication. They ‘tend to treat communication as an extra that can be reduced or dispensed with altogether in a tight budgetary situation’ and, ‘while there may be strong interest in undertaking and enhancing

[28] The profile for *Inspiring Australia* program will be $4.5 million in 2011-12, $4.5 million in 2012-13 and $12.0 million in 2013-14 (Marceau, et al., 2004, p. 12).

science communication at middle management levels, there may not be the same level of interest as senior management levels' (p. 67).

This may be so today, but there was a time when things were different. CSIRO's successful National Awareness Program was based on vision, experience, market research to understand their target audiences and evaluation to measure their success (Parsons, 1998). These audiences included not only those who read newspapers, watched television or listened to the radio, but also politicians and key government officials; the business, farming and industry press; industry organizations; overseas news agencies and journalists; and women's, general and specialist magazines (Parsons, 1998). This innovative programme, like a shooting star, had a stellar trajectory across Australia's science communication practice. While it had the strong support of CSIRO's senior management, it shone brightly for all to see between 1996─2002. Communication approaches and techniques developed and put to the test for this program have subsequently been extended by their creators to other Australian government departments and agencies (Cribb, 2011; Cribb & Hartomo, 2002; Parsons, 1998, 2001b, 2004).

Chapter Summary

The problem of poor communication between scientists and the public(s) identified in the first chapter, originated within an international culture that is masculine, competitive, male dominated (both in number and seniority), biased against women, and strongly self-regulating through peer approval and disapproval. While it is difficult to find evidence of how these cultural characteristics have inhibited or enhanced communication with the public, as compared with a more cooperative and gender-balanced, and less discriminatory and judgmental science culture, change on many fronts has been called for to improve scientists' communication with the general public. Journal papers, written for and reviewed by scientific peers, were and are the most important way for scientists to communicate their research findings and to progress professionally.

Cultural differences within science, between science disciplines, and between academic, government and business sectors organisations, have been found to exist. Significantly, some aspects of the international culture of science have

changed in recent decades in response to the increased importance of public opinion upon the conduct of and direction of science, declining public funding for research, and increased public accountability for the funds that are awarded through increasingly competitive, short-term grants. Many have argued that public support for science could be improved through a better communication between 'science and society' and there have been a small number of national science communication initiatives in response.

The culture of science in Australia has evolved to sustain itself within the context of declining Australian Government funding for R&D. The decades-long decline in federal funding has been offset to some degree by State and Territory funding in the emerging sciences, such as biotechnology, in recent years. The ever-present pressures on scientists to collaborate and commercialise, the increasing frequency of short-term employment contracts and contestable funds for research, however, have taken their toll on the recruitment of people to a career in science. Retention of scientists in jobs has also suffered because of poor job security, low salaries and a poor work-life balance. There are current and predicted shortages of scientists in an aging, gender-biased workforce where most science graduates are employed first in the public sector. Research has shown that there are many pressures upon scientists in their workplace to compete for academic recognition, funds and collaborators, while the funding for their science becomes harder and more time consuming to secure.

There have been many well-written, -researched and -intentioned reports and reviews in Australia about what has and could be done to improve communication between science and society. The effectiveness, however, of the few Australian Government science communication initiatives and programs funded over last two decades has been rarely assessed for impact or achievement against goals. Australian Government funding for research and programs to improve scientists' communication with the public has been limited, especially when compared to government and NGO funding in countries such as the United Kingdom.

Chapter 4 focuses on what was known about scientists' communication with the public until the time of this current study. It begins with an overview of research focussed on scientists' views and activities around their communication with the

general public. The rules for scientists' communication with the general public and the risks they take and obstacles they encounter are then described. Why, when and how scientists communicate with the public is explored, and what has been done to help scientists communicate more effectively is briefly described.

CHAPTER 4. SCIENTISTS' COMMUNICATION WITH THE GENERAL PUBLIC – THE RULES, RISKS AND OTHER RESTRAINTS

Introduction

Science is inherently a communicative culture (Merton, 1973, p. 33) and scientists communicate very effectively with other scientists within their own fields. This is because communication, especially but not exclusively through research publication, is the basis for an academic career in science. 'Paper publication in peer-reviewed journals is the only accepted form of communication of results that the scientific community engages in en masse' (Suleski & Ibaraki, 2010, p. 117).

Scientists' communication with peers is essential for professional recognition and rewards; and the advancement of scientific methods and knowledge, as will be discussed later in this chapter. Communication with the general public, however, has been an entirely different matter. In the United Kingdom, it was reported that, 'There is a widespread feeling that the communication of science needs to be improved and that the public would like more information on science and science issues' (MORI, 2005a, p. 12). According to the 2010 review by the InterAcademy Council of the Processes and Procedures of the IPCC[29], 'Scientists have long struggled to effectively communicate their findings to wider audiences (InterAcademy Council, 2010b, p. 47). Australian researchers, Metcalfe and Gascoigne reported in 2009 that, 'To many scientists the opportunity to discuss their work publicly is more a threat than an opportunity….But pressure on scientists to communicate [their message …succinctly and clearly] is mounting' (p. 41).

[29] The Intergovernmental Panel on Climate Change (IPCC) is the leading international body for the assessment of climate change.

Numerous other commentators such as Neidhardt (1993) have stated since the 1990s that communication between scientists and the public is poorly done (p. 340). As a result the public do not understand science, and do not get the information they want and need. Further, scientists do not understand the public. Analysis of the literature suggests that this problem can partially be attributed to the rules of communication with the public that are firmly entrenched in the culture of science. These rules evolved to protect and enhance the status and reputation of scientists, their employers, their scientific disciplines, the profession and scientific knowledge as a whole. They are taught to, or osmotically absorbed by, scientists during their training as students or as apprentices in the workplace, and are discussed in detail later in this chapter.

These rules of communication arguably have restrained or prohibited scientists from being more effective communicators. Inadvertently they have also set scientists up for criticism as poor communicators from almost everyone, it seems: the public, the media and their own political and scientific leaders. It appears therefore that these rules are losing their usefulness. In response to scientists' need for more public support (that includes funding), their failure to communicate effectively, and the publics' increasing desire to know and influence what is happening in science, the rules are being modified by scientific leaders in modern Western democracies. What is known about scientists' communication beyond the anecdotal is addressed in the next section.

Scientists as a Subject for Research

Public opinion about science, scientists and scientific issues has been a particular focus for researchers within the last decade (European Commission, 2001, 2005a; Harris Interactive, 2004, 2007 2008; Hipkins, et al., 2002; National Science Board, 2008, 2010; Office of Science and Technology and The Wellcome Trust, 2000; Woolcott Research Pty Ltd., 1995). As stated in 2001 by Market and Opinion Research International (MORI) in their study called *The Role of Scientists in Public Debate*:

> Research into the field of 'public understanding of science' has tended to focus on identifying and understanding the views of the general public towards science. Little effort has been made to understand how scientists

> themselves perceive increasing calls for them to become more involved in communicating their research to the public, and to increase dialogue on the social and ethical implications of this research. (MORI, 2001a, p. 1)

This observation about the paucity of research focussed on scientists was relevant five years later when Pitrelli, Brunelli and Murelli (2006) stated: ‘The dispute about science communication has tended to focus on public opinion and attitudes towards science and scientists’ (p. 173). These attitudes were generally perceived as negative. For example, researchers who asked the public about their image of scientists found that ‘students and some teachers often depict scientists as socially inept workaholic males (Losh, 2010, p. 372). Losh wryly commented that the portrayal by ‘public figures and media’ of ‘scientists as eccentric, obsessed, lonely workaholics’ would not increase personal respect for scientists or interest in science careers (ibid., p. 381).

Research about what scientists think and do, however, is much less common. In 1976 Mahoney wrote that, ‘we know very little about the behaviour patterns of scientists’ (Losh, 2010, p. 381; Mahoney, 1976, p. 172). Since then there have been a number of ethnographic studies of scientists and the culture of science including Latour (1987) and Charlesworth, Farrell, Stokes and Turnbull (1989). Often, however, these studies have focussed on the elite: the eminent, the productive or published, and the publicly recognised. Some research, for example, was based on interviews with eminent scientists (Roe, 1953; Rosser, 2004; Zuckerman, 1970, 1977) or those who were outspoken and publicly-recognised (Goodell, 1977). It also seems that many of these studies of scientists, especially those in the latter half of the 20th century, focussed upon or included physicists in particular as if they were the archetypal scientist who conducts basic research (S. Cole & Cole, 1967, p. 23). Because of their narrow focus on particular groupings of scientists, the findings of these studies may not, however, be representative of the majority.

Some research has examined larger groupings of scientists across disciplines such as three New Zealand studies in 1996, 2000 and 2008 that surveyed scientists and technicians about their concerns, their values relating to science and society, and their opinions on the performance of the New Zealand research,

science and technology system (Serio & Sommer, 2000; Sommer, 2010; Sommer & Sommer, 1997).

Research has also focussed on scientists' motivations to choose a career in science, such as the 2009 survey of 2,533 members of the American Association for the Advancement of Science (AAAS) and 2,001 public respondents. It was reported that 'an overwhelming share of scientists (86%) say an interest in solving intellectually challenging problems was very important. This view is widely shared across scientific specialties' (The Pew Research Center for the People & the Press, 2009, p. 45). This study also found that scientists' desire to work for the public good varied with their sex, age, disciplines and employment sectors. For example, women and younger (under 35) scientists were found to be more likely to have become scientists because of a desire to contribute to the public good. The survey also found that 'nearly half (49%) of those who work in the public sector identify working for the public good as a very important factor in their decision to go into science, compared with 45% working for non-profits and smaller percentages in academia (41%) and industry (38%)'. More applied scientists, compared with those involved in basic research, were found 'to attribute their career decision to working for the public good (48% versus 34%)' (ibid., p. 45).

Studies that have focussed specifically on scientists' communication with the public have increased over the last decade but are much less common. Bodmer and Wilkins (1992, p. 9) pointed out how limited the existing knowledge was about scientists' attitudes and noted the need to improve understanding of 'how we can best help and encourage more members of the scientific community to become involved'. Since this time a few relevant studies have been undertaken such as MORI (2001b) referred to earlier.

In a large 2008 study of French researchers, published after this current survey was conducted, the authors stated that, 'The interpretation of our results is otherwise not easy, as there have been few qualitative studies on the perception by scientists of popularization or voluntary teaching practices' (Jensen, Rouquier, Pablo Kreimer, & Croissant, 2008, p. 537). This review of the literature shows that scientists have very rarely been the subject for science communication research until perhaps the last decade. This indicates that the

many public declarations that scientists need to communicate more, and more effectively, as presented in Chapter 2 were generally made on the basis of very little, if any, empirical evidence about scientists' communication activities.

Much of the following discussion will focus on research (surveys, focus groups, interviews of scientists) conducted within the last 10 years to ascertain what is already known about what scientists think and do about communicating with the general public. But first, whether there are differences between scientists communication with the public in different countries will be reviewed.

In Australia

In 1994, Gascoigne and Metcalfe's described the organisations that delivered, funded and represented science and scientists in Australia. In writing about challenges for science communication, they were also implicitly writing about the culture of science in Australia in the 1990s. Although the culture has changed since the 1970s, it still needed to change further from the point of view of the 13 science communicators surveyed by Gascoigne and Metcalfe :

> There has been a growing pressure on the public purse [over the last 20 years] and this has led to increased demands for accountability ─ the demand for more relevance to national objectives, and bigger benefits to industry and other users. As science has come under pressure, scientists have become both more political and more ready to regard communication as a respectable activity…. The link between scientific achievement and national prosperity is gaining wider recognition.… Debate on the environment, nuclear issues and biotechnology have raised public interest in science, as a potential source of solutions ─ and a possible cause of the problems. We need to guard against presenting science as if all breakthroughs and developments are beneficial… We are aware of the dangers of presenting scientists as if they could do no wrong'. (Gascoigne & Metcalfe, 1994, p. 425)

They also recognised that the Australian science community needed to communicate the relevance of science, so as to enter the mainstream of public and political debate, and attract the best to study science at universities. 'Science needs to push the relevance message hard, to bring science into the centre of the

national debate ─ and it also needs an image change, to begin to attract the best and brightest of the university entrants' (ibid., p. 426).

These authors also foresaw that scientists would have to adjust to increasing 'interference in their work' from 'non-technical people' as 'The question of scarce resources looms over the future, and science is going to come under increased pressure to justify its existence'(ibid., p. 426).

Other researchers in Australia have focussed on scientists within a particular sector, such as the 2002 study of academics from 12 universities by Anderson et al. (2002) or on particular kinds of scientists, such as the 2003 online survey of 520 research scientists, across research fields and sectors, conducted to study their career patterns (Marceau, et al., 2004).

The little research that has been conducted specifically about scientists' communication with the general public has focussed on their communication with the media (Australian Science Media Centre & Australian Science Communicators, 2007; Gascoigne & Metcalfe, 1997; Metcalfe & Gascoigne, 2009; Morelle, 2005). One reason for this paucity of research, given in a 2005 report, was the difficulty of collecting data about communication other than that published in academic journals:

> Data relating to non-publication-based knowledge diffusion activity are not currently collected in the same detail as academic quality data are collected; and a greater focus on data that relate to non-academic impact is, however, now emerging[30]. (The Allen Consulting Group Pty Ltd, 2005, p. 52)

Research in two papers by Gascoigne and Metcalfe (1994, 1997) stands out, however, because of its relatively early focus on scientists' communication with the public, if not its sector-wide and discipline-wide coverage. The 1997 paper involved 178 scientists, most from CSIRO, and described factors that encourage or discourage scientists to communicate their work through the media. In a third

[30] 'For example, the range of diffusion data collected by the Victorian government for its STI initiative, under the headings of science awareness and collaboration, is reasonably extensive...'

paper that reported on an Australian survey conducted in 2007, Metcalfe and Gascoigne (2009) stated that the results of the survey of 446 self-selected scientists[31] indicated that: 'The majority of scientists have very little contact with the media; 40% of scientists feel they are either discouraged or not specifically encouraged to use the media, and only 35% of scientists have had media training'. The authors observed that, 'Most scientists feel that Australian scientists, in general, are sometimes discouraged from interacting with the media' (p. 44).

An indicative international listing of the studies and accounts of scientists, based on interviews, focus groups, surveys and their publication records, from 1995 – 2010 is presented in Table 1. As can be seen, there are few published studies that have been conducted of all scientists across fields and sectors in Australia to examine their attitudes toward communication with the general public.

In some ways, this gap is unexpected because it implies that the calls by Australian leaders for more effective communication between scientists and the community have been based, at best, on observation and anecdotal information.

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[31] This online survey was conducted by the Australian Science Communicators and the Australian Science Media Centre in 2007.

Table 1. Studies of scientists' communication with the general public

Australian studies are highlighted.

Year	Title	Country	Author(s)
1995	...the Contribution of Scientists and Engineers the Public Understanding of Science and Technology	UK	Wolfendale et al.
1997	Incentives and Impediments to Scientists Communicating Through the Media	Australia	Gascoigne & Metcalfe
1997	Profiles: a survey of New Zealand scientists and technologists	New Zealand	Sommer & Sommer
2001	The role of scientists in public debate	UK	MORI
2002	Changes in Academic Work: Implications for universities of the changing age distribution & work roles of academic staff	Australia	Anderson, Johnson & Saha
2003	How researchers view public and science	Sweden	Vetenskap & Allmanhet
2003	Science and policy: the view from the world of scientists	US & Canada	Alm
2004	Innovation agents & innovation tracks: The place of research scientists in the Australian national system of innovation	Australia	Marceau, Turpin & Woolley
2004	Hands across the water. Developing dialogue between stakeholders in the New Zealand biotechnology and debate	New Zealand	Cronin & Jackson
2004	Australian scientists survey conducted in 2003	Australia	Marceau & Turpin
2005	Consultation Report for the Australian Science Media Centre	Australia	Morelle
2005	Talking to scientists: the role of scientific knowledge in environmental policy-making – a case study in biotechnology and genetics	UK	Burchell
2006	Factors Affecting Science Communication: A survey of scientists and engineers	UK	People, Science & Policy
2006	Scientists' view about communication in the Italian context	Italy	Pitrelli, Brunelli & Murelli
2007	Scientists and science communication: A Danish survey	Denmark	Nielsen, Kjaer, & Dahlgaard
2007	Free to speak? A survey of Australian scientists and their interaction with the media	Australia	AusSMC & ASC
2007	Scientists' communication with the general public – an Australian survey	Australia	Searle (this study)

Year	Title	Country	Author(s)
2007	Science, Society, Ethics, and Trust. Scientists’ Reflections on the Commercialisation and Democratization of Science.	New Zealand	Small & Mallon
2007	CNRS researchers’ popularisation activities: a progress report Sept. 2007	France	Jensen & Croissant
2007	European research in the media: the researchers point of view.	Europe	European Commiss.
2007	Scientists And Public Debates: A case study of media comments…	Australia	Hayes

Scientists' Rules for Communicating with the Public

The cultural practice of scientists' communication with the public has evolved, more to protect and enhance the credibility and image of scientists, scientific institutions and the knowledge system of science as the sources of impartial knowledge (Marburger, 2005, p. 96), than to meet the needs of the public(s). This cultural practice is strongly entrenched in written and unwritten rules within the scientific community, especially amongst those who believe they have more to lose than gain from such communication. For example, Mitroff (1974) wrote that, '…it has long been an unwritten rule of science that you don't divulge what you're up to until you're 99% sure that you've got the competition beat in the race to print…' (p. 593)

Goodell's (1977) description of how the scientific community handled its desire to communicate with the public is more than thirty years old and was written about scientists in the United States. Nevertheless this account describes a professional science culture with an agenda to popularise science that influences scientists' communication with the public to this day.

Goodell listed six ways in which she believed the scientific community handled the conflict between long-range ambitions to inform the public and more pressing needs to concentrate on basic research. The six 'rules' are presented in Figure 2.

Figure 2. The science community's rules for communicating with the general public (Goodell, 1977, pp. 91-92)

Rule 1: He should confine his activities to the government advisory system if at all possible. The scientist who… perhaps once a month evaluates new research proposals for technological programs as part of a respected, selective elite, is fulfilling scientists' public obligation in the approved way.

Rule 2: The scientist would limit his public activities to a small percentage of his time. After all, research is his goal, and the rest is mostly distraction.

Rule 3: The scientist should try to postpone most of his public efforts until after his most productive years are over. Since it is also an adage of the scientific community that 'science is a young man's game,' an older scientist, especially a successful one, is allowed more time for public activities. Whether or not it is true, the adage becomes a self-fulfilling prophecy: during their life course of the typical scientist, the amount of time spent on research steadily decreases, and the amount of time on public activities, administrative duties, and 'gate keeping' functions (like refereeing scientific papers and distributing research funds) increases.

Rule 4: The scientist should restrict his public communications to those that can be considered in his 'area of expertise.' He is only an expert on subjects related to his PhD, no matter how much he may have studied other areas.

Rule 5: The scientist should confine his remarks and activities to those that will enhance the public image of science and its propensity to provide funding. Popularisation is better than politics, because it is safer and extols the virtues of science. As a corollary, the scientist, by all means, should not dredge up and expose controversies that are raging in the scientific community behind closed doors…. Whether political or scientific (if there is a distinction), controversies will detract from the image of science and scientist as objective and rational.

Rule 6: If the scientist feels he must express political opinions, he should keep them in the moderate range of the political spectrum, avoiding extremes…. In general, political activities that protect and enhance the scientific establishment are acceptable; those that threaten is, not surprisingly, are not. Since the scientific establishment is vitally connected to government and industry, activities that question the overall established structure of the nation in the long run are rejected.

Twenty years later, Gregory and Miller (1998) repackaged these same rules or 'strictures' which they described in the context of 'scientific tradition', and included references to scientists as 'he or she'. They also commented that these rules were 'largely at odds with the demands of the mass media' (p. 82). Once again we are told that 'the scientist-populariser …should popularise only when one's productive research life is over; stick strictly to a specific area of

expertise; act only to improve the public image of science, especially where funding may result; and avoid extremes of opinion'. They wrote that 'another unwritten rule of science popularisation is that a scientist must first establish a reputation as a credible researcher before he or she is entitled to communicate with the public'. Gregory and Miller also wrote that 'the popularisation of the particular piece of knowledge should happen only after… it had been published 'in the technical literature' (ibid., p. 82).

Contradictions and tensions remain to this day, in the scientific community's attitudes to popularisation or making scientific knowledge accessible and comprehensible to a wide audience. For example, Gregory and Miller quoted Bruce Lewenstein who suggested that 'the rules of appropriate behaviour with regard to popularisation are used self-servingly ─ they are stressed by scientists who want to criticise or limit other scientists' behaviour but are ignored by the same scientists with regard to their own behaviour'. Lewenstein wrote, for example, about the contradiction in the views of those scientists who do not popularise who 'see popularisation as something that would damage to their own career' but 'also think that other scientists use popularisation to advance their careers' (ibid., pp. 82-83).

Trench and Junker (2001) also recognised that, 'Communication beyond the boundaries of the scientific system was governed by implicit or explicit rules of professional conduct on speaking only about a recognised specialism and only after formal scientific publication' (p. 1). They observed, however, that 'the decision whether or not to engage in public communication and the manner and content of such communication were matters for the individual scientist, and thus wholly distinct from professional communication' (p. 1).

Different scientific leaders and prestigious scientific organisations began to modify the rules within the last decade, and in doing so, diffused their immutable power. For example, Leshner (2006) wrote about four important lessons that the scientific community had learnt 'after two decades of working on a respectful dialogue with the public to help assuage public fears about new areas of research' (online). These lessons echoed Goodell's, and Gregory and Miller's observations of the science establishment's rules for science popularisation; but went further to state that scientists should 'never insert their

personal values into discussions with the public about scientific issues' and that they should help the public to understand the nature of science. This new set of rules is shown in Figure 3.

Figure 3. AAAS lessons for the scientific community (Leshner, 2006, B20)

Never pit science against religion

Those two fields of inquiry are concerned with different domains and types of questions. Most mainstream religions generally coexist well with science, despite zealots in both camps. Evangelical atheists among our scientific colleagues are as intractable and harmful to genuine dialogue as are evangelical religious fundamentalists: Whether God exists is not a question that can be answered scientifically, and we should stick to our own area of expertise.

Never debate a known ideologue

That is really a corollary to the first lesson. Scientists are bound by data and their limits. Ideologues are not; they are free to say whatever they want. It is therefore nearly impossible for even the smartest among us to win a debate with an ideologue.

Protect the integrity of science

Credible scientists never contradict or go beyond the available data. We should never insert personal values into discussions with the public about scientific issues. When a scientist brings personal views into a supposedly scientific discussion his or her credibility as a source of neutral facts is automatically diminished no matter what a scientist believes about moral issues, if an opponent in a debate introduces values or beliefs, the scientists should disclaim any ability to comment on those issues as they are outside the scientific realm.

Be very clear about the nature of science

We need to help the public understand what is and what is not science: what scientific inquiry cannot cover, like the existence of God; what are data and what are not ─ "the plural of anecdote is not evidence" is a useful cliche here; and how the word "theory" is used differently in science and in common speech, so that evolution and gravity are equally "just" theories.

Go glocal

We also need to stop expecting people to come to us at our universities or conferences. Scientists have volunteered to meet with local religious groups, fraternal organisations, and school groups

Work with small groups for true interaction

An academic's normal tendency is to give a public lecture, then allow members of the audience to ask questions. But such events are only preaching to the choir ─ those people already interested in the topic. And public lectures can easily be taken over by zealots, who hog the microphone or intimidate more mainstream participants from speaking out.

Listen

The most important ─ and most difficult ─ lesson to learn is that public engagement involves genuine dialogue, which means both parties must listen and be willing to modify their own positions. Studies conducted for the Department of Trade and Industry, in Britain, have suggested that the public is very skeptical of so-called public engagement events. We have to mean it when we do it.

Leshner's lessons, 'Be very clear about the nature of science' and 'Go glocal', reflect the recent challenges in the United States to 'science' which now has to work harder to remain a respected voice in public discussions. Interestingly the second lesson, 'Protect the integrity of science' appears to be at odds with a guide produced in 1989 and updated in 1999 by other prestigious science organisations in the United States. This was called: *On being a scientist. A guide to responsible conduct in research* (Committee on Science Engineering and Public Policy, National Academy of Sciences, National Academy of Engineering, & Institute of Medicine, 1989, 2009). In this guide the authors recognised that when scientists 'become advocates on an issue, they may be perceived by their colleagues and by members of the public as biased'. They argued, however, that scientists, 'have the right to express their convictions and work for social change, and these activities need not undercut a rigorous commitment to objectivity in research' (Committee on Science Engineering and Public Policy, et al., 2009, p. 48).

In 2008, Australia's Science Minister, Senator Kim Carr, asked Australia's scientists to both 'put their emotions aside' and 'remember [their] humanity' as he described the rules of professional scientific conduct in the context of a society that funded science and expected 'a fair return on that investment':

> …Everybody here knows the rules of professional scientific conduct – think independently, put emotion aside, reject received authority, be faithful to the evidence, communicate openly. These are good rules – rules I wholeheartedly endorse – but there's one more I'd like to add – remember your humanity (Carr, 2008d).

These rules present a dilemma for scientists who, on the one hand, are advised to speak only to their area of specialist knowledge, and on the other hand are increasingly expected to compete for funding by presenting their findings in a broader and more relevant context for their public audiences. To do so means they have to first understand that context for themselves – something they often lack the time, confidence and expertise to do. For example, Cooke, Pieri and Robbins (2004) found in interviews with crop and food genetic modification (GM) scientists, that there was a:

> virtual absence of reference to concerns about the political and economic implications of GM, how policy decisions are made about it, the nature and speed of its implementation, or accusations of improper influence being exerted by governments, corporations will scientific bodies ─ even though these arguments for feature prominently in the anti-GM literature. (p. 445)

Scientists appear to be constrained in their communication with the general public – reluctant to involve ‘human interests’ and comment ‘about the conflicts that arise in trying to meet real human needs and values’ because the ‘official ethos of academic science systematically shuts out all such considerations’ (Ziman, 1998, p. 1813). Ziman memorably described the ‘official ethos’ that affected scientists’ communication: ‘In pursuit of complete ‘objectivity’ ─ admittedly a major virtue ─ the norm rules that all research results should be conducted, presented, and discussed quite impersonally, as if produced by androids or angels’. He also ironically observed that scientists’ selective use of Merton's norm of ‘disinterestedness’ certainly did not apply to their quest for knowledge or promotion of their own discoveries or the advancement of knowledge in general (ibid., p. 1813).

The dichotomy, of the detached public pretence and the private passions of the scientist, has long been recognised and psychological studies were published on the subject in the 1960s. For example, the public image of scientists that includes ‘coldness, remoteness, and objectivity’ as a reinforcement of the impersonal character and emotional neutrality, another of Merton’s norms, of science, ‘could hardly be further from the truth’ observed Roe (1961, p. 456) . She stated that, ‘The truth of the matter is that the creative scientist, whatever his field, is very deeply involved emotionally and personally in his work, and that he himself is his own most essential tool’ (p. 456). Scientists themselves have been shown to believe that this ‘naïve’ view of the scientist as ‘purely objective, emotionally disinterested scientists’ was only taken ‘literally and seriously by the general public or beginning science students’ (Mitroff, 1974, p. 588). Gieryn (1983) pointed out, however, that it is scientists who continue to present ideologies of science as ‘distinctively truthful, useful, objective or rational’ because they are ‘useful for scientists’ pursuit of authority and material resources’ (p. 793). ‘Especially when scientists confront the public or its

politicians , they endow science with characteristics selected for an ability to advance professional interests (ibid., p. 783).

Gieryn stated that, ‘Scientists have a number of ‘cultural repertoires’ available for constructing ideological self-descriptions , among them Merton’s norms, but also claims to the utility of science for advancing technology, winning wars, or deciding policy in an impartial way’ (ibid., p. 783).

Perhaps scientists feel reluctant, possibly with good reason, to break away from the norms of ‘disinterestedness’ and ‘emotional neutrality’ in the way they represent and present their science. They arguably use two of the three rhetorical appeals to persuade their audience of the truth of what they say. For example they use, consciously or unconsciously, rhetorical devices such as ‘logos’ and their status as scientists or ‘ethos’ to give their argument weight. But most seem to consciously shy away from the use of ‘pathos’ or an appeal to their audience’s emotions through what they say or how they say it, because it may undermine their status as experts or reliable source of logical information and argument.

The rules, guiding and detrimentally limiting the effectiveness of scientists’ engagement with the public, are becoming less clear cut as scientists’ need for public approval and support has increased in a world where these can no longer be taken for granted.

Failure to Communicate Well

According to Ziman (1998), scientists are taught the scientific attitude which he described as meaning, in practice, that scientific literature rigorously excludes ‘all reference to economic, political, religious or other social interests’. He believed that, ‘Academic scientists are taught to think of themselves as persons who know nothing, and care less, about social problems, who solve intellectual puzzles without reference to their practical significance, and who do good automatically by producing valid knowledge’ (p. 1813).

Scientists’ adherence to and enforcement of ‘the rules’, however, has begun to change, albeit slowly. Perhaps this slowness is because as Ziman (2000) argued, academic science was not designed for communication with the general public in the first place. In his words, academic science has no established machinery

for sharing its findings in larger communities, so it happens informally, by default (p. 113).

It appears these 'rules' are becoming less helpful to the scientific profession, especially where its members are more answerable to the policies and funding of their governments and employers, rather than their academic discipline. These changes are also occurring in response to assertions by many commentators over decades that scientists are poor communicators with the general public. For example, Weigold wrote in 2001, 'There is a widespread perception that scientists are not effective communicators, at least when the audience is the general public' (p. 172). A year later, Treise and Weigold (2002) summarised the situation when they wrote that, 'The writings of science communication scholars suggest two dominant themes about science communication: it is important and it is not done well' (p. 310).

From their survey and interviews that involved more that 1,400 scientists and journalists, Hartz and Chappell (1997, p. 8) observed that, 'Very few scientists are any good at talking to the public and/or the news media'. They concluded that a consequence of this was that 'American taxpayers really don't understand what their investment in research and development is buying because scientists themselves aren't explaining it' (p. 91). They attributed American taxpayers' lack of understanding to the 'inability of researchers to move from the jargon-filled laboratory into the "real" world' (ibid., p. xii).

Some commentators have suggested that scientists are not suited psychologically to communicating with the public because they 'are aloof, isolated from society, absorbed in their work, and uncomfortable in interpersonal and political situations'; they risk 'antagonising' their employer, losing their funding or their job (Goodell, 1977, p. 90); they are not adept at describing and characterising the nature of their work in a broader context; and therefore are 'not particularly well-equipped to engage in debate about the nature and status of science, and do not typically do a good job when it comes to controversies about the nature and status of science…' (Chalmers, 1999, p. 252).

For various reasons therefore, public leaders of science and scientists have knowingly or unknowingly challenged the rules of scientists' communication with the public. This resultant change, which had its beginnings more than 40 years ago, is gaining momentum in response to trends such as declining public

funding for scientific research, an increase in short term-employment contracts, greater public expectations that scientists communicate as a return on public investment, and a democratisation of science that includes greater public participation in the direction of science.

Scientists themselves are very aware of these public perceptions; that either they do not communicate with the general public at all, or they do it poorly. A focus group of Australian scientists and engineers believed that the public were critical of scientists' communication skills and narrow perspectives: 'The public see scientists as poor communicators with unrealistic expectations, and inward or narrow focus on what was important and that they are totally immersed in the detail of what they do' (Department of Industry Science and Tourism, 1996, p. 19).

Professor Dame Nancy Rothwell, Fellow and Vice President of the Royal Society, defended scientists, including herself, against criticism they were poor communicators. She believes that a 'great deal is expected [of scientists] - sometimes unfairly' and that they are also unfairly criticised as 'disinterested in discussing what they do or explaining their research, [refusing] to appear in the media and that when they do, they are tongue-tied, boring and unable to give a straight answer' (Rothwell, 2002, p. 139).

Recent commentary, however, suggests that these characterisations and criticisms of scientists continue to prevail and are of continuing concern to scientists:

> …we scientists are the cause of our own demise – most are not good communicators in the public domain and when we do speak we often speak over the head of our audience. From the public's point of view we can appear arrogant, reinforcing a public perception that we think we are a superior breed and would like to be 'a law unto ourselves'. (Edmeades, 2009b, p. 36)

Perhaps scientists' failures to communicate effectively are understandable. According to the National Science Board in the United States, 'There are few incentives — and in some cases, severe disincentives — for scientists to make their own work or that of others accessible through popular literature or the broadcast media' (National Science Board, 2000, p. 1). The 2006 survey of

academic scientists and engineers in the United Kingdom suggested why scientists did not communicate with the general public:

> The biggest constraint on [public engagement] activity is that it is not seen as part of the research job, much less an important part of the job. In large part this perception is driven by institutions' (and the research community's) pre-occupation with research and publication rather than education. (People Science and Policy Ltd., 2005, p. vi)

Despite the fact that 'Public engagement is acknowledged to be an increasingly important aspect of the scientific profession', Burchell et al. (2009) found that little was changing in the UK: 'at the same time, and in contrast to other core scientific activities such as doing science, teaching and clinical work – it is universally seen to be under-incentivised and under-rewarded, potentially detrimental to research, and professionally stigmatising' (p. 7).

Scientific leaders have nevertheless been overtly encouraging scientists' communication with the public since at least the 1990s. Gregory and Miller (1998) wrote that scientists 'are being told by the great and the good scientists that they have no less than a duty to communicate with the public about their work' (p. 1). For example, *The National Science Board Strategic Plan* identified public understanding and appreciation of science and technology, and public outreach by the science and engineering communities, as essential for successful science and technology policy that will benefit society (National Science Board, 2000, online).

Hartz and Chappell (1997) believed that the need for professional survival and funding, brought about by eroding public support, was behind this positive change toward communication with the United States public. Scientists had been 'jolted' from a complacency where their funding used to come 'without question' and they rarely had to explain 'the intricacies of their work to the public' within the 'climate of urgent support and ardent secrecy' that existed until the end of the Cold War' (p. xii).

In 2005 the International Council of Science stated that, 'Many professional scientific organisations are urging members to play a more active role in communicating their research results and their significance to the public' (International Council for Science, 2005, p. 18). It appears that this 'urging' has

yet to be successful. Claessons (2008), writing about European scientists, observed that, ‘Despite a growing interest among the European scientists in science communication and media reporting, Europe still lacks a genuine communication culture between the scientific community and the public’ (p. 35).

In a study of European research institutions, Neresini and Bucchi (2011) stated that, ‘public engagement functions are often still performed as a sort of “goodwill exercise” and as opposed to their more traditional and teaching duties, are not based or evaluated on any established indicators or standards’ (ibid., p. 64). They concluded that in the context of public engagement, ‘The concepts themselves of “success” and “positive outcome” appear ill-defined’ (p. 66).

There are also personal and professional risks, however, that silence scientists’ public communication and these are reviewed in the next section.

The Personal and Professional Risks of Communicating

Scientists can risk more than just criticism from their peers, their employer and the public, when they communicate. Edmeades stated that scientists risk losing their funding or their jobs or both by speaking out publicly against the wishes of their employer or funder (2009, p. 36). There are other personal risks, such as lost promotions for scientists who hold views or conduct research with which others disagree (Gascoigne & Metcalfe, 1997). Media reports of scientists, who have been abused and threatened for their views in recent years concerning climate change, animal testing, genetically modified organisms, stem cell research or the Large Hadron Collider[1], are evidence of these risks. For example in Australia in 2011 it was reported that:

> climate scientists from the Australian National University, the University of NSW, the University of Melbourne and other unnamed universities had been subjected to threats of violence, sexual assault or attacks on family members. (Creagh, 2011a, 2011b)

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[1] The Large Hadron Collider, located near Geneva Sitzerland, is world's largest and highest-energy particle accelerator.

The risk, however, that most frequently influences the public communication of most scientists, irrespective of their field of study or employer, is the professional risk of disapproval or other negative reactions that affect their reputation for reliability or their credibility with their scientific peers. As pithily observed by Cribb in a national radio broadcast: 'Indeed it sometimes seems to me that scientists are rewarded for publishing science - and punished for publicising it'. Cribb continued: 'There is a growing disconnect between the emphasis placed on scientific publication, as the main way forward in a scientist's career, and the delivery of the knowledge that they have generated to society' (Cribb, 2011, online).

Who punishes scientists for publicising their science? Their scientific peers do. According to Gascoigne and Metcalfe (1997) with regard to communication via the media: 'There is a concern that colleagues do not react favourably to scientists whose work receives media coverage' (p. 273). Tellingly, however, Gascoigne and Metcalfe found that scientists' concerns about colleagues' reactions declined with increased media experience. Nevertheless, that message of the value of gaining media experience does not seem to have overridden the fears that many scientists have of each other, as is explained in the next section.

Critical peers

Given the importance of peers to a scientist's professional standing and progress, fear of peer criticism is understandable and ingrained. As stated by Ziman (2000), a scientist's credibility:

> is so valuable as a long-term source of material support and social esteem that it is not to be risked for short-term gain. This is strongly emphasised in the education of scientists and their apprenticeship to research, and reinforced by a variety of social practices. (p. 160)

The following examples, presented in chronological order, show that this risk of criticism by peers has been of concern to scientists for decades; that it is not without justification, but may be declining as '…the science community as a whole is starting to acknowledge that it must interact with the public more fully' (Winston, 2009, pp. 22-23) and more scientists gain media experience.

In the United States Goodell (1977) observed research scientists' negative perceptions of their 'own' who were involved in public communication:

> …activities such as popularising [were] viewed as a little lowly, distracting at best, demeaning at worst. Popularising, administration, or other maintenance functions may be all right for the scientist who is past his prime, or who cannot make the grade in the laboratory, but they are not of a serious researcher. (p. 90)

Goodell also observed that the scientific community resisted the participation of the public in science and disdained those scientists who communicated with the public, stating that 'the scientific community is as uncomfortable about the democratisation of science communication as the rest of us are about some of the other effects of technology' (pp. 8-9). She observed that the visible scientists[2] 'are seen by their colleagues almost as a pollution in the scientific community ─ sometimes irritating, sometimes hazardous' (p. 9).

In Brockman's *The Third Culture: beyond the scientific revolution* (2006), Hillis described scientists' preference for keeping scientific controversies between themselves away from the public: 'There is a feeling in biology that scientists should keep their dirty laundry hidden…But it's also true that popularised is a pejorative term among scientists generally' (pp. 26-27). Some authors specifically described scientists' criticism as arising from professional jealousy. Hillis, for example, spoke about scientists' jealousy of those who communicated well: 'When you get somebody who's very articulate, like Gould or Dawkins, other scientists get a little bit jealous, because those two are explaining to the public the issues we're arguing about. That's particularly true in biology' (ibid., pp. 26-27).

Hartz and Chappell (1997) specifically referring to communication though the media, found that although most (72 per cent) scientists wanted the public to know about their work, quite a number (nearly 40 per cent) were: '…afraid of being embarrassed before their peers by news stories about their work' (p. 29).

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[2] The new visible scientists are visible to the general public primarily because of their 'activities in the tumultuous world of politics and controversy' (Tune, 2010).

They also reported the extreme reactions from judgmental colleagues that scientists could expect if they spoke though the media, giving the example of Sagan who was blackballed[3] at the International Academy of Sciences (IAS), almost certainly because of professional jealousy among his peers (p. 9). Some have called it the 'Carl Sagan effect': peers in the science community felt that he was spending too much time talking to the public and not enough time on his research. The authors quoted Lee Hotz, science writer for the *Los Angeles Times,* who recalled that 'many of the IAS members felt it was unseemly for him to be so popular, so well-spoken, to get so many lucrative book contracts'(p. 42). Hotz also cited Diamond at UCLA, as another example of a gifted populariser of science who was 'continually encountering bitter criticism from many of his scientific colleagues about his willingness and his ability to speak to the general public' (p. 42). Hartz and Chappell also described scientists' jealousy of the public profile of peers and the 'stuffiness in the scientific community with regard to media interaction' (p. 9) .

This concern about scientific peers is not unwarranted, as further evidenced by the statements of scientists who are popular with the public. Winston wrote revealingly of his ostracism from the scientific community in the 1990s because of his communication with the general public:

> When I started making science television programs, I was frequently accused of dumbing down. After the BBC transmitted The Human Body series 10 years ago, I was painfully ostracised at scientific meetings and at the Royal Society, even though the series was viewed by around 19 million people in its first weeks and widely used as teaching material in schools. (Winston, 2009, pp. 22-23)

In 2001, Weigold explained how the possibility of negative judgment and criticism from their scientific colleagues made scientists reluctant to 'go public'. The peer judgments he described all arose from the belief that peer-reviewed publications were the only way for scientists to share science. Any other communication with any other audience was apparently suspect: the 'broadcast

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[3] The National Academy of Science rejected the nomination of Sagan for membership.

media were trivial', 'the rewards of a media career can compromise a scientist's integrity', scientists should not have the time or the inclination 'to blow their own trumpets' and the public may 'distort', or 'get excited' about the wrong side of, the story. Weigold said that scientists apparently believed that 'scientists should be humble and dedicated to their work' (2001, p. 173).

Marburger, Science Advisor to the President of the United States and Director, Office of Science and Technology Policy, put it bluntly when he stated that a scientist risked being judged by scientific peers as a 'media tart' rather than a serious scientist (Marburger, 2005, online). In the United Kingdom, interviews with academic scientists and engineers revealed a split in scientists' opinions concerning critical peers, that was summarized as 'Public engagement is seen by some as a hindrance to career development, others see it as a potential way of standing out from the crowd and advancing a career. (People Science and Policy Ltd., 2005, p. 8):

> A further message that emerged was that public engagement was done by those who were 'not good enough' for an academic career; and that public engagement was seen as' light' or ' fluffy', and risked reinforcing the negative stereotypes for women involved in such activity.(The Royal Society, 2006a, p. 11)

Within the last decade, quantitative data has also been collected regarding scientists' views on peer criticism of communication with the public. The People Science and Policy study for The Royal Society found that: 'A fifth of respondents said that taking part in public engagement activities was perceived as a barrier to career progression by their peers' (The Royal Society, 2006a, p. 32) [4]. A study in Spain of scientists[5] participating in PCST-Madrid Fairs found that, 'According to some respondents, certain colleagues consider that those who

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[4] In the online questionnaire, 20% agreed that 'Scientists who communicate a lot are not well regarded by their peers' and 54% disagreed with this statement and 22% neither agreed or disagreed (Goodell, 1977, p. 4).

[5] This study was based on face-to-face interviews to 167 research practitioners (researchers, technicians, support staff and fellows) at the Spanish Council for Scientific Research (CSIC) who participated in the Madrid Science Fair in the years 2001 to 2004.

participated in this type of PCST event "have nothing better to do" or "aren't good enough for more important activities". The authors reported that, 'This is an opinion that extends to any activity other than carrying out funded research and the subsequent publication of results in prestigious international journals' (Martin-Sempere, Garzon-Garcia, & Rey-Rocha, 2008, p. 357).

According to a survey of media contacts of scientists in top R&D countries (United States, Germany, France, United Kingdom and Japan) in 2008, 'Possible critical reactions from peers' were considered important concerns for 42% of the respondents. A similar proportion (39%), however, found 'enhanced personal reputation among peers' to be an important outcome of media contacts (Peters et al., 2008, p. 204).

In 2009 Burchell, Franklin and Holden reported that a number of scientists in their study 'rejected the notion that scientists' participation in public engagement brings with it the risk of professional stigma or opprobrium (Burchell, et al., 2009, p. 61). Despite this, the authors concluded that there was a 'professional anomaly' because 'although [public engagement] is increasingly recognised as valuable to science in general, and as individually rewarding', they wrote that, 'public engagement activity is also seen to be potentially detrimental to a professional scientific career':

> Public engagement is acknowledged to be an increasingly important aspect of the scientific profession, yet – at the same time, and in contrast to other core scientific activities such as doing science, teaching and clinical work – it is universally seen to be under-incentivised and under-rewarded, potentially detrimental to research, and professionally stigmatising. (Burchell, et al., 2009, p. 7)

In summary, criticism by conservative and jealous peers has been shown to arise from a number of cultural beliefs such as scientists should not 'air their dirty laundry', blow their own trumpets or trust the media to report their science accurately. Serious researchers, apparently, do not spend their time communicating with the public nor risk their professional reputation by being seen as a 'media tart'.

Other Obstacles to Scientists' Communication

Adding to the risks, scientists have also identified other obstacles to their communication with the general public. For example, Woolley, President of Research!America, stated that polling conducted in 2001[6], 'affirmed what we've been hearing anecdotally for years'. Scientists are not involved in outreach because 'they do not know how to become involved', and 'they do not have time to participate in outreach activities'. She also said that researchers 'often choose not to talk about their work with neighbors, friends, and others who are not part of the research community because they feel those people are not interested in science or are hostile to it' (Woolley, 2002, p. 137).

The increasing prevalence of short-term work contracts and the threat of legal repercussions (and worse) if scientists breach national and commercial secrecy are other obstacles. On the one hand these obstacles appear to reward scientists for sticking to the rules, but at the same time they fly in the face of the rhetorical exhortations to scientists to communicate openly with the public that funds them. This is despite the fact that, for many scientists today, communicating science and technology to the public is growing into a recognized activity (European Communities, 2007, p. 3).

According to Felt (2003), several European studies have shown that these obstacles are a combination of social, cultural, educational and practical factors (p. 2). 'Many of these are barriers have been found within the scientists' workplace: employer sanctions, organisational policies, bureaucracy and protocols, lack of support from management, lack of funding and time for communication activities (European Communities, 2007, p. 16).

Another obstacle to scientists' communication is their employment on short-term contracts and workplace agreements. These are becoming the norm for scientists entering the workplace in Australia and elsewhere, as opposed to the tenure-track model with a permanent position at the end. This employment practice influences scientists' communication in a number of ways. For

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[6] in partnership with Sigma Xi, the scientific honorary society

example, Ziman wrote about the effect of short-term contracts on the open and timely publication of scientific knowledge. He stated that these contracts often present scientists ‘from disclosing all the results immediately’ if they choose to ‘share in the (potential) profit from a patentable invention’. Ziman argued that ‘the traditional mechanisms motivating prompt and full disclosure of research findings’ had been weakened in the current culture of science and that this created ‘serious personal and institutional dilemmas in the scientific world’ (Ziman, 2000, p. 115). Scientists on short-term contracts may be concerned that their contract may not be renewed if they incur their employer’s displeasure by expressing their views publicly.

Collaboration, commercialisation and competition are also obstacles to the scientific traditions of scientific openness and sharing, not only between peers, but with the wider community.

Secrecy

The idea of ‘science as part of the public domain is linked with the imperative for communication of findings’ according to Mitroff (1974). ‘Communism’ was one of Merton’s norms and this meant that ‘Secrecy was the antithesis of this norm; full and open communication [of scientific results] its enactment’ (Merton, 1973, p. 274)

The culture of science in the 20th century, however, was thrown into shape by war (Cribb & Hartomo, 2002; Hartz & Chappell, 1997) and secrecy was a necessity for successive generations of scientists working during the First and Second World Wars and the Cold War[7]. According to Hartz and Chappell (1997) ‘Many of the nation's most brilliant theorists and experimentalists have been engaged in top-secret government work for the majority of their careers. Under such circumstances, talking about their research is a criminal offence’ (p. 9). They observed, however, that whether scientists were doing defence work or not, they have ‘seldom been encouraged to share their discoveries with the

[7] The Cold War began in 1947 and ended in 1991.

general public'. 'The Cold War climate of secrecy still envelops nearly every discipline engaged in the drive toward discovery and creation' (ibid., p. 9).

National security concerns are obviously an issue for scientists working for government defence departments and agencies, but today, the more ubiquitous demands for scientists' secrecy are coming from commerce. Ziman (2000) believed that secrecy in science had less to do with defence and 'more to do with commerce, and control by corporate and political interests' (p. 116).

Cribb, stated that as a science journalist he has 'frequently encountered fisheries scientists, forestry scientists, biologists, medical researchers, ecologists and others employed on the public payroll being ordered to keep their mouths shut about some important discovery, insight or expert opinion' (Cribb, 2011). 'To speak or not to speak?' ─ that is the question that scientists thought they had the freedom to decide for themselves but those times, if they ever truly existed, have changed.

How secrecy has affected scientists' communication was described in 1997 by a high-level United States Roundtable[8]: 'Prompt and full disclosure of research findings' is prevented by 'publication delays, censorship, nondisclosure agreements, patent protection and the licensing of research tools'. This increased secrecy was attributed to increased collaboration between those with differing value systems, especially the involvement of industry and its reliance upon and control over university-based research. Competition for funds and promotions amongst academic researchers also contributed to this secrecy as did 'myriad legal and regulatory concerns'(The Government-University-Industry Research Roundtable, 1997, online).

The Roundtable described how competition 'for funding or in the race for scientific primacy' had caused researchers to withhold their results from a public that was interested or could use them. Commercial considerations had inhibited others who 'succumb to pressure from university administrators to maximize

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[8] The Government-University-Industry Research Roundtable was created in the mid-1960s in the USA. It was called 'Openness and Secrecy in Research: preserving openness in a competitive world'. It provides a forum for dialogue on science and technology issues among top government, university, and industry leaders, and is sponsored by the National Academies of Sciences and of Engineering and the Institute of Medicine.

patent royalties, or from industrial sponsors trying to protect trade secrets'. The free dissemination of research results had also been inhibited by 'some universities and their faculty [who] view research results increasingly as potential intellectual property that must be developed and protected…' (The Government-University-Industry Research Roundtable, 1997, online).

In Australia in the same year, it was observed that scientists were 'concerned about the increasingly commercial face of science' because 'the government is pressing research groups to raise funds from outside normal public funding avenues. Scientists see this as a potential source of conflict with the traditional function of research groups to offer impartial advice'(Gascoigne & Metcalfe, 1997, p. 272). These authors also saw evidence of a significant contradiction for scientists who were entirely or substantially funded by the government. On the one hand government required scientists to justify themselves in a public arena, because it was under increasing pressure to justify expenditure in an age of fiscal restraint', while on the other hand, their organisations wanted them to gain additional funding from industry, and this sort of funding often carries commercial agreements that preclude public disclosure (ibid., p. 266).

Ziman (2000) believed that secrecy in science signified 'increasing subordination to corporate and political interests that do not put a high value on the production of knowledge with the benefit of society at large'. He pointed out the irony of this situation as 'in the long run, it is precisely the openness of academic science, its respect for the communal norm and its grounding and reproducible empirical observation, that are the best guarantees of its practical reliability ─ for good or for ill' (Ziman, 2000, p. 116). There is evidence to show that scientists themselves do not like the restrictions imposed by commercial agreements. For example, Gascoigne and Metcalfe found in their 1997 study that Australian scientists regarded commercial agreements as a major obstacle to working with the media (1997, p. 267).

A New Zealand study of 21 scientists[9], a decade later, found that scientists felt 'muzzled' by commercialisation processes. 'The majority of interviewees held

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[9] The study of 21 scientists was based on 11 men and 10 women of different ages, seniority, disciplines employed by three Crown research Institutes and one university.

mostly negative attitudes toward the commercialisation of science' because 'The profit imperative was seen as leading to increased secrecy to protect intellectual property (IP) as a source of competitive advantage and wealth'. They expressed concerns about its effects on science quality, public good, public's perception of science, scientists' careers, and scientists' ethical behaviour. It obviously slowed down the flow of knowledge within the science community, let alone to the community outside of science, because of a 'reluctance to publish before patents were approved' (Small & Mallon, 2007, pp. 112 - 113).

Edmeades (2009b) described the censorship of 'commercially and politically sensitive science bureaucracies' on scientists' communication as the 'cone of silence that most scientists must now operate under or risk losing their funding or jobs – or both. There was a time when the concept of intellectual freedom was sacrosanct'. Edmeades also believed that scientists' communication with the general public was only permitted if it promoted their institutions: 'We can do public relations exercises for our institutions, but we scientists no longer adequately defend the values of truth, objectivity and impartiality'(p. 36).

It seems that not only are scientists often 'muzzled' by commercial concerns but they are expected, along with public relations people, to perform as required by their masters. Bauer and Bucchi (2007) explored two causes of this within the print media: the increasing private patronage of scientific research which displaced the logic of journalistic reportage with the logic of corporate promotion and the increasing adoption by scientific institutions of the strategies and tactics of corporate communication for image, reputation and product management (p. 1).

Pockley (2007) stated that in Australia, the spin of prolific media releases associated with commercialization of research eroded the reputation of scientists. He also believed that another response by organisations to the government-imposed imperative to commercialise research had been 'to recruit many PR operatives who are often placed in a larger marketing arm'.

In Australia, competition for government funding has placed pressure on university researchers, and directed how they communicate their research findings. 'Competition is the main instrument to control research quality in Australia' (Scott, 2004, p. 121). The Australian government's distribution of public funds through two main public research councils [ARC & NHMRC] is

determined in part by university performance in raising research income (60 per cent), attracting students (30 per cent), and the 'quality and output of publications' (10 per cent) (ibid., p. 121). As can be seen, this performance assessment does not include communication with the public.

A scientifically ignorant or critical public

A number of scientists believe that their communication problems with the public are due either to the public, or the 'messengers', such as the mass media, or both. For example, some studies have shown that scientists believe that there are problems with the public's lack of scientific knowledge and understanding of the how science is conducted or their 'scientific literacy'. Statements that the public is ignorant of aspects of the scientific endeavour can easily be found in the research literature, such as, 'The wider public has little idea about the kind of work that is performed and the precise nature of scientific and technological advances, their possibilities and constraints' (Felt, 2003, p. 2).

There is recognition that this lack of understanding of science can have both good and bad effects on the public's perception of the value of science and scientific knowledge. In controversies, for example, Felt suggested that the difference between the reality of science (e.g. that there often exists different legitimate interpretations of data and different models of explanation) and the politically powerful image of science (as a producer of 'objective knowledge' that eliminates uncertainties) created serious problems. In some circumstances: 'Public perception of science can rather unexpectedly shift from support and admiration to refusal and fear'.

In a recent survey by the Pew Research Center[10] (2009), it was found that 'the majority of scientists consider the public's lack of scientific knowledge to be a major problem for science':

> While the public holds scientists in high regard, many scientists offer unfavorable, if not critical, assessments of the public's knowledge and

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10 This survey was conducted in partnership with the American Association for the Advancement of Science (AAAS) and surveyed their members.

> expectations. Fully 85% see the public's lack of scientific knowledge as a major problem for science, and nearly half (49%) fault the public for having unrealistic expectations about the speed of scientific achievements. (p. 55)

Several years before, however, Yankelovich (2003) was very critical of 'Science's assumption that scientific illiteracy is the major obstacle' to closing the gap between science and society. Therefore the solution was:

> …to do a better job at science education and so bring nonscientists around to a more scientific mindset. This assumption conveniently absolves science of the need to examine the way in which its own practices contribute to the gap and allows science to maintain its position of intellectual and moral superiority. In addition, on a purely practical level a superficial smattering of scientific knowledge might cause more problems than it solves. (Yankelovich, 2003, online)

Yankelovich warned the American scientific community that it was their own belief ─ that the goal of engagement was to raise scientific literacy ─ that was contributing to this gap, not the scientific literacy of the public. He advised scientists to move beyond their assumptions and recognise that, 'Citizens do not need to be second-hand scientists. But they do need to be able to make sound judgments about science policy choices, ranging from global warming and genetically modified foods to nuclear proliferation and human cloning' (ibid.online) .

Page, co-founder and former CEO of Google, observed at the AAAS annual meeting in 2007 that despite the importance of science, this was a marketing issue: 'If …all the growth that's happened in the world is due to science or technology or whatever you want to call it, and nobody really pays any attention to you, then you have a serious marketing problem' (Ham, 2007, online).

It has also been suggested that scientists may not welcome communicating with those who disagree with them:

> …dealing with dissent in dialogue with stakeholders may not always be easy for scientists who may question the competence of stakeholders and emphasise their own 'scientifically' based judgement. Conversely stakeholders may end up confirmed in their

> views that scientists live in a different reality ─ often in the so-called 'ivory tower'. (Welp et al., 2006, p. 173)

Rier (2003a) writing about scientists in fields directly relevant to the daily lives of the public, said that they face an additional set of risks and benefits if their publications are widely distributed. For example, 'audiences beyond the formal scientific community may accord more weight to a published study than do the study's authors, treating preliminary claims as definitive facts' (p. 272).

Some United Kingdom scientists and engineers were also found to believe that their research was too specialised to be of interest to the general public. The 2006 *Factors Affecting Science Communication* survey found that there were two distinct attitudinal groups[11] within the overall sample, although the difference between them was small. There were either those who 'felt that their research was interesting to the non-specialist public[12]' or those that 'felt that their research was too specialised to make much sense to the non-specialist public' (People Science and Policy Ltd., 2006a, p. 43).

Scientists have also been reported as having particular perceptions about interest and trust that arguably affect their communication with the public. In a Swedish study by Vetenskap and Allmanhet (2003), it was found that many researchers doubted that the public was interested in research; only half of the researchers believed that people in general think it is important to fund research, and only half of the researchers believed that people in general were interested in research in their subject. In spite of this, they felt that the public trusted researchers (p. 9).

Irwin has been quoted as saying scientists did not trust the public: 'Too often, scientists appear to fear and reject public opinion, criticising the public for a lack of trust in science without scrutinising their own lack of trust in the public' (Mellor, 2008).

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[11] The distinction was small and therefore not used in further analyses (The Royal Society, 2006a, p. 32)

[12] 'By this we mean adults with no specialist knowledge of, or training in, science'.(People Science and Policy Ltd., 2006a, p. 26)

Lack of funding and support

All the obstacles reviewed so far have limited scientists' communication with the general public. The lack of funding for communication has also been shown to be both a barrier and an incentive to communicate with that public, because of concerns about increasing, maintaining or acquiring public funds for research.

Goodell (1977) identified a relationship between public funds and scientists' attitudes toward communication with the public in the 1970s and stated that, 'Without public goodwill, research freedom and funding are in jeopardy'. She wrote that 'the scientific community is a morass of conflicting and changing attitudes on the subject of communicating with society' (p. 90) but observed that, 'it is fairly well accepted today that scientists must do some public relations work, some popularising, in order to loosen the public purse strings. This view increases as funds decrease and fears of anti-science sentiment grow. Scientists, previously afraid they would be misunderstood if they were involved with popular communication, now find they are misunderstood because they are not' (p. 90).

In Australia, it appears that many institutions are more concerned about controlling the message and the image of their scientists' public communication than facilitating a greater public understanding of science. Morelle (2005) reported, from her interviews with 30 Australian news editors, science and medical journalists, scientists, communication officers, and science communicators that, with the exception of medicine, scientists commented that their communication with the media was controlled by their institutions:

> Many believed that the increasing commercialisation of science, increased pressures over funding, or government links - all creating an increased need for "good PR" – were placing restrictions upon scientists when it came to speaking openly to the media either about their own research, the research of others, or even broader issues around science itself.

These institutional restrictions had led to:

> communication officers keeping a very tight grip on their scientists and on their freedoms to speak to the press. (Morelle, 2005, p. 11)

Pockley (2007) was critical of the heads of Australia's scientific organisations for their lack of leadership for communication of science through the media. He stated that 'few do more in public than worry about financial constraints, extol the virtues of their latest restructuring or defend their organisation when challenged publicly over some alleged failing'. Pockley asserted that this lack of leadership by example 'in promoting trust in science', meant that 'research scientists down the line do not see a career benefit for them in engaging in broader communication initiatives than merely fronting up for a quickie interview in support of a media release. Indeed, they are more aware of the potential internal perils of doing so' (p. 28). Perhaps it is not surprising then, that many scientists identify a lack of time as an obstacle to this communication. This is discussed in the next section.

Lack of time

Scientists need time to conduct research. There are many descriptions of scientists as busy people who lack time to communicate with the general public. Gascoigne and Metcalfe (1997) suggested that this was 'related to the way in which scientists performances are measured' because 'As long as scientists feel that they would be better off spending time on preparing formal publications and that their employers do not value efforts in media work, they will give the latter activity a low priority in crowded personal schedules' (p. 279). In 1997 the particular need for 'time – even years' by academics, as opposed to other scientists, to create databases and 'to explore and to analyse that information and to prepare publications' was explained. 'In such cases, premature public release of such information could deprive researchers of the benefits of their own labor' (The Government-University-Industry Research Roundtable, 1997, online).

Four years later in the United Kingdom, time was also identified by scientists as a constraint to their communication: 'Many scientists feel constrained by the day-to-day requirements of their job, leaving them with too little time to communicate or even to carry out their research' (MORI, 2001b, p. 4). Rothwell (2002) also expressed the sentiment that scientists do not have enough time to do what they are trained and employed to do, let alone communicate with a public that may not understand or is critical:

> Scientists are trained and employed to do research, not to appear on TV or talk to schoolchildren. We are already very busy and often have difficulty communicating with our scientific peers, let alone to an audience who may have had no formal scientific education after leaving school. Some aspects of science (e.g. research on animals) can bring unwelcome attention and actions. (p. 139)

The UK survey, *Factors Affecting Science Communication: A survey of scientists and engineers,* asked academics to indicate what was stopping them 'from getting (more) involved in activities that engage the non-specialist public in science?' 'Most (64%) selected that 'I need to spend more time on my research'; 43% selected 'I need to spend more time getting funding for my research'; and 34% selected 'I would have to do it in my own time'. The researchers commented that these selections showed that it was pressures from research activities that were against respondents 'doing more public engagement work' (People Science and Policy Ltd., 2006a, pp. 39 - 40) .

Edmeades observed three years later how much scientists were required to do to be accountable for public funding and that this left them little time to communicate with the public:

> '…modern scientists are overloaded with work they despise: preparing proposals with all those make-believe costs and benefits, completing milestone reports, annual reports, reviews, etc. It is endless and there should be small wonder that there is little time or energy left to help the public. (Edmeades, 2009a, p. 19)

In summary, it is evident that for at least the last 15 years, and in a number of countries, scientists' communication with the public is not a priority use of scientists' time and that includes the media.

The media

In 1997, Hartz and Chappell wrote that 'Until recently, most scientists thought it was superfluous at best and a waste of time at worst to talk to a newspaper or television reporter...' (p. 9). The public was obviously of little interest to scientists even though the mass media are most commonly the messenger (albeit one that may change the message on route) between them and the public.

Evidence of scientists, taking a shot at the messenger, however, is not hard to find. For example, in 1997, American science writer, Franklin wrote, 'Scientists are forever complaining that they are misunderstood and misrepresented, and I agree'. It is therefore ironic that the media is so important to science's communication with the public: 'While the benefits and desires for communicating science to the public are widely accepted, the primary responsibility for communicating science to the public rests on the shoulders of the news media' (Suleski & Ibaraki, 2010, p. 118).

In Europe, three recent studies of scientists and the media seem to indicate a more positive attitude to the media than in Australia today or previously thought of in Europe. The study by Nielsen et al. of Danish academics found that:

> …our survey and the British one [Government Office for Science United Kingdom, 2007] both indicate that scientists … critically and constructively evaluate the news media as a very important channel for communicating with the public. In other words, scientists are happy to appear in the news media, and seemed to be well aware of both the dangers and the benefits of reporting science through this medium. (Nielsen, et al., 2007, p. 10)

In a second survey, which involved 100, mostly senior researchers[13], the key findings were that scientists were motivated to communicate with the media because they felt accountable to, and wanted to inform, the taxpayers who indirectly supported their research. They were also motivated to communicate with the media to provide 'information to correct or avoid misconceptions of science…particularly given their fear that scientific information is sensationalised if not provided by trustworthy sources' (European Communities, 2007, p. 7). The study concluded that between scientists and the media, 'the relation [sic] seems to be regarded as better than it is commonly understood to be' (European Communities, 2007, p. 6). It also found that researchers recognised the 'need for scientists to be more open towards journalists and

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13 These researchers represented many scientific fields and nearly all EU27 member States and the results were based on in-depth telephone interviews

media in general' and commented on the favourable impact of the Internet on 'the communication of science and its relationship with the media':

> '…The big jump ─ according to many ─ was caused by the Internet, which strongly accelerated the pace of science and research by making it easier to obtain and disseminate information on nearly every topic and thus by stimulating scientists to communicate outside their usual circles. (p. 25)

The authors of a third study, which included researchers from France, Germany, United Kingdom, Japan and the United States, 'challenge[ed] several of many negative impressions of science-media interactions that are still all too common'(Peters et al., 2008). On the basis of their survey data, from 1,354 researchers[14] across five countries and two research fields, they found that:

> … interactions between scientists and journalists are more frequent and smooth than previously thought. The five countries survey also suggested that the scientists most involved in these interactions tend to be scientifically productive, have leadership roles, and ─ although they consider concerns as well as perceived benefits ─ that they perceive the interaction to have more positive than negative outcomes.

The authors found that the basic patterns were 'surprisingly similar' across the five countries and suggested that, 'The functional necessity of public science communication may be a global phenomenon in democratic knowledge societies' (ibid., p. 205). Comparing survey results from large-scale US and UK surveys in 1999 (The Pew Research Center for the People & the Press, 2009) and 2005 (The Royal Society, 2006a), Besley and Nisbet (2011) concluded that: 'Scientists are critical of media coverage generally, yet they also tend to rate favorably their own experience dealing with journalists, believing that such

14 The 2005-2006 study involved 1,354 researchers (who had published during 2002─04 in peer reviewed journals) compared scientists' public communication attitudes and activities in the fields of epidemiology (648 epidemiologists) and stem cell (706 stem cell researchers) research in the United States (n = 358), Japan (n= 239), Germany (n=283), United Kingdom (n= 281), and France (n=193).

interactions are important both for promoting science literacy and for career advancement. (p.1)

Suleski and Ibaraki (2010), however, made the point that very little of the research that is published is ever communicated with the public: 'The high volume of output and scientists' strained relationship with media coupled with the small number of science journalists, all contribute to limit the flow of output to the public' (pp. 122-123).

Australian research, over the last decade and a half, seems to indicate that the necessarily symbiotic relationship between scientists and the media is improving, but scientists have also been critical of the media. For example, a focus group of Australian scientists and engineers in 1995 believed that, 'The media's coverage of scientists' achievements is often over-hyped and does not portray the underlying research' (Department of Industry Science and Tourism, 1996, p. 19). Gascoigne and Metcalfe argued in 1997 that this relationship would benefit from scientists having a better understanding of the media:

> Not every scientist has the personality or the inclination to work effectively with the media, but some basic understanding of the processes takes on a new significance in today's world of increasing demand for public accountability for scientists working in government-funded organizations. (1997, p. 278)

In 2005, Morelle reported, however, that science was sidelined in the Australian media:

> On the question of whether scientists thought that they should be engaging with the news media, the general conclusion was that many had some reserves about the media but on the whole thought it was important to engage. There was a question by some whether fellow scientists were being proactive enough when it came to talking about the big issues within science…(Morelle, 2005, p. 9)

Pockley (2007) described the paucity of scientists who were recognised by the public in Australia:

> …Recognition by scientists of the need to communicate their case better is welcome. But the number of scientists whom the public

> would be able to name and recognise as frequently expositors of science and debaters of issues involving science can probably be counted on one hand. (p. 28)

He also pointed out, however, that there were few opportunities for scientists to hone their communication skills in the media because: 'Mostly, scientists appear in the media in short grabs – only a 'few words [are] allowed in these outlets'. He added that, 'The more talented among them seldom have wider opportunities to hone their skills and become recognised popularisers' (ibid., p. 28).

It appears, from the 2007 survey of scientists and the media, that a small majority (55%) of Australian scientists were having 'mostly positive' experiences with the media according to an online survey (Australian Science Media Centre & Australian Science Communicators, 2007). Those who did not have this view were deterred from speaking with the media because they were concerned about inaccuracies, misquoting and over-sensationalism of their research (Metcalfe & Gascoigne, 2009, p. 42). The authors concluded that Australian scientists are also deterred by 'a lack of experience or training and lack of time to prepare for interviews' (p. 43).

Chapter Summary

This review of the literature reveals a plethora of impediments preventing or negatively affecting scientists' communication with the public. These obstacles range from the rules enforced by the scientific community to protect and enhance the profession, critical peers; the communication constraints upon the profession enforced by collaboration, commercialisation, competition and short-term contracts; and scientists' beliefs about an ignorant, disinterest, distrustful or critical public. There is also an often uneasy alliance between scientists and journalists, whom scientists fear, or expect, will include inaccuracies and misquotes in the presentation of their research, or over-sensationalise it.

It seems that the obstacles imposed by the science profession have been added to within the last decade by the employers and funders of scientists, and a more questioning and a less deferential public. With all these obstacles in their way, why do scientists communicate with the general public? This will be discussed in the next chapter.

CHAPTER 5. SCIENTISTS' COMMUNICATION – WHY, WHEN, HOW AND WHAT WOULD HELP

Why do Scientists Communicate with the Public?

Researchers such as Pearson, Pringle and Thomas (1997), Gascoigne and Metcalfe (1997), Gregory and Miller (1997), (European Communities, 2007) and Martin-Sempere, Garzon-Garcia, and Rey-Rocha (2008) have described scientists' motivations to communicate with the general public. These include feelings of accountability to the taxpayer; a desire to educate and inform the public, to share knowledge and learn; a public duty, a need to maintain or increase public funding, a desire to promote their area of research, gain public approval or to recruit new scientists and science students. Martin-Sempere et al. (2008) found that 'The motivations of the participants seem to reflect something more than the simple desire to communicate scientific knowledge' and 'the most important motivations were related to the desire to stimulate the public's interest in and enthusiasm for science, to increase the public's scientific culture, and to enhance public awareness and appreciation of science and scientists' (pp. 360-361).

Responsibility and duty

The social responsibility of any profession, according to Frankel (1989), is part of a negotiation process that is based on the tension 'between the professions' pursuit of autonomy and the public's demand for accountability':

> Society's granting of power and privilege to the professions is premised on their willingness and ability to contribute to social well-being and to conduct their affairs in a manner consistent with broader social values (p. 110)

Over the last four decades, those who have written about the specific responsibility of scientists to communicate with society have included scientists themselves. For example, in 1971, Brown described the 'new' relationship

between government and the scientific estate to his fellow psychiatrists and stated that[15] scientists had a responsibility to inform the public: 'The scientific estate must become public informer and educator by initiating the objective dissemination of its specialised knowledge and information to a deserving, interested and sometimes confused public' (Brown, 1971, p. 228).

Goodell (1977) was much more cynical about the sincerity of the science community's increasing sense of social responsibility, linking this with 'public anti-science feeling, job shortages, funding restrictions, and technological dilemmas': 'Sceptics question whether the new sense of social responsibility runs very deep in the scientific community' (pp. 96-97).

In the United Kingdom, the word 'duty' has often been used, rather than 'responsibility'. For example, the *Bodmer Report's* directives to the scientific community stated emphatically that communicating with all segments of society was a scientist's personal duty: 'Our group, though certainly not exclusively scientific, was a product of the scientific community, and so it is appropriate that our most direct and urgent message is for the scientists — learn to communicate with the public, be willing to do so, indeed consider it your duty to do so' (Bodmer, 1985, p. 24).

The working group pointed out that scientists often excluded themselves when considering who should communicate with the public and paraphrased scientists' views as follows:

> After all, scientific research is what scientists are good at, what they are paid to do and what should have first claim on their attention. Communicating science to the lay public is not easy and, it may be thought, should be left to those whose full-time job it is. [such as professional science writers]'. (ibid., p. 24)

The group also recognized that 'within the scientific community there is still often a stigma associated with being involved with the media' despite the fact that 'some outstanding research scientists have also been outstanding

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[15] in addition to the scientific community adapting to a significant cutback in Federal funding of research.

popularizers'. Nevertheless, despite the demands of scientific research on scientists' attention and the stigma they associated with communicating with the lay public, the working group clearly stated that 'scientists as a whole had the responsibility to speak to the lay public' and the attitude held by scientists that communicating science to the lay public should be left to others was 'no longer appropriate, and probably never was'….'It is clearly a part of each scientist's professional responsibility to promote the public understanding of science'(Bodmer, 1985, p. 24).

Ten years later, the Wolfendale Report stated that publicly-funded scientists, engineers and research students had a duty to communicate with the general public, although perhaps not all. 'Wolfendale recognized that not all scientists would be equally skilled at communicating to a wider public but suggested that extreme cases of inability to communicate are likely to be few' (Pearson, 2001, p. 135). There are, nevertheless, any number of idealistic assertions by scientists that all scientists have a responsibility to communicate their scientific knowledge with those who have an interest in knowing or using it. It was in 1997, as discussed in Chapter 2, that Lane promoted the concept of the 'civic scientist' and said that public outreach was among the professional responsibilities of scientists and engineers (Lane, 1997).

In the same year, the summary of the ideas exchanged at a Government-University-Industry-Research Roundtable[16] ended with the following reminder of a scientist's duty: '…working scientists must acknowledge that their private privilege to seek the truth implies a personal duty to serve a broader public interest' (The Government-University-Industry Research Roundtable, 1997).

In the United Kingdom, research found that 'the vast majority scientists believe it is their duty to communicate their research and its social and ethical implications to policy-makers, and to the non-specialist public' (MORI, 2001a, p. 3). More specifically 84% agreed that 'Scientists have a duty to communicate their research and its implications to the non-specialist public' (MORI, 2001b, p.

[16] The Roundtable was called 'Openness and Secrecy in Research: preserving openness in a competitive world.'

21). The majority also felt that among the groups who communicate science, scientists should be the major contributors:

> Seven in ten scientists feel that they themselves should have the primary responsibility. Scientists who feel equipped to communicate their research, and those aged 45+ are more likely to say that scientists should bear the main responsibility. Scientists do see other groups as having similar responsibilities in this area, namely funders of scientific research (46%), specialist science communicators[8] (42%, as distinct from journalists, marginally behind at 39%), and the government (40%). (ibid., p. 7)

Gascoigne and Metcalfe had earlier found that media experience influences the views of scientists as to whose responsibility it was to communicate with the general public. Based on information collected through 10 focus groups and from 92 (mainly CSIRO) scientists through a mail questionnaire, they wrote that:

> 'Media-experienced scientists feel that the responsibility for 'getting the message out' is their own. They tend to wish to continue their "hands-on" involvement but also are more likely than their inexperienced colleagues to ask for assistance from communications specialists. They see the role of the communicator as being very important, partly for their role in coordinating media output' (Gascoigne & Metcalfe, 1997, p. 274).

In contrast, 'The untrained group generally felt that it is their organisation's responsibility, not their own, to get stories into the media. They are more ambivalent about the role of communicators, with some seeing them as important and others seeing them as a hindrance …' (ibid., p. 274).

In 2002 Rothwell stated unequivocally that scientists had a responsibility to 'disseminate and explain what [they] do and discover, the implications and applications of our research and the potential benefits, and being honest and open about potential disadvantages or failures'(p. 137). It is also interesting to note that Rothwell wrote that the responsibilities of scientists to society at large had changed significantly since the early 1990s for several reasons, including 'the public becoming more aware, more knowledgeable and often more

concerned about the impact of science and technology on their lives'. This meant that scientists could no longer 'work on whatever they chose' without responsibilities to non-scientists (ibid., pp. 137-138).

In the following year in Sweden, it was reported that eight out of 10 Swedish researchers believed that dialogue with the public is an obligation of every researcher (Vetenskap & Allmanhet, 2003, p. 21). Leshner (2005b) wrote that scientists 'must take some responsibility for the uses of science and how it was portrayed to the public' (Leshner, 2005b, p. 221).

In 2006 the Federation of Australian Scientific and Technological Societies (FASTS)[17], developed a policy on scientists' responsibility to communicate publicly-funded scientific research. It declared that communication of science was 'a responsibility both of scientists, and of government' (FASTS, 2006, online).

In the United Kingdom, in the same year, the Royal Society clearly stated that scientists' have two responsibilities for communication with the general public, within both the public and private sectors:

> The first is to attempt an accurate assessment of the potential implications for the public. The second is to ensure the timely and appropriate communication to the public of results if such communication is in the public interest. These twin responsibilities ought to be embedded within the culture of the research. (The Royal Society, 2006b)

These strong statements draw, no doubt, upon the 2001 MORI report discussed earlier in this chapter. The beliefs were also incorporated into a United Kingdom government initiative *Rigour, Respect and Responsibility: the Universal Ethical Code for Scientists*[18] (King, 2007, online).

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[17] FASTS represents 60,000 working scientists and technologists and promotes the views of working scientists and technologists on a wide range of policy issues in government, industry and the community.

[18] 'By scientists we mean anyone whose work uses scientific methods, including social, natural, medical and veterinary sciences, engineering and mathematics'.

In a 2007 Danish survey, participants were asked ‘Who ought to have the main responsibility for “disseminating knowledge about scientific methods and results” from the universities to the public’. ‘Nearly half of the respondents (43%) preferred that the scientists themselves aught to handle the universities obligations to report scientific results. More than 54%, however, would prefer the responsibility be placed elsewhere (e.g. separate communications departments, administration of faculty, institute or department, university administration. Almost 4% preferred that scientists equally share the responsibility with a communication staff, placed in separate communications departments[19] (Nielsen, et al., 2007, p. 7).

Hayes (2007) wrote in a review of the literature that: ‘there is broad acceptance amongst scientists that they bear some social responsibility to participate in society, with public debates being one mode of participation’. She found, however, that: ‘Involvement in politics, via public debates, was more contentious, with the literature indicating it is still a minefield for scientists. Scientists are considering internal and external judgments on their objectivity, status and appropriate role in politics before engaging in political debate’ (p. 75)

Carr, Australia’s Science Minister, spoke several times in 2008 about scientists’ responsibilities, obligations and rights within publicly-funded research institutions (Carr, 2008d). In February 2008, for example, he spoke about scientists’ responsibilities to communicate:

> Scientists' responsibilities go to the society and the country in which they live, and which provides them with financial support…The stereotypical bench scientist is a shy and retiring one. But researchers are like everyone else – they need to engage actively with the broad community. The government encourages scientists to be good citizens. (Carr, 2008c)

Addressing a room full of scientists in March 2008, he urged those present to, ‘Remember you’re part of a wider society – one that you have a special ability and therefore a special duty to serve’ (Carr, 2008d).

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[19] These responses were based on answers from at least 1,038 scientists based in six national universities.

Carr also placed this responsibility at the feet of public research institutions as well as the scientists they employed: 'Public research institutions, and the dedicated professionals working within them, have a right as well as a responsibility to represent the findings of their work and to actively participate in public debate' (Carr, 2008b).

In December 2008, Carr and Chairs of the Boards of four publicly-funded agencies (CSIRO, AIMS, ANSTO and AIATSIS) signed charters that entrenched a set of general principles that included the recognition of the role of researchers in the open communication and dissemination of research findings, and in debate on research issues of public interest (Carr, 2008e).

FASTS argued in June 2010 that in certain circumstances every scientist had an obligation to contribute to scientific discussion:

> When scientists engage with small informal gatherings, e.g. at dinner parties or with school groups, it can be argued that in such circumstances there is an obligation on *every* [original italics] scientist to contribute to scientific discussion, particularly if it is to correct scientific misconceptions amongst their audiences (FASTS, 2008b, online).

Winston wrote in the magazine, '*New Scientist*' about scientists' duties which went beyond telling people, to listening and researching how best to have an impact:

> We scientists have a duty not merely to tell people what we are doing (a skilled not taught as well as it should be in most universities), 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)

Interestingly, given the history of social research on science communication in the United Kingdom since the 1980s, Winston observed that 'there is still no consensus on the best way to conduct such studies' … 'to ensure that the ways we attempt to engage really do have an impact' (ibid., p. 23).

A month later, across the Atlantic, it was stated that researchers have the 'responsibility to reflect on how their work and the knowledge they are generating might be used in the broader society' (Committee on Science Engineering and Public Policy, et al., 2009, p. 48). Indicating a cultural shift

amongst scientists belonging to the AAAS, an online survey conducted in May – June 2009, found 'Nearly all (97%) [of 2,533 American scientists surveyed] indicated it is appropriate for scientists to become actively involved in political debates on controversial issues such as stem cell research and nuclear power' (The Pew Research Center for the People & the Press, 2009). Arguably, part of this cultural shift may be due to the differing values of the younger scientists entering the profession as suggested by Martin-Sempere, et al. (2008, p. 356).

In 2010 this responsibility was a focus of the International Council for Science (ICSU) Committee on Freedom and Responsibility in their advisory note on science communication. This stated that, 'The effective communication of scientific results and viewpoints to the public is an important responsibility of the scientific community. This is particularly so for science that has been publicly funded'. The note was directed towards scientists, and included the guidelines that 'Scientists are individually accountable for their public communications and should be aware of their potential impact on both science and society' and 'Scientists have a special duty to communicate findings that have implications for human survival or well being, including threats to the environment' (International Council for Science Committee on Freedom and Responsibility in the Conduct of Science, 2010, pp. 1-2). One of the guidelines in this note recognised that scientists' communication was 'primarily' directed 'towards selected groups in society, such as politicians, industrialists and advocacy groups' but advised 'they should, as far as possible, be publicly accessible' (ibid., p. 2).

Research has shown therefore, that irrespective of the secrecy requirements of industrial cooperation, commercialisation and competition for funding, scientists, particularly those that are publicly-funded, feel that they have a responsibility or duty to communicate their research findings with the general public. Such responsibilities and duties are being articulated and incorporated in national and international guidelines for science communication.

Attracting support

'Without an informed public, scientists will not only be no longer supported financially, they will be actively persecuted'
(Asimov, 1983, p. 119).

The duty to communicate also incorporates the need for more communication by scientists to secure public support; which no doubt, includes public funding. Mayor, Director-General of UNESCO, did not mince words about the importance of public support and strong research policy for science when he addressed the many government representatives present at UNESCO's World Conference on Science in 1999 and said, 'direct, public support is the lifeblood of basic research and of all levels of science education. Make no mistake: science needs political will'. In return for 'funding and structured support' he said that science 'must respond to the needs of society' (Mayor, 1999, p. 26).

Mayor then stated that a government's responsibility went further than setting 'aside a budget percentage for science' ─ 'we cannot just set funding levels and leave science to 'get on with it'(ibid., p. 26) because 'Science is too important to be left to the markets'. He also believed that the public needed to be involved: 'As for so many other areas of human activity, democracy ─ active, participatory democracy ─ is a key part of the solutions we are seeking'(ibid., p. 27). In the *Declaration on Science and the Use of Scientific Knowledge*, there was the suggestion that public trust and support for science could be strengthened through democratic debate between the scientific community and decision-makers (I. C. o. S. UNESCO, 2002, p. 462).

The belief that communicating science will secure, maintain or increase funding, is a strong motivator for scientists and scientific institutions alike. Gascoigne and Metcalfe (1997), probably reflecting the views of the CSIRO scientists who were the dominant grouping amongst their 178 informants, reported that:

> There also is a widely perceived need to maintain the image of research organisations as a means of delivering long-term benefits to the country. This implies keeping the public informed about research progress and maintaining public confidence in organisations that are supported with billions of dollars of taxpayers' funds annually. (p. 270)

The authors found in their research that the possibility of attracting funding through communication via the media was important to Australian scientists:

> All groups see a benefit in using the media to persuade decision makers in government, funding agencies, and commercial partners to

> provide an adequate funding base for science. About 90 percent of funding for government scientists in Australia comes from the public purse, and the mass media provide a legitimate tool to reach and influence the general public (and hence politicians) and specific fund-providing groups (Gascoigne & Metcalfe, 1997, p. 270).

Whiteman, in promoting her science communication training courses for scientists, described the benefits from 'articulating your science clearly and succinctly' under five headings: 'Win funding', 'Get jobs'. 'Make breakthroughs [through bridging the gap between increasingly specialised disciplines]', 'Convey breakthroughs' and 'Improve scientific literacy [of the public]' (Whiteman, 2000).

In the United Kingdom, the MORI (2001a) study found that scientists cited similar personal benefits from communicating their research and its implications to the public'. These were described:

> as attracting possible funding, personal satisfaction and providing help with their career (for example, through publicising their work or offering job security). Those being funded by industry are among the most likely to say that a personal benefit is the possibility of attracting funding. (p. 5)

Claessons (2008) commented on the assumptions that many European scientists have about communication with the general public: '…effective science communication is seen as a means of attracting extra funding for research. Of course, the danger is that funds will go to the most effective communicators rather than the most excellent researchers' (p. 36).

Welp et al. (2006) stated that seeking: '…financial support for the research as well as seeking acceptance for the produced results should not be ignored' as an implicit goal of science-based dialogues with stakeholders (p. 173). Public accountability was another important reason for scientists to communicate with the general public: '…Communicating the results of research is important to

inform the actual financers of the work and to ensure continued funding' (European Communities, 2007, p. 7).

Interestingly, in the 2006 UK study [20] the qualitative research revealed that 'public engagement does not bring in significant funding and is not therefore a higher priority activity' [for universities]. Low priority does not mean unimportant' (People Science and Policy Ltd., 2005, p. viii).

Altruistic reasons for communicating

Few studies have explored the personal importance to scientists of their communication with the general public, but one of them, the UK study *Survey of factors affecting science communication by scientists and engineers*, revealed interesting trends amongst academic scientists and engineers. Participants were asked two questions, how important they thought it was that they personally, in their current post, engaged directly with nine groups such as general journalists, policy-makers, schools and school teachers and the non-specialist public and how important it was that they engage directly with the non-specialist adult public about particular aspects of their own work or science in general (People Science and Policy Ltd., 2006a, pp. 25, 27). It was found that, 'Many researchers regard communicating science as an important thing to be done, although not always as important as other tasks'. A key finding of the study was that, 'There was a strong positive relationship between the number of activities undertaken by a scientist and their perceived importance of public engagement' (The Royal Society, 2006a, p. 10).

The detailed results also showed that those who rated direct engagement as more important than their counterparts were: male researchers, more senior and older researchers, those with teaching as well as research responsibilities, those who thought their work had social implications; those who were active engagers; those who had received training in communication skills, and those who felt it was easy to get involved in engagement activities. Reaching policy makers was

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[20] The *Survey of factors affecting science communication by scientists and engineers* (2006) was sponsored by the Research Councils UK, the Wellcome Trust and the Royal Society and conducted by People Science & Policy Pty Ltd.

an activity that stood out as being 'very important' to relatively more scientists and engineers. The study also found disciplinary differences in the importance for scientists engaging with different groups: it was more important for clinical researchers for example to focus on communicating with general journalists (The Royal Society, 2006a, p. 16).

The researchers also asked the respondents why they thought scientists and engineers generally engage with the non-specialist public (People Science and Policy Ltd., 2006a, p. 27). The 'range of reasons cited for the importance of communicating science' included 'public accountability, a better informed public, generating support (financial, social, political) for specific areas of science and engineering', and 'recruitment of students' (People Science and Policy Ltd., 2005, p. iv).

Other United Kingdom researchers, Poliakoff and Webb (2007), surveyed 169 academic staff and postgraduates from the English University of Manchester using a questionnaire (p. 249). The researchers found that 'Contrary to expectations, factors such as time constraints, money constraints, and (lack of) career recognition did not influence participation intentions' (p. 259). The authors recognised that this finding seemed at odds with conventional wisdom, and suggested these factors play a role in the translation of scientists' positive intentions to participate into actual participative behaviour (p. 258).

They identified four factors that predicted scientists' intentions to participate in public engagement activities; 'past behaviour, attitude, perceived behavioural control, and descriptive norm'. In other words, scientists who decide not to participate in public engagement activities do so because (a) they have not participated in the past, (b) they have a negative attitude toward participation, (c) they feel that they lack the skills to take part, and (d) they do not believe that their colleagues participate in public engagement activities (ibid., p. 259).

Studies in Spain found that scientists were influenced by an 'ensemble of motivations related significantly more frequently to altruistic reasons than to reasons of professional promotion or personal reward' (Torres-Albero, Fernández-Esquinas, Rey-Rocha, & Martín-Sempere, p. 20). The main motivations of the scientists who took part in the PCST-Madrid Fairs were found to be related to 'the desire to arouse or increase the public's interest in and enthusiasm for science, the public's scientific culture, and public awareness and

appreciation of science and scientists' (Martin-Sempere, et al., 2008, p. 349; Torres-Albero, et al., 2011, pp. 20-21).

Gascoigne and Metcalfe (1997) identified 'personal benefits' for Australian scientists who worked with the media. The researchers grouped these benefits into the following: funding, corporate image, personal benefits and 'other benefits'. 'Other benefits' from publicising their work through the media were many and included 'stimulating the next generation of young scientists', 'satisfying public interest in science', and 'transferring technology'. 'Media coverage helps to counter negative publicity by educating the general public about scientific methods'. Scientists also found publicising their work was 'a useful feedback mechanism', and that it assisted them to develop 'a more extensive network of personal contacts' and improved 'the international prestige of their organisations' (p. 271).

Eight out of 10 Swedish researchers[21] said that communication with the public provided new perspectives on their own research (Vetenskap & Allmanhet, 2003). This benefit was also described by UK scientists who talked about professional benefits such as developing a deeper insight into their own work:

> Some scientists believed that communication work helps them become better researchers. Having the depth of insight needed to communicate effectively with non-experts meant that these scientists could make new inroads. (People Science and Policy Ltd., 2005, p. 9)

UK researchers reported that: 'Interviewees discussed public engagement as a means of accessing the highly valuable substantive contributions that the public can make to identifying scientific priorities, improving scientific projects, positively refocusing scientific objectives and improving clinical practice'. The scientists also said that '…public engagement was often discussed as "the right thing to do"; here, highly reciprocal relationships with patient groups, medical research charities and society in general were evoked by interviewees' (Burchell, et al., 2009, p. 52).

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[21] More than 400 were surveyed through interviews by telephone.

Scientists generally do not formally talk about their emotions and positive feelings in public or these are not touted as a benefit from their communication with the general public. People's emotional responses associated with science communication have been more often discussed as an outcome for the participants, meaning the 'audience' rather than the scientists involved. Australian researchers, Burns, O'Connor and Stocklmayer (2003), for example, described participant responses (using the AEIOU vowel analogy[22]) as a continuum of desirable personal reactions to science communication: enjoyment and other affective responses may evoke positive feelings and attitudes that may lead to subsequent, deeper encounters with science. The authors stated that 'Enjoyment of science may occur at two broad levels: At a superficial — but nevertheless important — level, enjoyment may be described as a pleasurable experience with science as a form of entertainment or art' and at 'A deeper level of personal involvement and satisfaction is usually derived from discovering, exploring, presenting or resolving science-related matters'. These findings show the importance of positive attitudes to motivate participation in public engagement activities for the presenters and the audience.

There are occasional references to scientists' feelings of satisfaction or improved self -confidence or enjoyment and surprise. In 1995 for example, the United Kingdom Wolfendale Report stated that 'finding that the public are in fact interested in and appreciative of one's work' increased scientists' self-confidence and satisfaction:

> For example, both staff and students co-opted to assist at stalls and explain science to passers-by at special events set up for National Science and Engineering Week, in the main and despite initial reluctance in some instances, found that they enjoyed the experience. (Wolfendale, et al., 1995, p. 3.6)

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[22] Science communication (SciCom) is defined as the use of appropriate skills, media, activities, and dialogue to produce one or more of the following personal responses toscience (the AEIOU vowel analogy): Awareness, Enjoyment, Interest, Opinion-forming, and Understanding.

Rothwell (2002) wrote about the unexpected rewards of communicating with non-scientists: 'Those who do find some time in their busy schedule to communicate with non-scientists usually find it extremely rewarding and are surprised to discover how much their efforts are appreciated by the public' (p. 139). The 2006 UK study found benefits for scientists that included feelings such as sharing enthusiasm and enjoying the effect they had on others:

> Sharing enthusiasm was also referred to as a part of accountability to explain why scientists do what they do "Science is done by people who are besotted with what they do". Another scientist talked of being "evangelical" and enjoying seeing other people "enthused and excited". (People Science and Policy Ltd., 2005, p. 5)

These emotional benefits were also described in a survey conducted by UK researchers, Burchell, Franklin and Holden (2009). These authors wrote about the 'unexpected enthusiasm' described by scientists for the benefits of public engagement such as identifying scientific priorities, positively refocusing scientific objectives and improving clinical practice (Burchell, et al., 2009, p. 52). Their interviews with 30 UK scientists revealed that, 'Many of the interviewees' perceptions of the value of public engagement were based on first-hand experience of it, often accompanied by a "conversion narrative" of sorts, in which interviewees described unexpected enthusiasm for this type of activity in spite of its potential limitations, time-consuming nature and unconventional demands' (ibid., p. 52).

'Enjoyment' associated with communicating with the public via the media was also a finding of a survey that focussed on Australia's scientists interaction with the media. 'Some scientists enjoyed interacting with the media, and also enjoyed the public exposure it brought their work' (Metcalfe & Gascoigne, 2009, p. 42).

Woolley, President of Research!America, wrote in 2002, 'When scientists make the effort to engage in conversation with nonscientists using nonscientific language, they are often pleasantly surprised at the outcome' (Woolley, 2002, p. 137). Why are scientists surprised? They are no strangers to strong emotions when it comes to their work – passion is a word often invoked to describe how they feel – but perhaps they did not expect to have good feelings about

communicating with the public. Perhaps such feelings have not generally been part of the discussion within the culture of science. Perhaps such feelings change with age.

When do Scientists Communicate with the Public?

This section reviews the literature on the influences of scientists' age, seniority or career stage on when they communicate with the general public via the media and face-to-face opportunities. It is recognised that there is a body of literature about scientists' communication and productivity through their published journal papers, but this standard forum for communication between scientists is not the subject of this study.

Age and seniority

Gregory and Miller (1998) astutely observed, in terms of scientists' communication and their scientific career, that it was the retired scientists, or those with 'unpopular ideas' who would communicate with the public; 'when their institutional links are weak'(p. 85). Others have written about the trend towards increasing non-research responsibilities and associated decreasing time for research, that are a fact of life for many academics and scientists as they progress through their careers. For example, a 2002 Australian report found that: the 'increased administrative and managerial tasks' for more senior scientists have implications for those who are expected to communicate science with the general public, and how skilled they are (Anderson, et al., 2002, p. 7).

Research has shown that younger scientists seem to prefer that the older scientists do the communicating with the public. Rier (2003b) wrote that communicating with the media is riskier for the younger scientists: 'More generally, there are the risks to credibility arising from distorted media coverage of one's work and words, and media contacts may be riskier and less attractive to younger rather than senior scientists'(p. 272) . In the Royal Society-commissioned survey of scientists and engineers in higher education institutes, it was found that 'more senior and older researchers generally rated engagement with [various] groups as more important than their counterparts' (People Science and Policy Ltd., 2006a, p. 16). Qualitative research found that public engagement was seen as 'less of a personal priority' (p. iv) for some junior

researchers who, ‘keen to climb the research ladder were focussed on research and publishing and/or felt that they needed more experience before they could engage with those outside their research community’. Some junior researchers were ‘also concerned, that relatively junior researchers would have less authority in public fora’ (ibid., pp. 16, iv).

The survey also found that, although junior researchers believed that there were benefits from communicating with the non-specialist public, they were more likely to agree that ‘engaging with the non-specialist public is best done by senior researchers’ (ibid., p. 29). It was also found that senior[23], rather than junior[24], scientists felt very or fairly well equipped to engage with the public (p. 32).

The pressures on younger scientists to conduct research and secure funding also affect their communication with the general public. It was found for example that, ‘Researchers, especially in their early careers’ …‘do not give priority to science communication activities because they feel they need to spend their time on research although the majority of scientists wanted to be able to spend more time engaging with the public’ (People Science and Policy Ltd., 2006, online). There is also recognition that scientists continue working professionally or academically into their later years, whether they are employed full time or have retired from paid employment (Bryant, 2000).

In 2008 in Spain, a structured questionnaire survey using face-to-face interviews with 167 research practitioners[25] was designed to understand the motivations that led practitioners to get involved in a Science Fair and the mechanisms that underlie these motivations. It found that:

> Senior researchers appeared to be highly motivated by a ‘sense of duty’. This was also an important motivation for postdoctoral fellows

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[23] Senior was categorsied as Reader/senior lecturer/researcher/fellow or Professor or above

[24] Junior was categorised as Lecturer/researcher/fellow; Junior/assistant researcher/fellow, and Technician/other support

[25] Researchers, technicians, support staff and fellows from Spain’s largest public research organization, the Spanish Council for Scientific Research (CSIC) who participated in the Madrid Science Fair in the years 2001 to 2004.

> and technicians and support staff, whereas the youngest individuals in the sample (pre-doctoral fellows and technicians with a temporary position) were not primarily motivated by a sense of duty. (Martin-Sempere, et al., 2008, p. 356)

It seems that the younger scientists are a new generation who do not view popularization as a tedious activity in which one engages only out of a sense of duty, or in exchange for recognition or money (ibid., p. 362). These authors also found that:

> Some individuals specifically mentioned the satisfaction of working with children and watching them enjoy science. …Other aspects that were mentioned were helping to communicate the participation of women in science, getting away from the research routine, a change of scene and chance to meet other colleagues in another environment. (p. 358)

The authors surmised that the extent to which the 'collective of young scientists, particularly predoctoral fellows working toward their doctoral degree (tomorrow's scientists)', is 'motivated to undertake PUS[26] activities may be the result of the socialization process to which they are subjected during work on their advanced degrees' (p. 362). Interestingly though, the authors observed that ego may be a motivator for prominent scientists: 'it is true that prominent scientists are involved in popularizing science, because for them it is "the cherry on top" of their career' (ibid., p. 357).

Previous research shows that older scientists are expected by other scientists to be the communicators with the general public: they have established themselves as researchers within their discipline, they are more knowledgeable about their subject, believe they are better equipped to communicate; they have relatively more time to do so, risk less professionally, and believe it is worth doing.

Career stage has also been found to have a significant effect upon how much and how scientists communicate with the general public. For example, Jensen,

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[26] Public Understanding of Science

Rouquier, Kreimer and Croissant (2008) showed that 'some prestigious activities (press, radio and television) are mostly carried out by the scientific "elite" in academic terms' (p. 537).

Research has found that scientists' communication with the public is also influenced by their sex, discipline and employer. The following presents the little research that has been published on these influences.

Other Influences on Scientists' Communication

A scientist's sex

Whether a scientist is male or female has been found to affect what they think and do about communicating with the public, according to a study of academic scientists and engineers in the United Kingdom (People Science and Policy Ltd., 2006). The findings of this research are presented in some detail because of their direct relevance (both in subject matter and timing) to the aims of this current study.

Gender differences were found between the 1,078 men and 392 women (1,468 in total) who participated. For example, the researchers found that, 'There are …indications that male researchers think communication is more important than do women researchers' (People Science and Policy Ltd., 2006a, p. 16). This may well be the case as women are often not in more senior positions where they directly engage with the public. When asked about how many times they had communicated about science in the context of 'public engagement' (which had not been defined in the questionnaire) in the past 12 months, males were found to have significantly higher levels of 'high activity'[27] involvement than expected (p. 20). It was also found that 'While women are no more likely than men to say that they feel very well equipped [to engage with the non-specialist public about their research], men are more likely to say that they feel *fairly* well equipped (45% v 39%)' (p. 32). When asked about their level of agreement or

[27] High level of activity (at least 10 activities in the previous 12 months) (People Science and Policy Ltd., 2006a, p. 20).

disagreement with statements about engaging with the non-specialist public about science and engineering, the researchers found that women were more likely than men to agree[28] that 'Engaging with the non-specialist public might help researchers make new contacts for their research' and that 'Scientists have a moral duty to engage with the public about the social and ethical implications of their research' (p. 29).

It would seem that some women have been discouraged from communicating with the general public 'for their own good', as indicated by the following quote:

> …one, now, relatively senior female researcher said 'I have been gently warned by senior colleagues that "if you are female [in a certain topic] then you need to avoid light and fluffy topics". Public engagement is seen as light and fluffy'. (People Science and Policy Ltd., 2005, p. 8)

The study found that a higher proportion of women (20%) compared with men (7%) would be encouraged to engage with the non-specialist public if they had more skills and training in communication (ibid., pp. 35, 38). Also, women more than men, were found to be influenced to communicate if it helped their career, was part of the research assessment exercise (RAE)[29] and was recognised by giving the researcher's department an award.

A scientist's discipline

Disciplinary differences have been found in scientists' attitudes towards dialogue with the general public, how knowledge is 'diffused' to end users, and the extent of their media contact. In the 2003 Swedish study of more than 400 researchers, for example, researchers in the mathematics/natural sciences 'less often felt that a dialogue with the general public provides new perspectives on their own research' and researchers in technology 'prefer to stay in their labs'

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[28] This refers to those who said 'agree strongly' and 'agree' (Hartz & Chappell, 1997, p. 41).

[29] The RAE is used by the four UK higher education funding councils to evaluate the quality of research undertaken by British higher education institutions.

and 'are least interested in a dialogue with the general public' (Vetenskap & Allmanhet, 2003, p. 27). It was found that researchers in the humanities were 'interested in the general public but do not feel that it is mutual' and 'more often feel that a dialogue with the public is both valuable to researchers and their obligation'. They also believed that researchers in other sciences were worse at this [dialogue with the public]. Despite this, they do not have a more intensive dialogue with the general public. This point was taken up in an Australian report where it was stated that there were 'marked' differences between disciplines and research fields in how the knowledge was 'diffused' and therefore how its quality was best measured (The Allen Consulting Group Pty Ltd, 2005, p. 41).

Examining scientists' communication via the media, Peters et al. (2008) found significant disciplinary differences between epidemiologists and stem cell researchers across five countries in terms of their media contact. For example, epidemiologists had more professional contact than the stem cell researchers, in the previous three years, with journalists from the general mass media face-to-face, by phone or by mail/fax/e-mail'. This pattern was found across all countries France, Germany, Japan, UK and USA) and there were no significant differences between countries.

Scheufele at al. (2009), recognising the importance of disciplinary differences in communication frequency with lay audiences, had some reservations about findings from the 2009 survey conducted by The Pew Research Center for the People & the Press. This was because they were based upon a sample of self-selected across-disciplinary members of the AAAS which was 'very different from studies of experts in a given field of study'. They pointed out that as the member of the AAAS, an interdisciplinary scientific association, included students, emeriti and non-scientists who support the organisation's mission:

> The low overall contact frequency between scientists and journalists reported in the AAAS survey may, therefore, be an artifact of a sample that included both active and non-active researchers across a variety disciplines, including fields like mathematics that inherently receive less attention from journalists than medicine for instance. (p. 204)

Research within the last decade, although limited, has indicated that a scientist's discipline has an important effect upon with whom they communicate, how they communicate and how often they communicate with the general public, and that this should be taken into account in research design and analysis involving scientists' communication.

A scientist's employer

Gascoigne and Metcalfe (1997) observed that, in terms of 'the views and attitudes of Australian scientists on communicating through the mass media', there was a similarity in responses between those who worked for organisations entirely or substantially funded by the government, and that they are a culturally homogeneous group[30] (pp. 28-29). Describing in 2009, the results of an online survey of 446 Australian scientists in 2007, the same authors stated that the majority of the respondents had 'reported that their organization officially encourages media interaction':

> But most also reported that Australian scientists were sometimes discouraged from speaking to the media, which suggests a significant gap between official policy and reality…. (Metcalfe & Gascoigne, 2009, p. 43)

Respondents also recognised the negative attitudes of their organisations to the media as a problem, and identified this as an important or very important issue (ibid., pp. 42,44). The authors said that the results indicated that, 'scientists, especially those from government research agencies, have little regular interaction with the media' (ibid., p. 41).

Differences between employers

The practice of scientists' communication is influenced by the culture of their employer, according to research over the last four decades. Beginning with

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[30] For the 178 scientists who participated in focus groups and a mail questionnaire, it was found that those employed by a university, a government department, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) were a culturally homogeneous group.

Robbins and Johnston (1976) the authors observed differences between 'academic, government and industrial scientists [who] operate in widely differing institutional settings with differing norms of behaviour, differing modes of advancement and different peers'. The authors stated that 'it is not unlikely that they will adopt different perspectives concerning those issues of public concern on which they may advise and inform' (p. 354).

In 1996, Heaney stated that deep cultural differences between industry and academia were the basis of 'many of the obstacles to successful collaboration and communication' (Heaney, et al., 1996, p. 66). Bitmead also examined communication between researchers in universities and industry in Australia and found very different cultures between the two. For example, industry researchers experienced, 'The importance and place of timeliness and deadlines in the business environment' (Bitmead, 1997, p. 48) and 'emphasis on the short term and pressure to concentrate on the profitability of the company' that were part of the culture (p. 59). Alternatively, academics have a 'desire and expectation for independence' (p. 50). Little appears to have been researched about differences in activities and views about communication with the general public between scientists employed in different sectors.

There is awareness, however, of the difficulties of scientists communicating with each other between different employer types, let alone between scientists and the public. For example, in 2006, Spurling, then President of the Federation of Australian Scientific and Technological Societies (FASTS), wrote about the risks that knowledge transfer linkages between universities, industry and the broader community posed for academics and firms or industry bodies: 'They are risky for academics – where such activities are often not clearly rewarded, acknowledged or directly funded. They are risky for firms or industry bodies who typically have little deep knowledge or experience of academic cultures and drivers' (Spurling, 2006, p. 2).

Cultural differences, between different types of organisations, influence scientist's communication with the public, but little empirical research has been conducted to explore this in any detail.

How Do Scientists Communicate with the Public?

Scientists communicate with members of the public in many different ways for many different purposes. In terms of scientists' communicative stances, Trench and Junker (2001) stated that they range from imperatives about educating various publics about sciences and persuading them about its benefits, through statements about a moral responsibility to engage with the public, to propositions about possibly learning about science itself through the insights of others. The authors saw these 'positions as a spectrum ranging from more authoritarian to more participatory positions, or from more monologic (communicating to the public) to more dialogic (communicating with publics) (p. 4).

One-way communication

Research within the last decade has shown that scientists still generally communicate through a one-way transfer of their information (also described as the 'deficit model'). This is perhaps not surprising – it was only in 1996 that Greenwood explained that the inclusion of public sector interests, other than businesses, in research discussions was rare at that time (Greenwood, 1996, p. 933). He described a dialogue event between research scientists and administrators from the California research universities and national laboratories, business leaders in evolving high-technology industries, and mayors, local economic officers, and state politicians, that enabled them to talk about how to better understand each other's concerns and priorities and to build critical partnerships for the future.

Cook et al. (2004) found in their qualitative research[31] that the scientists working in crop and food genetic modification (GM) saw communication as the transfer of information: 'The scientists' main concern was with how technically complicated GM could be simplified to become accessible to the scientifically uneducated' and yet the scientists 'attempted to remain rigorously scientific and

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[31] Cook et al. (2004) investigated the views of GM scientists within one academic institution (18 experts (all GM scientists) and 15 non-experts from within the university, and 10 ' outside advisers' though interviews.

to use language only in a scientific manner'. The authors also explored a number of ironies and contradictions in scientists' approach to communication with non-experts and outside advisers (Cook, et al., 2004, p. 443). Two subsequent studies in the United Kingdom in 2006 and 2008, confirmed that most scientists view communication with the public as one-way. For example, the 2006 UK study[32] of university-based scientists and engineers found that 'many scientists see the main reason for engaging with the public [is] the need to 'educate' them rather than to debate, listen and learn as part of a genuine dialogue' (The Royal Society, 2006a, p. 14).

Davies (2008) also found that scientists and engineers[33] go to public communication activities assuming the 'sole primacy of scientific knowledge' (p. 430). Davies found a dominance of rather traditional discourses: of communication as one-way, as 'education', and as struggling to engage an unreceptive public… 'It seems likely', she wrote, 'that much of the time scientists and engineers will simply assume that any public communication in which they are involved is to be of one-way and for the purpose of educating and ignorant public' (p. 430).

It is clear from recent research that one-way communication from scientists to the public(s) is the norm. The next section describes the calls for two-way communication and how little such communication has been embraced by the science community.

Two-way communication

Felt (2003) warned that an improvement in communication must be more than 'a mere increase in the quantity of information or better distribution' of validated information 'as a one-way, top-down transfer of information for the purposes of education and promotion' (p. 4). He is amongst the many who have called for two-way communication between scientists and the various publics.

[32] 'Survey of factors affecting science communication by scientists and engineers' conducted by People Science and Society. Final report on The Royal Society website.

[33] Davies' research was based on seven group discussions with each made up of between three and 10 participants (scientists and engineers).

Many terms have been used, interchangeably and confusingly, to call for and describe two-way communication. Depending on who is using them, these terms and the processes that they describe may have different purposes such as dialogue, engagement, public participation, interactive communication and deliberative democracy. Irrespective of the term and intent, however, they all involve a movement away from traditional one-way delivery of scientific information by scientists to others.

Cynicism is evident about the commitment to two-way communication in the conduct of science. In 1999, a journalist, reporting the news that the presidents of the eight major German science organisations had signed a memorandum agreeing to support dialogue between science and society, observed that the public understanding initiative had been welcomed by scientists. She observed, however, that there, 'is a suspicion that the initiative is simply seeking more acceptance of science in society rather than really trying to stimulate critical discussion between both sides' (Tuffs, 1999, p. 12).

These ideas of a two-way communication between 'science and society', however, have been around for decades. Gascoigne and Metcalfe (1994), for example, foresaw that, 'Interactive communication between scientists and the public is the way of the future' (p. 426). No discussion of two-way communication in science and technology, however, would be complete without a reference to the oft-quoted the *House of Lords Science and Society - Third Report* six years later. It stated that there was a 'new mood for dialogue and debate, to which existing institutions must respond and in many cases are already responding' (House of Lords, 2000, Section 3.59). In the United Kingdom this report was an important catalyst for research that has rapidly expanded to identify better two-way communication or dialogue between scientists and the rest of society (N. Pitrelli, 2003, p. 3).

In 2008, however, Davies stated that despite all the talk since the House of Lords report, little had actually changed in scientists' views about communication with the public. One-way communication was the dominant framework: '... most talk by scientists about communication, constructs it in a way more suited to the 'traditional PUS' movement…'.(Davies, 2008, p. 430) This assessment could be construed as rather dispiriting for those involved in science communication in the United Kingdom; after eight years of funded

research, events and other activity to increase ‘dialogue’, ‘public engagement’ between ‘science and society’, little had changed.

Following international trends, nevertheless, in 2010 the Australian *National strategy for engagement with the sciences* made a strong stand for the need for two-way communication or ‘public dialogue’:

> …A strong message from the state and territory consultations was that communicating science must not be a one-way channel out, telling the public what they should know or believe. To create a scientifically engaged Australia, it must be multi-way channel – ears as well as voices – facilitating public dialogue with scientists and policy makers, intellectual involvement and active participation’. (Davies, 2008, p. 430) (Department of Innovation Industry Science and Research, 2010, pp. 8-9)

There is certainly increased awareness amongst scientists that science communication with the general public is important whether it be one way or two way. In France, for example, it was found that researchers believed that ‘popularisation is now a key and unavoidable component of research work’ but is this all just rhetoric? The methods and frequency of scientists’ communication with the general public also varies demographically and this is discussed in the next section.

Frequency and method of communication

Research indicates that in the United States, United Kingdom, Europe and Australia scientists communicate episodically or rarely with the general public, either directly or via the media, unless it is part of their job. For example, Hartz and Chappell (1997) found that:

> Most [American] scientists and engineers are willing to talk with the media, but many said they seldom do. Only 4 percent said they talk to the media as often as once a month. Forty-five percent said they talk to reporters every few years. …About one fourth (26 percent) said they have never been interviewed or written about in a science story during their entire career! (p. xi)

It was found that university-based scientists and engineers in the United Kingdom communicated more often than this when they were asked about not

only the media but other communication as well. In a study of university-based scientists and engineers, 'Of those surveyed, 74% reported having taken part in at least one science communication or public engagement activity in the past 12 months (The Royal Society, 2006a, p. 10).

Three levels of public engagement activity for scientists emerged from this study:

> those who undertake no activity (26%); Low to medium level activities (defined as 1-10 activities per year) (63%); and high-level activity (more than 10 activities per year) (11%). (The Royal Society, 2006a, p. 10)

About half of the 100, mostly senior, scientists interviewed in 2007 across European countries were found to have episodic interaction with the public via the media that was usually linked to specific projects or events. 'Most scientists report that they both take initiatives themselves and respond to media approaches'. They were divided into three groups of scientists in terms of their degree of involvement in communicating science to wider audiences: those that have limited contact (about one third of the scientists); those with episodic interaction, usually linked to specific projects or events (nearly half of the sample); and about 20% who have an active and periodical interaction with the media (ibid., p. 10).

Those scientists with episodic interaction 'usually highlight that their specific fields of work are not actively sought for by the media. In general, they acknowledge some sporadic contacts with the media ─ mostly newspapers and radio ─ in the past 12 months' (European Communities, 2007, p. 15). The smallest group ─ [about] 20% of the scientists sampled ─ had the most frequent contact with the public. 'They tend to have weekly contacts with newspapers ─ either as regular columnists or as consultation sources ─ and combined these with monthly or bimonthly appearances in radio or TV' (ibid., p. 15):

> These are mainly researchers who ─ besides being adequately supported in this role by their institutions ─ are also active individual seekers and supporters of links with the media. They may be favoured to some extent by the attractiveness of their specific fields (e.g. waste disposal, safety issues, environment), or by their critical impact to

> society (e.g. health research) but their hands-on approach is what generally makes the difference. (ibid., p. 15)

In the United Kingdom, researchers found that three quarters of the 1,485 scientists in the sample had undertaken at least one public engagement activity in the past 12 months. Unlike the European Communities study, however, this contact was not restricted to the media:

> Forty per cent had taken part in a public lecture; 33% had engaged with policymakers; 30% at work with schools; 25% had written to non-specialist publications; and 20% had taken part in a public dialogue or debate. (ibid., p. 15)

The researchers identified 'Three low levels of public engagement activities for scientists: those who undertake no activity (26%); low to medium level activities (defined as 1-10 activities per year) (63%); and high-level activity (more than 10 activities per year) (11%)' (p. 10). In a 2007 Danish survey that used an Internet-based questionnaire[34], it was found that 70 ─ 80% of all respondents had contributed to science communication on the Internet (personal and university homepages) while little more than half had participated in science communication in the news media, within the previous 12 months (Nielsen, et al., 2007, p. 7).

A five-country study based on a survey of 1,354 scientists (United States, Japan, Germany, United Kingdom, France) that focussed on scientists' interactions with the mass media, found that the media interview was the most common interaction: 'nearly two-thirds of the respondents (64%) said that they had been interviewed by journalists at least once in the past three years' (Peters, et al., 2008, p. 204). This cross-country study found an association between how often scientists communicated, their leadership role, research productivity and personal attitude, and this formed a pattern across the five countries [United States, Japan, Germany, United Kingdom and France]. For example, those researchers who most enjoyed communicating were deans, directors, department

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[34] The survey was based upon 1,038 completed forms and 142 partially completed by scientists working in six national universities conducted in 2004-2005.

heads or chief executive officers; those who had the highest number of peer-reviewed publications (in their career as author or co-author) and those who had the most frequent (i.e. > 10 times) contacts with the media.

In Australia an online Internet survey[35], that asked scientists about their experience with the media found that for most scientists, media activity was an 'optional extra' and that 'most of the respondents to the survey interacted with the media less than twice a year' (Australian Science Media Centre & Australian Science Communicators, 2007). It was reported that 43% spoke to journalists or had contact with the media a few times a year. Fourteen per cent had never had contact with the media (Metcalfe & Gascoigne, 2009, p. 42)

In the same year it was reported that an American survey of 2,533 scientists (members of the AAAS) had found that, 'In terms of public outreach, nearly eight–in–ten scientists (77%) say they often or occasionally talk with non-scientists about science or research findings' (The Pew Research Center for the People & the Press, 2009, p. 18).

These studies seem to indicate that most scientists have some contact with the public each year, and that some of this is proactive and some reactive. Up to one quarter do not engage at all with the public. In Australia, however, data about the frequency and method of scientists' communication is lacking.

What Would Help or Has Helped Scientists to Communicate?

To help scientists, several guidelines and codes of conduct, either specifically focussed on scientists' communication or including a few references to scientists' communication, have been developed recently in the United States, Europe and the United Kingdom. These may be more relevant and less self-serving versions of 'the rules' discussed earlier in this chapter. Media, communication and participations skills training are now offered by some organisations, and there are claims of improved institutional support for and recognition of their scientists' public communication activities. The following

[35] 'Free to speak?' was conducted in March-April 2007 to survey Australian scientists by the Australian Science Media Centre) (AusSMC) and the Australian Science Communicators (ASC). Of the 446 scientists who took part, nearly half (49.6%) worked for universities.

sections address suggestions made to help scientists' communication with the general public: improved institutional recognition and support, and communication skills training.

Improved institutional recognition and support

There have been many suggestions that improved institutional recognition and support would help scientists to communicate with the general public. These have been met with some resistance. For example, the 1995 United Kingdom Wolfendale Report Committee recorded that 'that some universities are not yet persuaded that encouraging public understanding activity is in their interests' (Wolfendale, et al., 1995, Section 3.7). Under the heading of 'Creating Incentives', the Committee proposed that 'success in promoting the public understanding of science or engineering should be recognised in terms of appointment and promotion prospects, which should depend on a mix of research, publications, teaching, administration and public understanding skills' (ibid, Section 3.81).

In Australia Gascoigne and Metcalfe (1997) suggested no less than a 'cultural change', brought about by 'policy and administrative changes', was required to 'move the scientific culture toward more influential modes of communication'. Their findings showed that scientists believed that media coverage of their work had significant benefits but that the research organisations offered them little support and often greeted their efforts with indifference. The authors stated that the use of the media had 'to become an accepted, rewarded, recognised, and legitimate activity, encouraged at the highest levels and actively promulgated through research organisations' (p. 280). Another 13 years were to pass before their recommendations were voiced at an Australian Government level in the findings of *Inspiring Australia - A national strategy for engagement with the sciences. A report to the Minister for Innovation Industry Science and Research* (Department of Innovation Industry Science and Research, 2010, p. 75).

Recognition that responsibility rested with research organizations and the funders of research was clearly stated in the United Kingdom in 2000, in the *Science and Technology ─ Third Report*, ordered by the House of Lords. The Science and Technology Committee emphasized that 'these responsibilities [to promote both scientific outreach activities themselves and the training need by

scientists] are shared between all the sponsors of research and the universities themselves. The Committee recommended that:

> grant-giving bodies should give researchers every encouragement to share their research with the public which, one way or another, is usually paying for it, and should support and reward those who do so; and that universities should for their parts see this as a shared responsibility.(House of Lords, 2000, Section 3.26)

Carrado, Pooni and Hartfree (MORI, 2001b) concluded from their research, '*The Role of Scientists in Public Debate*'[36], that increasing 'communication between scientists and the public, whether through 'public understanding' initiatives or through the more participatory public engagement and dialogue' would require 'institutions and funders to commit to efforts at public dialogue, and this attitude needs to filter through all levels of an organization and down to individual scientists. Secondly, practical initiatives are needed, both at a national level, combining the resources and experience of interested organizations, and particularly at the institutional and individual level' (p. 49).

They specified that, 'science organizations [would have] to become communicating organizations, where public consultation is built into and informs the research process from the beginning. This means the allocation of time to communication, the provision of training and incentives, and encouragement and support of scientists by their institutions and funders' (ibid., p. 49). They also stated that institutions and funders must 'encourage young scientists to consider science communication and the development of links with the community as an integral part of a scientific career' (p. 49).

The researchers recognised that 'scientists are busy people' and stated that 'It is therefore critical that they are fully supported in their efforts to communicate, and that they receive adequate recognition for this' ….'The next generation of scientists ought to be able as well as willing communicators, which will benefit

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[36] This quantitative research was based upon face-to-face interviews with a random sample of 1,540 research scientists at 41 Higher Education Institutions (HEIs), and 112 scientists at 42 Research Council-funded establishments in Great Britain.

not only the public, but also scientists themselves, and science and scientific research as a whole' (p. 49).

One of the key findings of the Royal Society-commissioned study four years later was that funding of communication activities at a department level, support from their head of department, and evident career advantages would encourage scientists to undertake more public engagement:

> Bringing more money into the department was the top incentive (81% saying it would encourage them a great deal or to some extent to undertake more public engagement). Grants that covered staff time as well as other costs were also important (78%). Awards or prizes for departments (56%) were preferred to awards to individuals (39%). (The Royal Society, 2006a, p. 11)

Nevertheless, as also stated by the authors of this study, funders:

> are aware that their research grants provide a powerful tool for stimulating public engagement activity. However, they are also aware that they can be seen as simply making additional demands and funders are looking for more ways to support researchers (People Science and Policy Ltd., 2005, p. vii).

Improved institutional recognition, support and funding for scientists communication would presumably occur if it was part of a scientists' job and they were funded to do so. The demand for this to occur more commonly is reviewed in the next section.

The job description

In Australia in 1997 Gascoigne and Metcalfe suggested that if research organisations wanted to make better use of the media to gain support, they should include public communication in job descriptions and duty statements of research scientist at all levels: 'The performance of individual scientists in public communication should be formally assessed in evaluation processes and taken into consideration in promotion cases' (Gascoigne & Metcalfe, 1997, p. 280). This view that research and performance assessment should include public communication activities was echoed by UK scientists and engineers:

> Sixty-one per cent said changes to the research assessment to encompass public engagement activity would act as an incentive: more for senior (71%) than junior (58%) staff the need to better recognise non-research activities was also highlighted in the interviews [for this study] (The Royal Society, 2006a, p. 12).

A conclusion by the authors of this UK study was that the biggest constraint on public engagement activity is that:

> it is not seen as part of the research job, much less an important part of the job. In large part this perception is driven by institutions' (and the research community's) pre-occupation with research and publication rather than education (People Science and Policy Ltd., 2005, p. vi).

Other statements about the importance of institutional attitudes in this UK report were:

> ….Institutional leadership is important, if no one at the top of an institution regards communication as serious then it will always be a fringe activity. However, middle managers can dilute the messages given out by senior academics. (ibid., p. vii)

Leshner, citing funding initiatives by the Wellcome Trust in the United Kingdom, and other organisations such as U.S. National Science Foundation and National Institutes of Health in the United States, specifically called for a scientific reward system to support scientists' efforts to interact with the general public concerning their work and its implications. He also suggested that public outreach efforts be included among the metrics used to decide scientists' promotion and tenure in academic institutions (2007, p. 161)

In the same year, in-depth telephone interviews with 100 European researchers revealed that they wanted support, recognition and accountable funding for their communication with the public (European Communities, 2007).

A number of studies have shown that scientists want training to help them communicate more effectively with the general public. There are also commentaries by high profile scientists who have called for this training to occur. Both are reviewed in the next section.

Communication skills

Training and experience

Studies in Australia, the United States, the United Kingdom and Europe have found that scientists have a positive attitude toward media training. For example, 'Media skills training is valued by those who experience it' (Gascoigne & Metcalfe, 1997, p. 267). And according to Hartz and Chappell in the same year, 'Scientists [surveyed in America] were also asked if they would be willing to take a course that would help them communicate better with journalists. The scientists reported that they are "very willing" (31 percent) and "somewhat willing" (50 percent)' (Hartz & Chappell, 1997, p. 29).

Further evidence of the benefits to communication from scientists' experience and training was provided by the 2001 MORI study in the United Kingdom. It found that scientists were more likely to have communicated in the past year, if they had received training, felt equipped to communicate the scientific facts and implications of their research, or had experience in teaching non-specialists. The researchers concluded that: 'Participation is related to scientists' skill and confidence: those who feel equipped to communicate the scientific facts and implications of their research, and scientists who have received training, are more likely to have participated' (MORI, 2001b, p. 4).

The United Kingdom *Factors affecting science communication* survey found that when asked to what extent would they be personally encouraged to get more involved in activities to engage the non-specialist public in science and engineering, junior staff and younger researchers and women scientists responded that: training would influence them 'a great deal' (People Science and Policy Ltd., 2006a, p. 38). In 2007, the solutions proposed by the 100 European scientists to improve the relationship between scientists and the media included training in specific communication skills:

> Scientists are conscious that they do not always recognize the socio-economic context of their work and are often not good communicators. Many feel that if they received training on specific communication skills, they would probably be better prepared to interact with the wider public through the media. (European Communities, 2007, p. 8)

Leshner strongly supported media skills training for America's scientists and was instrumental in the establishment of the AAAS Center for Public Engagement with Science and Technology[37] which offers such training. He urged 'university science departments [to] design specific programs to train graduate students and postdoctoral fellows in public communication'. Leshner also recognized that such initiatives would have their costs but he felt that 'science' had no choice:

> This will doubtless be an additional burden on existing systems. Unfortunately, there is no alternative. If science is going to fully serve its societal mission in the future, we need to both encourage and equip the next generation of scientists to effectively engage with the broader society in which we work and live. (Leshner, 2007, p. 161).

He also acknowledged that such training would mean 'adding yet another element to already overtaxed research training programs. Many students acquire teaching experience through assistantships, but public engagement activities are different and require other strategies. We need to add media and communications training to the scientific training agenda' (p. 161).

Metcalfe and Gascoigne reported that many of the Australian scientists surveyed in 2007 wanted more frequent training and refresher courses and small classes that allowed a one-on-one interview experience (Metcalfe & Gascoigne, 2009, p. 43).

It would seem that, for more than 25 years, everyone from scientists to their scientific leaders across many modern westernised countries believes that scientists need, and should be provided with training and experience to help them communicate more effectively with the general public. Such opportunities and training, however, are more optional than standard or compulsory in both the universities and workplaces of Australia.

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[37] This was a partnership with the National Science Foundation to provide resources for scientists and engineers, both online and through in-person workshops to help researchers communicate more broadly with the public.

Chapter Summary

Empirical studies, reviews of research, and informed essays by researchers and eminent scientists published until 2011 are reviewed in this chapter to illustrate that overall, relatively little research has focussed on scientists themselves with respect to understanding and improving communication between scientists and those who want or need to know their scientific knowledge. This is particularly the case for Australia. The relatively small number of studies of scientists' views and activities around their communication with the general public have mostly occurred over the last decade in the United Kingdom, United States and Europe.

Surveys of scientists' communication have often focussed on very specific subject areas such as peer-reviewed publications (only) or scientists' communication via the media (only). Scientists and engineers in one particular sector, such as universities or government-funded research organisations, or in particular disciplines such as biotechnology, have more often been the subjects for research than broader scale studies across employment sectors and scientific disciplines. Some surveys asked about communication with the general public, but then did not define what was meant by 'general public'.

Research to date indicates that most scientists feel a duty to communicate with the general public and generally view communication as a one-way transfer of their knowledge. It appears that it is the more senior, male scientists who do most of the communicating. It has also been found that scientists encounter many more factors that discourage their communication, rather than factors that encourage them to communicate with the public. These discouraging factors are enforced by their scientific community, and the commercial and political concerns of their employers, amidst a declining public funding for science.

Scientists have identified conditions within their workplaces such as short-term contracts, industry collaboration, commercialisation, competition, lack of funding and lack of time, as obstacles to their communication. Different scientists have also described an ignorant, critical, uninterested and distrustful public as inhibiting their communication, as well as the mass media which has different timelines and agendas in their reporting. There were also some early indications, however, that attitudes of two minority groups in science ─ women and younger scientists ─ may be changing the culture of scientists'

communication, in terms of their willingness to be trained to communicate more effectively with the general public.

This literature review found that large-scale, national surveys of scientists across disciplines and employment sectors concerning their communication with the general public were rare. Such empirical research in Australia, that explores the views and activities of Australia's scientists beyond the media, does not exist or if so, is unpublished. It was also found that little research has been conducted to empirically explore the influence of the sex, age, discipline and employer of a scientist on their communication with the public either.

The next chapter describes how research was devised for this study to reduce these gaps in knowledge about the views and activities of Australia's scientists around their communication with the general public.

CHAPTER 6. RESEARCH DESIGN AND METHODS

Introduction

This research examined scientists' communication from the scientists' point of view and addresses the following research questions:

1. Do scientists think that it is their responsibility to communicate with the general public?
2. Do scientists believe that there are any benefits for them to communicate with the general public?
3. Is communication with the general public personally important to scientists?
4. What do Australia's scientists currently do to communicate with the general public?
5. Does anything hinder scientists from communicating in the way they would like with the general public?
6. Are there areas for improvement to facilitate communication between scientists and the general public?

Choice of Methods

This research is exploratory and descriptive (Birks & Mills, 2011; Creswell, 2007; Martin & Turner, 1986; Silverman, 2001; Strauss & Corbin, 1990). Methods used to analyse the qualitative data collected from open questions in the questionnaire included coding and categorisation of the codes into emergent themes for further analyses.

Choice of survey method – a questionnaire

Researchers examining scientists' communication this century have used the following survey methods, or combinations thereof, to study scientists: face-to-face interviews (Burchell, et al., 2009; MORI, 2001b), telephone interviews (European Communities, 2007; The Royal Society, 2006a), focus groups (Fry et

al., 2009) and online questionnaires (People Science and Policy Ltd., 2006; Petersen, Anderson, Allan, & Wilkinson, 2009).

As the aim of this research was to describe the attributes and communication experience, and explore the attitudes of as many scientists in Australia as possible, an online questionnaire, with both fixed-choice questions and open-ended questions, was deemed to be an appropriate survey method (C. Marshall & Rossman, 1995, p. 95).

Questionnaire – sampling, and delivery via the Internet

The survey data were drawn from the widest distribution of Australia's scientists possible: across geographic distance, different institutions and industry sectors (business, government (Commonwealth, State/Territory/Local), higher education and private non-profit) and disciplines. An electronic questionnaire was made available through an Internet link delivered in an invitation via email. This method of delivery was adopted because there is clear evidence that the Internet, which in Australia had its origins in the research sector, had been in increasingly common usage for higher education and research since the 1990's. The Internet has proved to be an effective vehicle to reach scientists in the academic and research community and beyond, and research has shown that the Internet, including email, is a commonly-used tool by most scientists (Gläser, 2003, p. 42).

It was also important for this research to include scientists who were no longer physically located in institutions such as universities and government departments and agencies ─ such as those who were working from home, self-employed, retired or semi-retired. Research on the general Internet usage in Australia showed that scientists, as higher-educated, and higher income people who perform intellectual work, are likely to use and have access to the Internet at home (Ewing, Thomas, & Schiessl, 2008). This meant that scientists whose principal Internet contact was through a home-based computer could also reasonably be expected to be reached because Australia has one of the world's highest levels of computer use at home (ABS, 2008d).

The research strategy assumed with good justification, therefore, that Australia's scientists had access to a computer, the Internet and email. Research also indicated that reaching scientists (both employed and retired) through the

Internet would be more likely to attract a representative ratio of men and women. Responses collected though an electronic questionnaire would also take less time to process and analyse, and errors due to the transferal of data from one type of software to another would be negligible, compared to transcribing them from paper questionnaires to Excel database analysis software, for example. Rowe, Poortinga and Pidgeon (2006) also stated that 'electronically administered surveys may actually provide an improvement over other methods [e.g. paper-and-pencil], in the sense of eliciting less biased, more truthful response' because the relative anonymity 'reduces respondents' concern with presenting themselves in a good light' (p. 356).

An online approach, however, competed with all the other email that scientists have to deal with in their busy lives and might not have attracted their attention. To add credibility to my invitation, support was sought from two influential organisations in the Australian science community: the Australian Academy of Science (AAS) and Science & Technology Australia (formerly the Federation of Australian Scientific and Technological Societies (FASTS)). Subsequent anecdotal information has suggested that this support, which was highlighted in the emailed invitation to participate, did give this request a higher priority than it might otherwise have had with some organisations such as State government departments. To further encourage participation, the questionnaire was anonymous for both respondents and their employer organization. This anonymity was also highlighted at the beginning of the questionnaire.

Development and piloting of online questionnaire

The focus and length of the online questionnaire was refined between October 2006 and February 2007 through consultation with 21 supervisors, advisers, scientists, and statisticians from The Australian National University (ANU) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO). Ethics approval for this survey was given by The Australian National University Human Research Ethics Committee (Appendix 1 ─ Protocol 2006/321). The questionnaire was piloted by 22 people who included university academics (ANU and Copenhagen); other researchers from CSIRO, the Australian Institute of Sport and Australian Capital Territory; CSIRO communication managers and policy advisers, and former Commonwealth public servants.

Data collection

Initial requests for support and participation were emailed by FASTS and the AAS to individuals and professional science associations, societies, associations and organisations which employed scientists. Contacts within those organisations that agreed to participate were followed up with an emailed invitation to be forwarded to each of their members or employees through their email contact lists. This invitation included a hyperlink to a dedicated webpage which presented the Internet-based questionnaire. One reminder was sent by FASTS, and others potential participants were reminded through cross-posting.

The online questionnaire was open between 7 May ─ 9 July 2007. After the first week of the survey, there were more than 500 returns, and respondents had made favourable comment about the purpose and design of the survey. Encouraged by this positive response, the survey was then rolled out to more than 52 government organisations including 42 Cooperative Research Centres (CRCs) and the Australian Science Communicators. To involve more scientists working in industry, organisations such as the Association of Professional Engineers, Scientists and Managers, Australia and members of Medicine Australia were also involved. Australian Government organisations whose scientists were invited to participate are listed in Appendix 2. Examples of the invitations emailed to organisations that represented or employed scientists, are shown in

Appendix 3 ─ Appendix 8.

A total of 1, 546 people completed the questionnaire. The final data base consisted of completed questionnaires from 1,521 valid respondents.

The most recent Australian census data[38], which described the number of Australia's scientists by occupation, was collected 8 August 2006 and publicly released in October 2007 (ABS, 2008e). As this was not presented at the level of description I required for comparison with occupational data collected for this survey (6 digit occupation classifications and the 4 digit industry classifications), the ABS were paid a consultancy fee ($A4,200) to provide the 2006 census data in the detail required (6 digit occupation classification and the 4 digit industry classification). This was provided in January 2008, together with advice that 'Data at this level of detail should be used with caution because it is based on self-assessment and relies on the accuracy of the occupation and industry descriptions provided by the person(s) who have completed the Census form' (Australian Bureau of Statistics email advice 24 January 2008 Pers. Comm. Clare Miller ACT Regional Office).

Polling and analysis software

Internet-based polling software developed by The Australian National University called ANU Polling Online (Version 3.02 of APOLLO) [39] was used for this survey. This is a free service to ANU researchers, and it is made up of administration, polling and reporting components. It enables the automatic capture and recording of people's responses for analysis. Each response was downloaded as an RTF file and the statistics were downloaded as a CSV file and

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38 The Census and Statistics Act requires the Australian Statistician to conduct a Census on a regular basis; since 1961 a Census has been held every 5 years. The 2006 Census is the 15th national Census for Australia and was held on 8 August 2006. For the 2006 Census, first release data was available on the ABS Website on 27 June 2007, and second release data (including occupation and industry of main job required for this study) on 25 October 2007.

39 APOLLO ANU Polling Online is a tool that staff and postgraduate students can use to create and conduct web-based online polls (surveys, ballots, exams or forms)… [It]has tools and reports that allow for the analysis of poll results (including exports to SPSS).

exported to Microsoft Office Excel (2003) which was used to create a table of responses. The unit of analysis was the individual scientist.

Statistical analyses were conducted using SPSS (Version 15.0 for Windows) and qualitative answers to the open-ended questions were analysed using QSR NVIVO (Version 7 and 8).

Definitions and Categories

Australian Bureau of Statistics (ABS) categories for questions and answer options for employer (by sector and institution or organisation)[40] (ABS, 2006a, 2006b), and discipline (Australian Standard Research Classification) (ABS, 1998) were used. The four age groupings were generational descriptions that were partially based on trends in Australian birth rates provided by the ABS (McCrindle Research, 2006) and these are discussed in detail later in this section.

Scientist – a definition

Definitions of a scientist vary widely. They may or may not be restricted to those who conduct research; they may include mathematicians or statisticians or engineers for example, or they may be limited to those with academic qualifications at a particular levels (such as a PhD), or disciplines (in natural and physical sciences for example). These different definitions of a 'scientist' can make it difficult to make comparisons.

For example, in the Australian report *Supply and demand for scientists and engineers*, the term 'scientist' was not explicitly defined but information was provided separately for scientists and engineers. It was stated that 'science' covered mathematics and computer science as well as the natural sciences which were chemistry, geology, geophysics, physics and the life sciences (Borthwick & Murphy, 1998, p. 5). This separation of scientists and engineers was also made by the ABS. The ABS definition of a natural and physical science professional, however, excludes mathematicians and statisticians. They are

40 These were asked in Questions 17 (sector) and 18 (Type of organisation or institution).

categorised as information and organisation professionals[41] along with actuaries (ABS, 2006c). For the description of a scientist by the ABS (1998), see Appendix 9.

In contrast, The definition of a scientist for this study was broad because many scientists do not stop doing science or communicating about science in general, or their specialised scientific knowledge in particular, when they retire or are no longer employed as a scientist. It included not only those who were employed as scientists, but those who were no longer employed as scientists but still saw themselves (or were seen by others) as scientists. Therefore it included those who had non-research roles such as administrators, managers and teachers, or who had 'retired' as well as those without a PhD in science or even a science degree. To meet the selection criteria for inclusion in this research, they needed to answer 'yes' to at least one of three definitions of a scientist (Questions 3-5).

General public – a definition

The concept of 'general public' was defined by exclusion. For example, I excluded scientists' clients, funders, collaborators or their students ─ people they would normally communicate with through the course of their work ─ to focus scientists' responses on the 'people in the street'. This definition included scientists who are outside a scientists' specialized field. The exact wording used to convey this particular definition of the 'general public' was:

> All the following questions are about your communication with the 'general public' - a term which has many meanings. For this questionnaire 'general public' means people outside your field who are unconnected with groups or activities associated with your work or field.
>
> This means, for example, we are not asking about your communication with your colleagues, collaborators, clients, industry or government funders, students you teach, or policy makers (politicians or government officials), regulators or lobby groups.

41 Unit Group 2241 – Information and organisation professionals

This is a different definition of the term 'general public' than used, for example, in the United Kingdom survey of academics (People Science and Policy Ltd., 2006) which defined a non-specialist public as 'adults with no specialist knowledge of, or training in, science'. The 'non-specialist public' was treated as a separate group to policy-makers, journalists, teachers, young people in and out of schools, industry, business community not directly concerned with funding their research, and non-government organization (People Science and Policy Ltd., 2006, p. 25). The Swedish study was broader however, using the term 'people in general' synonymously with 'the public' (Vetenskap & Allmanhet, 2003).

Communication – a definition

It was important to clarify what I meant by communication to avoid the confusion caused for respondents in earlier surveys when such as a clarification was not included (The Royal Society, 2006a, p. 15). Bauer and Jensen (2011) were later to define public engagement as 'broad and generic', and including 'all forms of communication with non-scientific audiences'(p. 3). My definition of 'communication with the general public' was similarly broad. It was described, however, rather than explicitly defined. Instead, communication was represented through examples of different types of communication activity in 18 questions of how and with whom they communicated in the last year (See Appendix 10).

Age categories – a definition

Respondents were asked to select their year of birth from a drop-down menu that ranged from 'before 1940', and 1941 ─ 1987 inclusive. For this study, the scientists were grouped into generations devised by an Australian researcher using Australian data (McCrindle Research, 2006)[42]. The four generations are shown in Table 2.

42 McCrindle Research developed descriptions and insights for the four generations that were based on quantitative and qualitative research involving a survey of 3,000 Australians in all States and Territories (McCrindle Research, 2006).

Table 2. Four generations by year of birth

Generation names*	Year of birth	Age (years) of respondents in 2007
Generation Y	1980 — 1994	21 — 27
Generation X	1965 — 1979	28 — 42
Boomers	1946 — 1964	43 — 61
Builders	Before 1946	62+

* McCrindle Research 2006 p. 8

McCrindle identified three broad factors that differentiate generational behaviour: age or life stage of the generation; conditions (economic, social and political), interacting with people of different ages, and experiences that occur during the formative childhood and teenage years (McCrindle Research, 2006). This more refined sociological and demographic view of a generation has been recently adopted by the ABS to allow 'more meaningful comparisons [of census data] across generations' (ABS, 2009b, p. 9) as they are based not only on birth rates but take into account other factors such as significant world events and shared life experiences, which broadly determine people's social and economic history and current characteristics. The ABS also noted that, 'While each generation shares certain characteristics, it should be acknowledged that within each generation a great deal of individual variety occurs' (ABS, 2009b, p. 9).

In January 2009 (18 months after this survey was conducted in mid-2007), the Australian Bureau of Statistics published a generational view of the 2006 census data population (ABS, 2009b). Its definitions differed slightly from those that were adopted for this current study which had been published by McCrindle Research in 2006. For example, the ABS definitions combined Generation X and Generation Y into a 20-year cohort (those born 1966-1986), while McCrindle Research defined them separately as Generation X (born 1965-1979) and Generation Y (born 1980-1994).

It is recognised that 'there is no widespread agreement about the names and definitions of these generations' (ABS, 2009b, p. 9). Also these generational labels and the start and end dates of each generational category differ from source to source. This has been discussed by several authors including the Australian Bureau of Statistics (2009a, 2009b), Levy et al. (2005), Mackay (1997), McCrindle Research (2006), Salt (2007), Twenge and Campbell (2008) and Wong et al. (2008).

Though using generations to examine characteristics and differences in attitudes and experiences is not without its problems[43] (Levy, Carroll, Francoeur, & Logue, 2005; Salt, 2007), especially in distinguishing generational differences from age differences (Wong, Gardiner, Lang, & Coulon, 2008, pp. 887-888), McCrindle (2006), however, suggested that employers should be aware of the generational differences in their management of employees. For a full description of their insights for employers, see Appendix 11. Australian researcher Salt (2007) described generational differences too, but with a particular focus on the funds management industry (Appendix 12).

Occupation

The respondents were asked to select from a list of 10 ABS occupations for 'science professionals'. These were slightly expanded from the eight classifications for natural and physical science professionals specified in the Australian and New Zealand Standard Classification of Occupations (ANZSCO) First Edition (Appendix 13). This expansion separated 'Chemists' from 'Food and Wine Scientists' and 'Geologists' from 'Geophysicists' and the final list of occupations was:

Agricultural or forestry scientist e.g. agricultural consultant, forester

Chemist

Environmental scientist e.g. environmental consultant, research scientist, park ranger

Food or wine scientist

Geologist

Geophysicist

Life scientist e.g. biotechnologist, botanist, microbiologist, physiologist, zoologist

Medical laboratory scientist

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43 'These characteristics include values and principles, sense of purpose, loyalty and job security, respect for positional power, view on career development, work/life balance, learning and development and expectations of management' (Sinclair, 1999).

Veterinarian

Other natural & physical science professional e.g. conservator, metallurgist, meteorologist, physicist

Qualifications

This study aimed to include people who had a tertiary qualification according to the ANZCO classification of a scientist: 'Most occupations in this minor group have a level of skill commensurate with a bachelor degree or higher qualification' (ABS, 2006c). Participants in this study, however, were given a wider choice of tertiary qualification and it was not stipulated whether this qualification had to be in science:

Q2.* Do you have a university or other tertiary degree?

Again this was a broad definition, recognising that some people work as self-identified scientists, having gained qualifications in other areas such as teaching.

Discipline or research field

Options from which scientists' could select to describe their discipline or research field were based on the Research Fields, Courses and Disciplines (RFCD) classification which is a standard Australian research classification (ABS, 1998) The RFCD Classification (ABS, 1998) is arranged in a hierarchical structure with 24 divisions, 139 disciplines and 898 subjects. The decision was made to include 13 of the 24 divisions plus 'Other research field. Please specify'. These are shown and shaded yellow in Appendix 14 which shows all 24 divisions together with their ABS codes. For a listing of the options used for this particular questions see Appendix 15.

The Field of Research, the second element of the classification, categorises research and development (R&D) activity by academic discipline (ABS, 1998). 'This classification allows both R&D activity and other activity within the higher education sector to be categorised' (ABS, 1998). All nine Fields of Research were represented in the answer options (see Appendix 16).

Employer – by sector and type of organisation

Two questions sought information about the scientist's employer – by four sectors (Business, Government, Higher education and Private non-profit), and by type of institution or organisation, according to the 11 types of institutions offered as answer options, and the additional 'Other - Please specify'.

The latter sought information on either their current employer, or if the scientist was no longer working, the type of institution or organisation for which they 'used to work for most of the time'. To protect the anonymity of the respondents the name of their employer was not sought. A screen capture of these two questions is shown in Figure 4.

Figure 4. Current employer by sector and type - screen capture

Section 6. YOUR CURRENT EMPLOYER
(Questions marked * are mandatory)

Q17.* Which best describes the sector to which you, or your employer institution or organisation belong?
Please select one:

[▾] if Other [ ]

Q18.* Which best describes the type of institution or organisation for which you work
or, if you no longer work, used to work for most of the time?
Please select one:

- ○ Commonwealth government science or research agency e.g. AIMS, ANSTO, CSIRO, DSTO, Geoscience Australia, GBRMPA
- ○ Commonwealth government department or agency (non-scientific or non-research) including regulatory bodies e.g. DAFF, DEST, DEWR, TGA
- ○ State/Territory government science or research agency
- ○ State/Territory government department or agency (non-scientific or non-research) including regulatory bodies
- ○ Local government
- ○ Hospital
- ○ Industry
- ○ Medical research institute e.g. WEHI, Garvan Institute, JCSMR, QIMR, POWMRI
- ○ Non government organisation (NGO)
- ○ Private consultancy business
- ○ University
- ○ Other - Please specify [ ]

The questionnaire

Description

The questionnaire 'Scientists and science communication in Australia', consisted of 61 questions, presented on 18 separate web pages. Only completed questionnaires were captured by the polling software.

The questions focussed on the opinions and activities of the scientists that were based on their own experience of communicating their specialised knowledge with the general public. There was a mixture of question types in terms of the content sought: 43 were factual (18 of these were demographic questions) and 18 were questions about the scientist's opinions.

Forty were closed response questions. Ten were a mixture of closed and open questions, and asked respondents, for example, to select from a list. To capture options not listed, questions asked 'Other …please describe'. There were 11 open response questions such as 'Please comment on your answer'. The rationale for these questions is discussed in the next section.

Piloting of the questionnaire suggested that people would take about 17 minutes to complete the questionnaire. The APOLLO software records the time that each respondent takes to complete the questionnaire and the actual median time taken was 19 minutes, and completion times ranged from 5—81 minutes.

Rationale for questions

The first five questions were filter or screening questions to ensure that the survey results represented the activities and views of scientists living in Australia, who had a tertiary qualification (not necessarily in science) and who identified themselves as a scientist. These criteria were used to exclude ineligible respondents and were first specified in the introduction to the poll, and then repeated in the first mandatory questions (indicated with *) of the questionnaire as follows:

Q1.* Do you live in Australia?

Q2.* Do you have a university or other tertiary degree?

Q3.* Are you employed as a scientist?

Q4.* AND/OR do you identify yourself as a scientist?

Q5.* AND/OR are you identified by others as a scientist?

There were then 13 demographic questions that asked about:

Sex, Location and Year of birth (3 questions)

Occupation, Employment and Role (3)

Qualifications – highest and year of completion (2)

Current discipline, Field(s) of interest, and Membership of professional society, institute or association (3)

Current employer (2)

The next group of questions explored the type and frequency of scientists' communication and what they communicated with the general public. At the

No	Once	2-10 times	>10 times

same time, these questions implicitly defined, by giving examples, what was meant by 'communication' and explicitly defined the 'general public'.

There were four response categories for respondents to describe their frequency of communication within the previous 12 months:

> 'Have you communicated your specialised knowledge with the general public in Australia over the past 12 months:

These differed from frequency categories used in other surveys. For example, the People Science and Policy survey (2006a, p. 46), used five frequency categories: None Once, times, 4-5 times and 'More than 5 times. In this study, the broader '2-10 times' frequency category reflected this researcher's experience as a scientist and science communicator that a single, reasonably successful media release generates several interviews for a scientists with the press, television and radio in Australia. The '>10 times' option was therefore designed to identify the scientists' whose communication may be associated with more than one media release, for example. It is appreciated, however, that this study asks about much more than scientists' communication through the media.

Scientists were then asked in two separate questions whether they benefited professionally or personally from communicating their work or specialised knowledge with general public. An open-ended format allowed for the full range of user-generated responses. The questions focussed on the scientists' own experience; not on whether their employer or the scientific community benefited from their communication:

> Q41.⁕ In your opinion, do you benefit professionally from communicating your work and/or specialised knowledge with the general public?
>
> Q42. If yes, please give examples of how it benefits you (list or dot points):
>
> Q43.⁕ In your opinion, do you benefit personally from communicating your work and/or specialised knowledge with the general public?
>
> Q44. If yes, please give examples of how it benefits you (list or dot points)

Scientists' workplace culture and communication skills

The scientists' workplace culture was explored by questions which asked whether communicating with the general public was part of the scientists' job, and whether it was financially rewarded, recognised or acknowledged in any way.

> Q45.⁕ Is communicating with the general public part of your job description/duty statement or project requirement?
>
> Q46.⁕ Is communicating with the general public expected by your employer?
>
> Q47.⁕ Does your institution or organisation financially reward your communication with the general public?
>
> Q48.⁕ OR does your institution or organisation otherwise recognise or acknowledge your communication with the general public?
>
> Q49. If yes to either question, how?

How skilled scientists felt they were in communicating with the general public, and why, was next.

Q50.⁕ How skilled do you feel you are to communicate your specialised knowledge with the general public?

Q51. Please comment on why you said that:

Hindrances to scientists' communication were explored through open questions:

Q52.⁕ Does anything hinder you from communicating in the way you would like with the general public?

Q53. If yes, please describe (list or dot points):

What would help scientists most was then identified using a closed question with options drawn from previous questionnaires and the pilot testing for this survey:

Q54.⁕ If you want or have to communicate with the general public, what, if anything, would help you most to communicate in the way you would like?

Four questions (Q55 — Q58) about the need for more effective one-way and two-way communication were intended to draw out scientists' views about the rhetorical trend by scientific leaders toward a two-way communication between scientists and society as noted in Chapter 2.

How strongly do you agree or disagree with the following statement:

Q55.⁕ There is a need for more effective one-way communication of knowledge and views from the scientific community to the general public?

Q56. Please comment on your answer:

How strongly do you agree or disagree with the following statement:

Q57.⁕ There is a need for more effective two-way communication of knowledge and views between the scientific community and the general public?

Q58. Please comment on your answer:

The penultimate question (Q59) explored whether respondents felt that scientists in general had a responsibility to communicate with the general public. It is a modified version of statements in The Royal Society publication, titled *Science and the Public Interest: Communicating the results of new scientific research to*

the public, which assert that all scientists have a responsibility for communication with the general public:

> The research community, within both the public and private sectors, needs to shoulder two main responsibilities in relation to public interest matters….The first is to attempt an accurate assessment of the potential implications for the public. The second is to ensure the timely and appropriate communication to the public of results if such communication is in the public interest. These twin responsibilities ought to be embedded within the culture of the research. (The Royal Society, 2006b)

It appears, through the public rhetoric in Australia discussed in Chapter 3, that government-funded scientists in particular are expected to communicate with the public that funds them. However the wording of The Royal Society (The Royal Society, 2006b), clearly states that all scientists, 'within both the public and private sectors' have a responsibility for communication with the general public. Did this statement ignore the workplace realities for scientists, particularly those working in the private sector or was it alluding to the Mertonian norm of communism? To find out what Australian scientists thought, the question for this study, a paraphrase of the Royal Society statements, was worded as follows:

> Q59.* How strongly do you agree or disagree with the statement:
>
> Scientists, within both the public and private sectors, have a responsibility to ensure the timely communication to the public of research results that are in the public interest.

The Likert scale options ranged from 'Very strongly agree' to 'Very strongly disagree' and there was an 'I have no opinion on this topic' option. They could also comment on their response.

Note that the statement specified that scientists have 'a' responsibility; not 'the' or 'sole' responsibility. The question was not directly asked in this questionnaire as to whose major responsibility it is to communicate scientists' specialist knowledge to the general public (e.g. research managers, science communicators, science journalists). This was a complex and multi-faceted statement that included a number of different and unexplained and undefined

concepts. Its purpose, however, was to encourage scientists to share their views, and in this regard it proved very successful as will be shown in Chapter 7.

The last question of the survey (Q61) provided an opportunity for the participants to volunteer their own information or comments.

These questions are summarised in Appendix 17 ─ Appendix 19: the first is a list of questions in the order in which they were presented (Appendix 17). This shows the logic of the survey with screening and demographic questions at the beginning, factual descriptive questions in the middle and opinion questions at the end. Appendix 18 is a screen capture of the first two pages of questionnaire. Page layout, font, colour, and different answer methods such as drop-down menus and check boxes, were designed to create an attractive user-friendly online format that facilitated understanding and answering of the questions. Appendix 19 groups the questions into screening, demographic, communication activities and questions about scientists' opinions.

Analysis of Communication Activity

To summarise how much scientists communicated with the general public, a 'communication score (total)' was calculated for each scientist by adding up the scores given to each communication frequency option for each of the questions Thus a scientist's 'communication score (total)' could potentially range from 0 ─ 54' as each question had four possible rating for each (0 ─ 3). Therefore the maximum communication score (total) score of 54 would be achieved if a scientist scored the highest score of 3 for each of the 18 questions (Appendix 20).

Analysis of Qualitative Responses

The words that scientists wrote in answer to the open-ended questions were first sorted into emergent categories. This was achieved through iterative passes which grouped them into categories that maximized similarity within and differences between them. They were organised and re-organised using Excel (2003). Each pass enabled a further refinement of the concepts or themes of these emergent groupings. Then the initial number of categories was further grouped into larger representative groupings. This coding was cross-coded by three science communication researchers. The emergent themes were entered

into QSR NVIVO software, and responses were manually sorted. Subsequent analyses were conducted using both NVIVO and Excel.

Limitations of Research Methods

Survey methods, like any other research method, have their limitations (C. Marshall & Rossman, 1995; Punch, 2003; Rowe, et al., 2006). For example, the quality of the data in self-administered, self-reported questionnaires, as used in this survey, is dependent upon the respondents for its reliability. Critique of the methodology could also suggest that the sample population may over-represent scientists with a positive view about science communication or a personal or general interest in scientists' communication in Australia. To explore this assumption, scientists were asked 'How important is it you personally that you communicate your specialized knowledge with the general public?' Gaining a representative sample of scientists across government and private employment sectors is not controlled using this non-random, self-selected, partial 'snowball' technique of participant recruitment. It was known that according to the national census', most scientists were employed in Industry. That is one of the reasons for approaching Science & Technology Australia (STA) (formerly known as the Federation of Australian Scientific and Technological Societies (FASTS) to encourage the participation of scientists beyond government and academia. The APOLLO polling software also enabled any strong skews towards one sector or another to be identified as the completed questionnaires were collated. When it became obvious that relatively fewer scientists from the private sector were responding to the survey, it was rolled out to those with links to industry such as the Cooperative Research Centres (CRCs), Medicines Australia, Ausbiotech Ltd and the Association of Professional Engineers, Scientists & Managers, Australia (APESMA)

The response rate for this questionnaire could not be estimated because the number of scientists in Australia who actually received an invitation to participate is unknown.

The disadvantage of online surveying pointed out by some researchers, that 'not everyone has access to a computer' (Rowe, et al., 2006, p. 354), is unlikely to apply to many scientists in Australia. Research also indicates that while online questionnaires were more likely to attract a representative sample in terms of the

ratio of men to women (Diment & Garrett-Jones, 2007; Ono & Zavodny, 2003; Rowe, et al., 2006), it may possibly discriminate against older respondents (Rowe, et al., 2006). Older specialist populations, such as scientists, however, were not expected to fit this characterisation because of their higher education and income in Australia.

Note on other National Surveys of Scientists' Communication

The survey questions for this study were developed with an awareness of other survey questionnaires and research findings focussed on scientists' communication with the general public in countries such as the United Kingdom, Denmark, Sweden, the United States of America, the European Commission and New Zealand. Comparisons with other surveys, to determine if Australia's scientists were different in their activities and views about science communication to scientists in other modern western countries, can be made at a general level in terms of purpose and focus, although it was not the primary aim of this research.

Any direct comparisons, however, between particular questions in national surveys are limited by their different purposes, different groupings of scientists sampled, and different definitions. For example, the differences in this study's definition of 'scientist' and 'communication' or 'general public'; the employer sectors sampled, the inclusion of retired scientists, and the definition of particular disciplines, limit direct comparisons for particular questions.

My study, for example, extended beyond academia and government agencies to give voice to scientists in the private sector. In this it differed from university-based or higher education institution scientists that were the survey populations in the United Kingdom (People Science and Policy Ltd., 2006) and Denmark (Nielsen, et al., 2007), or government researchers that were surveyed in France in 2004 ─ 6 (Jensen & Croissant, 2007).

This Australian survey is, however, narrower in scope than other surveys (Nielsen, et al., 2007; People Science and Policy Ltd., 2006; Vetenskap & Allmanhet, 2003) in one regard – the sampling strategy did not include engineers. This study did not aim specifically to include (or exclude for that matter) technologists either, as were surveyed together with scientists in New Zealand (Sommer & Sommer, 1997). Although engineers, mathematicians,

statisticians and science primary and secondary teachers were not included amongst the occupational groups specifically approached to participate in this survey, if any regarded themselves as scientists, their responses were included.

This research, unlike the 2006 UK study, was not 'Designed to be representative of scientists and engineers [some 60,000 individuals] undertaking research in UK higher education institutions (People Science and Policy Ltd., 2006a, pp. 3, 43)'. Rather, it aimed to document the range of views and activities of Australia's 60-70,000 ABS-categorised scientists around their communication with the general public.

Chapter Summary

As little is known about scientists' communication with the public, especially in Australia, this study aimed to establish a descriptive baseline. The survey was designed to encourage participation from male and female scientists of all ages across Australia, employment sectors and disciplines, using an Internet-based questionnaire. The questionnaire was completed in mid-2007 by 1,521 scientists, all of whom who had a tertiary qualification and identified themselves as scientists according to at least one of five criteria.

Quantitative and qualitative data were collected through 61 open and closed response questions to describe the activities and views of scientists. The data were analysed using quantitative analysis (SPSS) and qualitative (NVIVO) software and the manual sorting of written answers into emergent categories using Excel software.

This study's limited comparability with national surveys elsewhere because of different survey populations; definitions of 'scientists', 'general public' and 'communication'; and differing demographic categories such as discipline for example, was discussed. Chapter 7 presents the survey results that answer the six research questions posed by this study.

CHAPTER 7. RESULTS

Introduction

The chapter presents the results from the Internet-based questionnaire, 'Australia's scientists and science communication' completed mid-2007 by scientists who lived in Australia and had a university or other tertiary qualification. It begins with a description of the survey sample and is followed by the results which addressed this study's six research questions:

1. Do scientists think that it is their responsibility to communicate with the general public?
2. Do scientists believe that there are any benefits for them to communicate with the general public?
3. Is communication with the general public personally important to scientists?
4. What do Australia's scientists currently do to communicate with the general public?
5. Does anything hinder scientists from communicating in the way they would like with the general public?
6. Are there areas for improvement to facilitate communication between scientists and the general public?

Description of the Sample

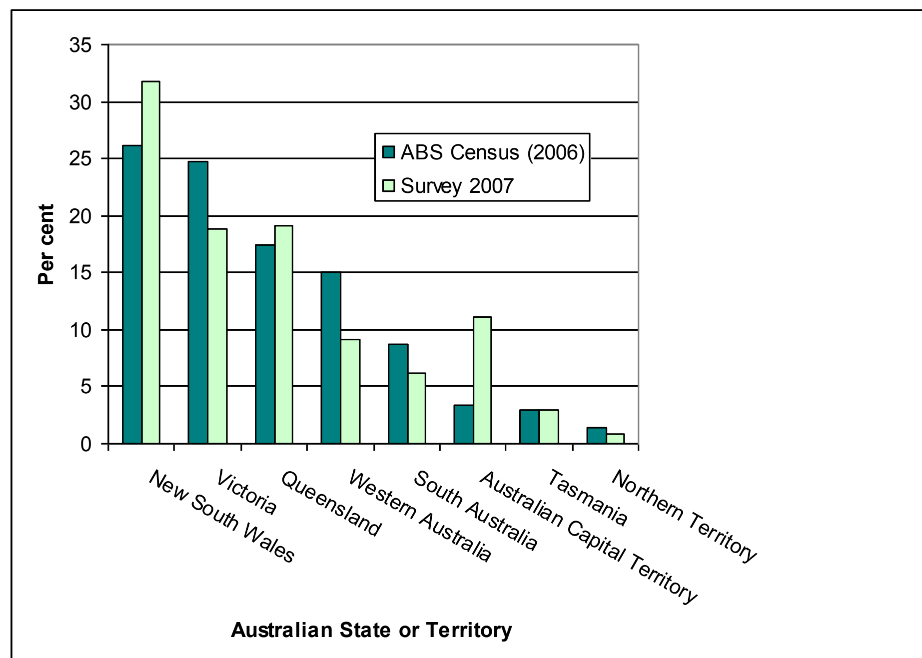
The questionnaire was completed by 1,521 scientists in mid-2007. According to the Australian Bureau of Statistics (ABS) 2006 Census of Population and Housing conducted in August 2006, there were 67,665 self-identified employed scientists living in Australia. The survey sample was approximately 2.3% of Australia's scientists.

Geographic location (Australian State or Territory)

Scientists from all States and Territories of Australia participated in this study, therefore making it a national study. Compared with the geographic distribution of scientists according to the national 2006 Census (ABS, 2006b) scientists were

over-represented in New South Wales, Queensland and the Australian Capital Territory, and under-represented in Victoria, Western Australia, South Australia and the Northern Territory. Nearly one-third (483) of the respondents were from New South Wales where just over a quarter of Australia's scientists live. There was a disproportionately large number of respondents from the Australian Capital Territory (170 or 11.1%), compared to the number of scientists who live there (2,316 or 3.4%). (See Figure 5).

Figure 5. Australian distribution of scientists in study (2007) and Census (2006)



How respondents identified as a scientist

The intention of this survey was to include as many scientists living in Australia as possible and the definition of 'scientist' was broad. To meet the selection criteria for inclusion in this research, they needed to answer 'yes' to at least one of the three definitions of a scientist (Questions 3-5). Most (1,262 or 83.0%) respondents answered yes to all three. Almost all (97.2%) were identified by others as scientists; a similar percentage identified themselves as scientists. A slightly lesser number, were employed as scientists (85.3%) while the reminder (14.7%) were not employed as scientists.

There were small groupings of scientists who met different combinations of these criteria. For example, twenty-three (1.5%) scientists were identified by

others as scientists, but did not see themselves as such, nor were they employed as a scientist (none of these were retired). Nineteen (1.2%) identified themselves as scientists, but were not employed as or identified by others as scientists (one was retired). Fourteen (0.9%) were not identified by others as scientists, but were employed as scientists and identified themselves as scientists, and nine people (0.6%) were employed as scientists but did not identify themselves or were not identified by others as scientists. There was no clear relationship between people who described themselves thus and their occupation, role or qualifications.

Highest completed qualification

More than half of the respondents had at least a doctoral degree as their highest completed qualification. Over one-third (39.1%) had bachelor degrees (including honours), a Masters or a Graduate diploma degree. See Table 3 for the frequencies of these qualifications.

Table 3. Highest completed qualification – frequency

Highest completed educational qualification	Frequency	Per cent
Doctorate degree	886.0	58.3
Bachelor (including Honours)	373.0	24.5
Masters degree	159.0	10.5
Graduate Diploma	61.0	4.0
Doctor of Science (DSc)	13.0	0.9
Diploma	11.0	0.7
Graduate Certificate	10.0	0.7
Certificate	5.0	0.3
MPhil (Master by research)	2.0	0.1
Medical degree	1.0	0.1
Total	1,521	100

Occupation

Scientists were asked to select their current occupation from a list of ten science professionals' occupations as outlined in Chapter 6. Most (81.7%) selected natural and physical science professional occupations and these are bolded in the

list used to generally classify scientists' occupations into ABS categories (plus retired and unemployed scientists). See Table 4.

Just over half (52.7%) of all scientists selected the following occupations as best describing their own: they were either life scientists, environmental scientists, agricultural or forestry scientists, chemists, or food or wine scientists.

An additional 19.9% were natural and physical science professionals who did not recognise themselves in any of the explicitly stated natural and physical ABS science categories. It is interesting to note that these ABS-defined options were not particularly helpful to a number of scientists (17%) who apparently did not readily recognise their occupation in this limited list. They thus selected 'Other' and then typed in what it was. Their answers therefore had to be subsequently categorised according to ABS categories (across all occupation categories).

An exception was 'Adviser: scientific, research, medical information' which was created by the researcher to represent three respondents.

There were 55 mathematicians/statisticians who identified themselves as scientists in this study. Mathematicians and statisticians are not classified as science professionals by the ANZSCO (2006) classification of occupations. There they are grouped under 'Information and Organisation Professionals' rather than 'Natural and Physical Science Professionals'. There were also engineers and Information, Communication and Technology (ICT) professionals who identified as scientists in this survey. These three occupations are not classified as a science profession and are highlighted in Table 4. It is also interesting to note the broad range occupations in which scientists work; such as specialist managers, health and medical professionals, social and education professionals, as well as the number of these which do not obviously include research. This confirms that the terms 'scientist' and 'researcher' are not interchangeable. The Natural and physical science occupations (ABS, 2006c) are bolded in Table 4.

Table 4. Scientists' occupations – frequency

Occupations	No.	%
Life scientist e.g. biotechnologist, botanist, microbiologist, physiologist, zoologist	**350**	**23.01**
Other natural & physical science professional e.g. conservator, metallurgist, meteorologist, physicist, astronomer	**303**	**19.92**
Environmental scientist e.g. environmental consultant, research scientist, park ranger	**212**	**13.94**
Agricultural or forestry scientist e.g. agricultural consultant, forester	**125**	**8.22**
Chemist	**90**	**5.92**
Mathematician/statistician	**55**	**3.62**
Medical laboratory scientist	**48**	**3.16**
Geologist, geophysicist, geochemist	**64**	**4.21**
Engineering professional/chemical & mechanical engineer	**29**	**1.91**
Food or wine scientist	**26**	**1.71**
Information, communication & technology (ICT) professional	**25**	**1.64**
Veterinarian	**25**	**1.64**
Specialist manager	23	1.51
Health professional/medical professional	21	1.38
Social professional e.g. geographer, anthropologist	21	1.38
Retired	20	1.31
Education professional	19	1.25
Science communicator	6	0.39
Economist	5	0.33
Manager - Chief Executive	5	0.33
Other information & organisational professional	5	0.33
Student (post-graduate)	5	0.33
Policy analyst	4	0.26
Adviser: scientific, research, medical information (author's cat.)	3	0.20
Commonwealth public servant	3	0.20
Judicial & legal professional	3	0.20
Other specialist manager	3	0.20
Science technician	3	0.20
Gallery museum & tour guide	2	0.13
Health & welfare support worker	2	0.13
Journalist & other writers	2	0.13
Sales, marketing & public relations	2	0.13
Contract, program & project administrator	1	0.07
Engineer, ICT & science technician	1	0.07
Internal medicine specialist	1	0.07
Management consultant	1	0.07
Medical technician	1	0.07
Miscellaneous education professional	1	0.07
Occupational & environmental health professional	1	0.07
Other engineering professional	1	0.07
Pharmacist (1), Registered nurse (1)	2	0.14
Telecommunications engineering professional	1	0.07
Unemployed (chemist in this case)	1	0.07
Total	1,521	100.0

Role

Twelve role categories were offered in the questionnaire as options[1]. The responses were categorised into 29 role categories which showed a greater complexity in scientists' roles than anticipated. These are shown in Table 5 where the original 12 options (plus 'Other – please specify') are shaded. Most (69.2%) of the respondents had either research only roles (28.4%); research and management (26.3%) or research and teaching roles (14.5%).

The attempt to categorise scientists' roles around research, teaching, administration and management appears to have represented most (89.3%) but not all that they do. It did not, for example, describe the mentoring, development/commercialisation, extension and policy roles of some scientists. The offered options failed to represent the role of 15 scientists involved in 'Analysis/diagnosis/testing/assessments', or those of 'clinical practitioners' (13), and 'operational meteorologists' (12).

Some 'retired' scientists were obviously involved in research, management, consulting, advising and mentoring (3.7%). Thus the use of the word 'retired' was not particularly useful for this question as many scientists who have retired from full-time paid employment still have active roles in and contribute to academia and/or research, including communication with the general public.

1 Plus 'Other – Please specify' and 'Not applicable'

Table 5. Scientists' roles in decreasing order of frequency

Scientists' roles and the original 12 options offered in the questionnaire are shaded yellow. The unshaded roles emerged from scientists' answers.

Role	Frequency	%
Research (only)	432	28.4
Research & management	401	26.3
Research & teaching	221	14.5
Technical research support	82	5.4
Consultant	52	3.4
Management & administration	47	3.1
Retired & research & management	30	2.0
Adviser	29	1.9
Management (only)	22	1.4
Other - please specify	19	1.2
Retired & consultant	18	1.2
Other research support	17	1.1
Teaching & management	16	1.1
Analysis/diagnosis/testing/assessment	15	1.0
Teaching (only)	13	0.9
Clinical practitioners	13	0.9
Operational meteorologist	12	0.8
Retired	11	0.7
Research, management & student mentoring	10	0.7
Retired & adviser	9	0.6
Clinical support & research	8	0.5
Communication/extension	8	0.5
Administration (only)	7	0.5
Research & development/commercialisation &/or extension	7	0.5
Technical (non-research) support	7	0.5
Policy development/implementation/regulation	6	0.4
Quality assurance/control (only)	4	0.3
Student	3	0.2
Research & quality assurance/control	2	0.1
Total	1,521	100

Sex distribution

Many more males (1.5 times) than females participated in this study and the ratio of male to female respondents was within 2.3% of the national average (2006 ABS Census).

Table 6 illustrates the close relationship between the frequency of sex distribution of scientists in the 2006 Population and Housing Census, and this survey.

Table 6. Sex distribution of scientists – frequency

Sex	2006 Census No.	%	2007 Survey No.	%
Males	39,514	58.4	923	60.7
Females	28,151	41.6	598	39.3
Total	67,665	100	1,521	100

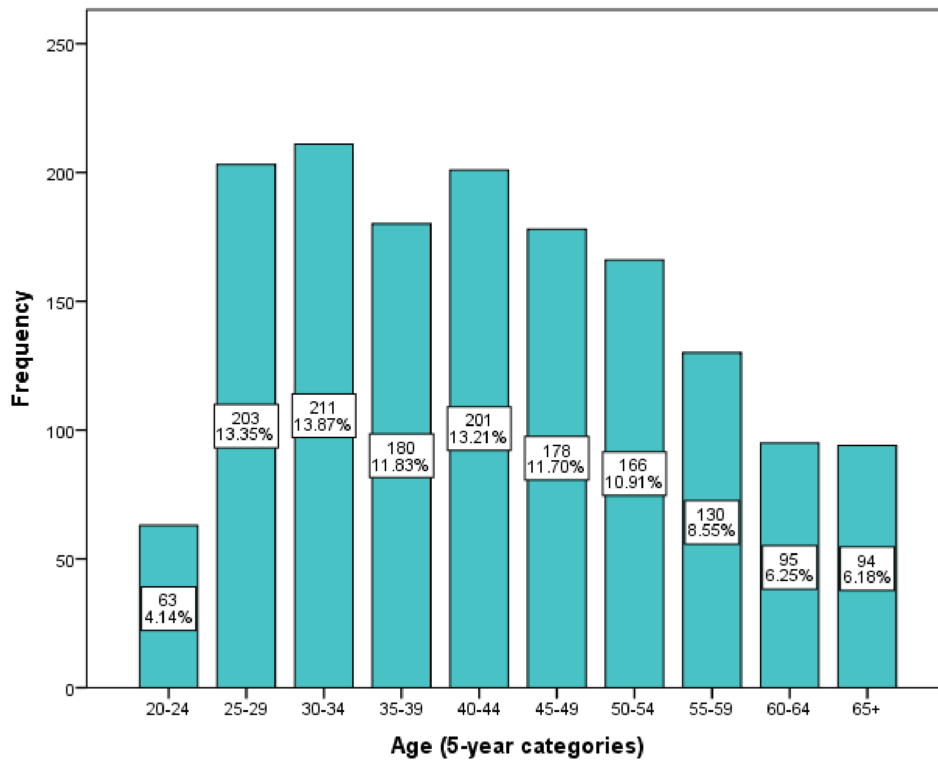
The age of scientists

There was a broad distribution of respondents by age. Respondents were asked to select their year of birth from either 1940 or earlier, or any single year from 1941 to 1987. Seventy-one scientists were 76 or older and the youngest five were 21. The mean age of the respondents was 43 (SD = 12.5). Overall there was a slight skew towards the younger ages (skewness 0.264).

In the group of 189 scientists who were aged 60 years and older, there were 167 males and 22 females. About half of those were over the retirement age of 65. The average age for the 923 male respondents was 46.4 years (SD = 12.4) and for the 598 females, it was 37.7 years (SD = 10.7).

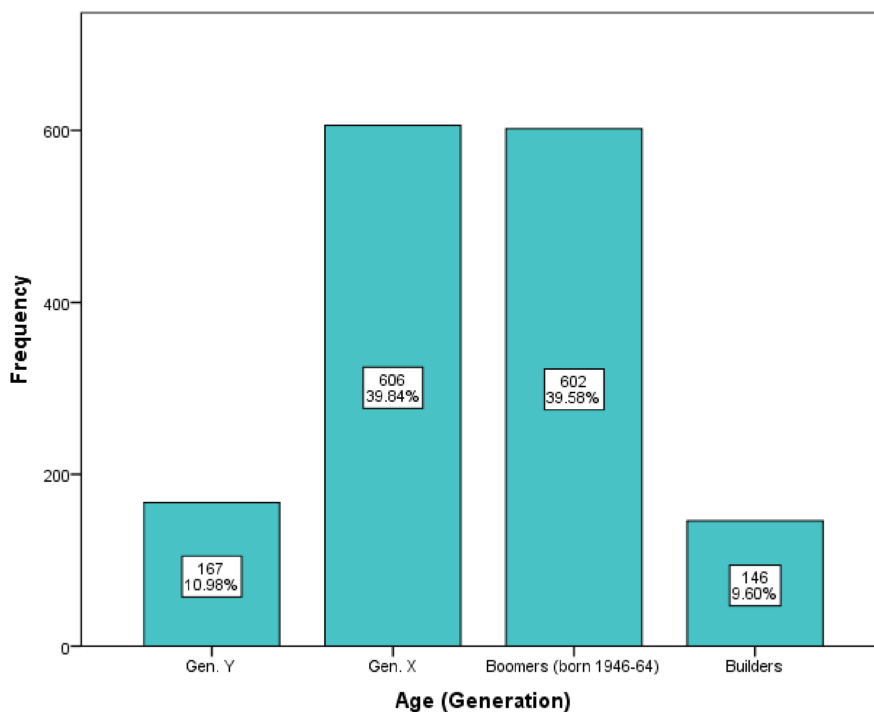
Grouping respondents' ages into five-year age categories, the most frequent were 25─29 (203 scientists), 30─34 (211 scientists) and 40─44 (201 scientists). See Figure 6.

Figure 6. Age distribution (five-year categories) — frequency



There were almost equal numbers of scientists in Generation X and the Boomers, and together they made up 79.4% of the survey population (Figure 7).

Figure 7. Age distribution x Generation



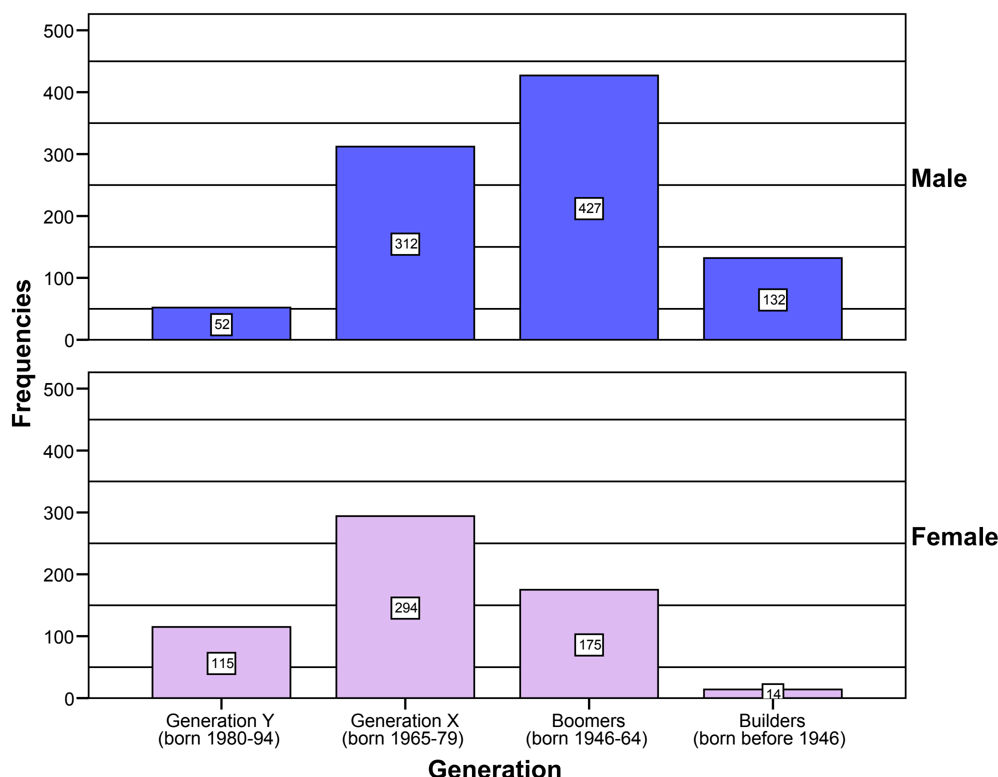
The pattern of scientists' age distribution differed markedly between the sexes with males dominating the age categories over 40 and a slight skew (skewness = -0.007). On the other hand, for females the age distribution was more strongly skewed (skewness = 0.650) toward the younger ages, with 39.9% of all females aged 25-34 years (See

Figure 8).

Figure 8. Age distribution of in 5-year categories x sex

Looking at the distribution of males and females across the generations there were large differences in the ratio of males to females within each of the four generations represented in the survey. These differences are graphed in Figure 9.

Figure 9. Sex x Generation— Frequency



A significant relationship existed between the sex and the age of scientists in this survey: in the youngest generations (X and Y) there were relatively more females than males, and the in the older generations (Boomers and Builders), relatively more males than females (Pearson Chi-Square $\chi 2$ (df = 3, n = 1,521) = 163.165, p = 0.000, Cramer's V = 0.33).

Discipline

Respondents were asked to select from a list of 13 categories (ASRC 1988), the one that most closely described their discipline or research field. There were 11 'science only' categories and two others: 'Architecture, urban environment and building', and 'Social Sciences, humanities and arts'. If none of these was appropriate, respondents were able to specify their research field. Table 7 shows frequencies for a total of 17 categories. Three additional ABS categories:

‘Journalism, librarianship & curatorial studies’, ‘Economics’, and ‘Studies in human society’ were added to the results to include additional disciplines/research fields specified by respondents.

Analyses by discipline or research field have been limited to the eight categories with 50 or more scientists (≥3.3% of the total number of scientists). These eight categories are shaded blue on 7 and represent 1,426 scientists and will be referred to as ‘Discipline’ in the remainder of this thesis.

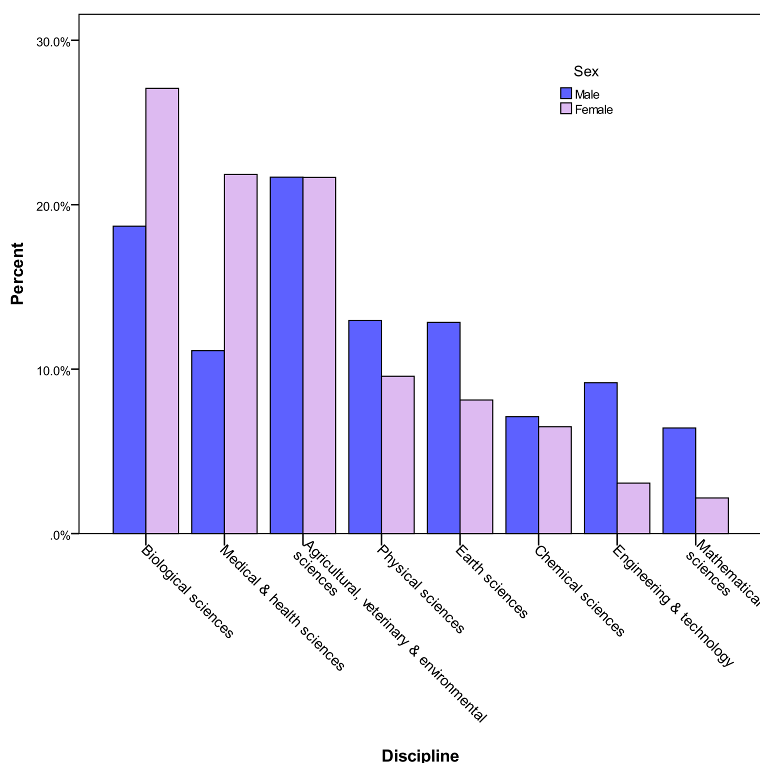
Table 7. Current research field, course or discipline - frequency*

Current research field, course or discipline (ASRC)	Frequency	%
Biological sciences	313	20.6
Agricultural, veterinary & environmental sciences	309	20.3
Medical & health sciences	218	14.3
Physical sciences	166	10.9
Earth sciences	157	10.3
Chemical sciences	98	6.4
Engineering & technology	97	6.4
Mathematical sciences	68	4.5
Information, computing & communication sciences	35	2.3
Social sciences, humanities & arts	17	1.1
Behavioural & cognitive sciences	15	1
Journalism, librarianship & curatorial studies	8	0.5
Economics	6	0.4
Architecture, urban environment & building	6	0.4
Science (general)	5	0.3
Other	2	0.1
Studies in human society	1	0.1
Total	1,521	100

Discipline and sex distribution

All the discipline groupings were male-dominated with the exception of Medical and health sciences (males 44.5%: females 55.5%) as can be seen in Figure 10.

Figure 10. Discipline x Sex – frequency



There was a medium strength[2] association between Discipline and Generation ($\chi 2$ (df = 21, n = 1426) = 54.53, Cramer's V = 0.113). For example, the majority of Generation X (144 or 25.5%) and Generation Y (39 or 25.0%) were in the Biological sciences and the majority of Boomers (158 or 27.9%) were in the Agricultural, veterinary and environmental sciences (

Table 8).

[2] This was a medium-sized effect using Cohen's 1988 criteria.

Table 8. Discipline x Age (Generation) – frequency

Age in 2007 Discipline	Generations Builders (62+)	Boomers (43–61)	Gen. X (28–42)	Gen. Y (21–27)	Generation sub-total
Biological sciences	24	106	144	39	313
Agricultural, veterinary & environmental sciences	17	158	109	25	309
Medical & health sciences	21	73	92	32	218
Physical sciences	20	67	62	17	166
Earth sciences	18	63	60	16	157
Chemical sciences	13	27	48	10	98
Engineering & technology	15	38	33	11	97
Mathematical sciences	11	34	17	6	68
Discipline sub-total	139	566	565	156	1426

A closer examination of age distribution showed that the frequency of scientists peaked in their late 20's in two disciplines. For those in the Biological sciences there was a peak at ages 28, 29 and 30. Those in the Medical and health sciences peaked at 27 and 28.

Discipline and employer institution/organisation

Examination of the relationship between discipline and employer showed that most of the scientists in the Biological sciences were employed in universities or the government sector. These tended to be younger ($\bar{x}$ = 40.6 years) and female (47.4%). Most of the scientists in the Agricultural, veterinary and environmental sciences were employed by State/Territory/Local government departments or agencies. Males (61.7%) strongly outnumbered females (38.3%) in this category. Relatively more scientists in the Earth sciences were employed by Commonwealth government agencies/departments than any other discipline.

Government was the major employer of scientists in the 'Agricultural, veterinary and environmental sciences' (68.2% of the scientists), the average age of respondents was 44.6 years (SD = 11.2) and males outnumbered females (61.7% males: 38.3% females). In the Biological sciences, the scientists were principally employed by either the higher education sector (44.9%) or the government

sector (42.3%), were on average younger ($\bar{x}$ = 40.6 years, SD = 12.2) and there were relatively more females (52.6% males: 47.4% females).

Employer – type of institution/organisation

Most of the respondents in this study were employed in the Higher education and Commonwealth government sectors. Just over half worked in the government sector and of these, most worked for the Commonwealth (30.6%). Roughly a third of respondents (33.8%) worked in the Higher education sector and just under one-tenth worked in the Business sector (See Table 9).

Table 9. Employer institution/organisation – frequency

Employer sector/institution/organisation	Frequency	%
Higher education	514	33.8
Government (Commonwealth)	466	30.6
Government (State)	236	15.5
Business	137	9.0
Government (General)	81	5.3
Private non-profit	61	4.0
Cooperative Research Centre (CRC)	16	1.1
Government (local)	5	0.3
Other	3	0.2
Not applicable	2	0.1
Total	1,521	100.0

Employer sector/institution/organisation with levels of Government collapsed into one category	Frequency	%
Government	788	51.8
Higher education	514	33.8
Business	137	9.0
Private non-profit	61	4.0
CRC	16	1.1
Other	3	0.2
Not applicable	2	0.1
Total	1,521	100

As with the discipline groupings, however, only employer groupings with 50 or more scientists (representing ≥3.3% of 1,521 scientists) were used for further analyses[3]. The frequency distribution for the remaining seven employer categories is shown in Table 10.

Table 10. Employer – institution/organisation (with > 50 scientists) – frequency

Type of employer institution/organisation with >50 scientists	Frequency	Per cent
University	492	32.3
Commonwealth government agency/department	485	31.9
State/Territory/local government department or agency	254	16.7
Industry	85	5.6
Hospital	74	4.9
Medical research institute	55	3.6
Private consultancy business	51	3.4
Sub-total	1496	98.3
Other (including Non-government organisations (19)	25	1.6
Total	1,521	100

Current employment situation

Scientists were asked about their current employment situation and it was found that just over half of the 1,521 scientists had permanent, indefinite or tenured positions. Thirty-eight percent were either postgraduate students or on short-term contracts (Table 11).

Table 11. Current employment situation – frequency

Current employment situation	Frequency	Per cent
Permanent/indefinite/tenured	829	54.5
Term contract	441	29.0
Student (postgraduate)	136	8.9
Self-employed	44	2.9
Retired	68	4.5
Unemployed	3	0.2
Total	1,521	100

[3] This meant that the sixteen people who wrote that they worked for Cooperative Research Centres (CRCs)3 – an employer option not offered - were initially included in a separate emergent category but as there were less than 50 scientists in this category, they were excluded from the final analyses. No doubt a number of the respondents worked cooperatively in CRC programmes, but selected their employer instead of a CRC.

Employment situation and Sex

Twice as many males (67.1%) than females (32.9%) had permanent positions. There were almost equal numbers of males and females on term contracts. Of the 136 who were students (postgraduate), the majority were female (69.8%) and of those who were retired, 88.2% were male. Of the forty-four people (2.9%) who were self-employed, 75% were males. (See Table 12). This association between sex and employment situation was significant ($\chi2$ (df = 5, n=1,521) = 108.126, p<.001).

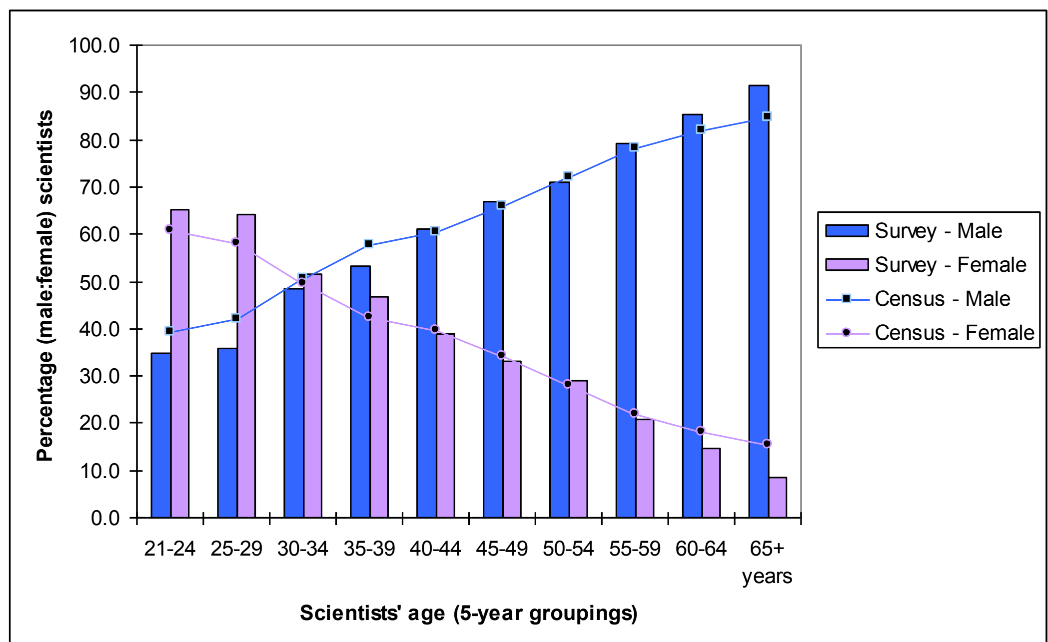
Table 12. Employment situation x Sex – frequency

	Sex	
Employment situation	Male	Female
Permanent/indefinite/tenured	556	273
Term contract	230	211
Retired	60	8
Student (postgraduate)	41	95
Self-employed	33	11
Unemployed	3	0
Total	923	598

National Representativeness of survey sample

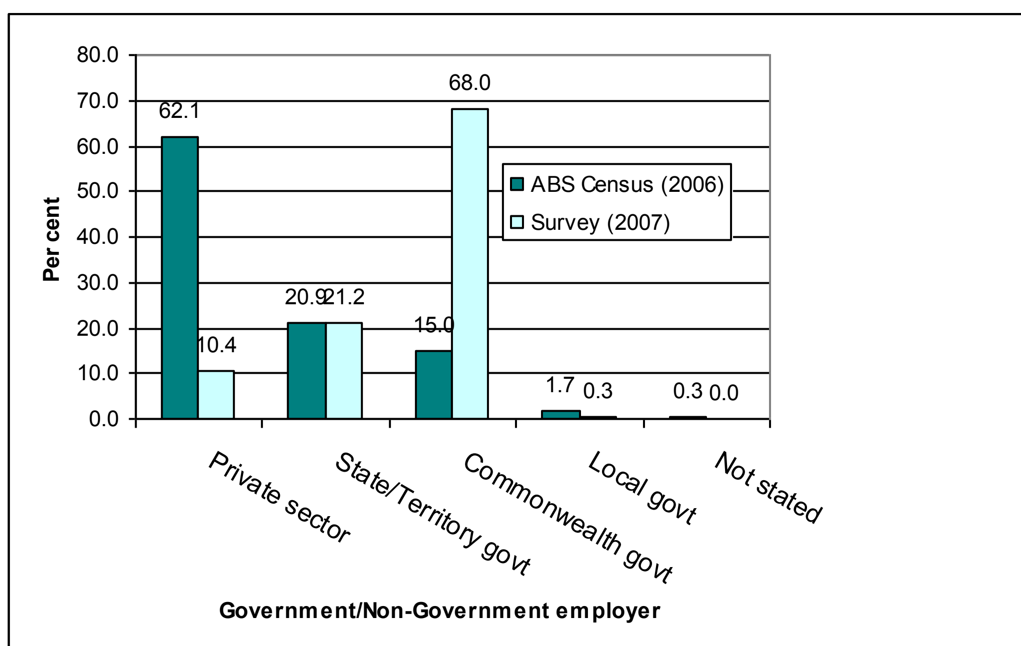
The following section compares the survey sample with the number and distribution of scientists in Australia by sex, age, sector, and occupation using ABS data. For example, the survey sample was representative of the age/sex distribution of scientists in Australia as recorded in the last Population and Housing Census (ABS, 2006b). The very close correspondence between the age and sex distribution of the survey respondents compared to the distribution for Australia's scientists in the census can be seen in Figure 11.

Figure 11. Age (5-year groupings) x sex (%) distribution – for '07 survey & '06 Census



In this study, relatively more scientists were employed within the Commonwealth Government[4] and relatively fewer employed within the private sector than recorded by the 2006 Census. A comparison between percentages of scientists across government/non-government employer sectors for the Census (2006)[5] and survey (2007) illustrates this difference (Figure 12).

Figure 12. Distribution of scientists in government/non-government employer sectors

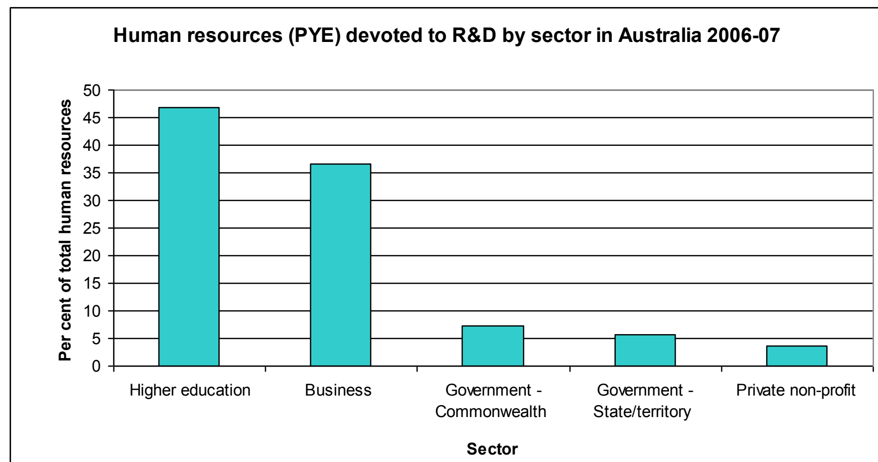


[4] For ABS purposes the category of Commonwealth Government also includes higher education (universities and TAFE's (ABS Pers. Comm. 2008)

[5] In the 2006 Census (held 8 August 2006), 67,665 people identified themselves as scientists by occupation. This includes people working both full and part-time. They represented 0.3% of Australia's total population (19,855,288) at that time according to the 2006 Census of Population and Housing Commonwealth of Australia (ABS, 2006b)

A broader description of accounting for people involved in research and development (R&D)[6], that is not restricted to scientists, is used by the ABS for its calculation of the 'Human resources[7] devoted to R&D, by sector—by industry—2006–07'(ABS, 2006c). Figure 13 shows that most human resources devoted to R&D in Australia are found in the Higher Education and Business sectors. These different ways of accounting for scientists in Australia or the time equivalent of people involved in R&D, meant that the person years of effort (PYE) devoted to R&D totalled 125,771 in 2006 ─07, compared with the 67,665 scientists identified by occupation in the 2006 Census (ABS, 2006b) (See Figure 13.)

Figure 13. Human resources (PYE) devoted to R&D by sector in 2006-2007 (ABS, 2006b)



[6] R&D activity is defined by the Australian Bureau of Statistics (Marceau, et al., 2004, p. 13) as: Systematic investigation or experimentation involving innovation or technical risk, the outcome of which is new knowledge, with or without a specific practical application, or new or improved products, processes, materials, devices or services. R&D activity extends to modifications to existing products/processes. R&D activity ceases and pre-production begins when work is no longer experimental.

[7] The effort of researchers, technicians and other staff directly involved with R&D activity. Overhead staff (e.g. administrative and general service employees such as personnel officers, janitors, etc.) whose work indirectly supports R&D are excluded.

Table 13 shows the occupations of natural and physical science professionals as a percentage of the 67,665 self-identified natural and physical science professionals in the 2006 Housing and Population Census (ABS, 2006b) and the 1,239 people who identified themselves as natural and physical science professionals in the survey. (Both these totals for the purpose of this comparison exclude mathematicians and statisticians). With respect to occupation, 'Agricultural and forestry scientists' appear to be represented; life scientists were over-represented and medical laboratory scientists, geologists and physicists and veterinarians were relatively under-represented in this study (Table 13).

This shows the occupations of natural and physical science professionals as a percentage of the 67,665 self-identified natural and physical science professionals in the 2006 Housing and Population Census (ABS, 2006b) and the 1,239 people who identified themselves as natural and physical science professionals in the survey. (Both these totals for the purpose of this comparison exclude mathematicians and statisticians).

Table 13. Scientists in government/non-government employer sectors

Occupation (ANZSCO 2006)	Census (2006)		Survey (2007)	
	Count	%	Count	%
Medical laboratory scientists	13,368	19.8	48	3.9
Environmental scientists	12,870	19.0	210	16.9
Natural & physical science professionals (nfd, nec & other)	10,46	15.6	299	24.1
Chemists, and food & wine scientists	7,417	11.0	116	9.4
Agricultural & forestry scientists	6,393	9.4	125	10.1
Geologists & physicists	6,097	9.0	66	5.3
Veterinarians	5,828	8.6	25	2.0
Life scientists	5146	7.6	350	28.2
Total	67,665	100	1,239	100
N.B. Mathematicians & statisticians	2,920		54	

According to the Census (2006), most (19.8%) of Australia's scientists are medical laboratory scientists. They 'conduct medical laboratory tests to assist in the diagnosis, treatment and prevention of disease' (ANZSCO 2006). They are alternatively called hospital scientists or medical scientific officers. Most

(86.5%) medical laboratory scientists (13, 368) worked in either hospitals (except psychiatric hospitals) (3,961 scientists), pathology and diagnostic imaging services (3,564 scientists), scientific researchers services (2,258 scientists) and Higher Education (1,781) (ABS, 2006b).

Most of the scientists (28.2%) in this survey on the other hand were Life scientists; described by the ABS (2006c)[8] as those who examine the anatomy, physiology and biochemistry of humans, animals, plants and other living organisms to better understand how living organisms function and interact with each other and the environment in which they live. Life scientists are categorised by the ABS under the following occupations:

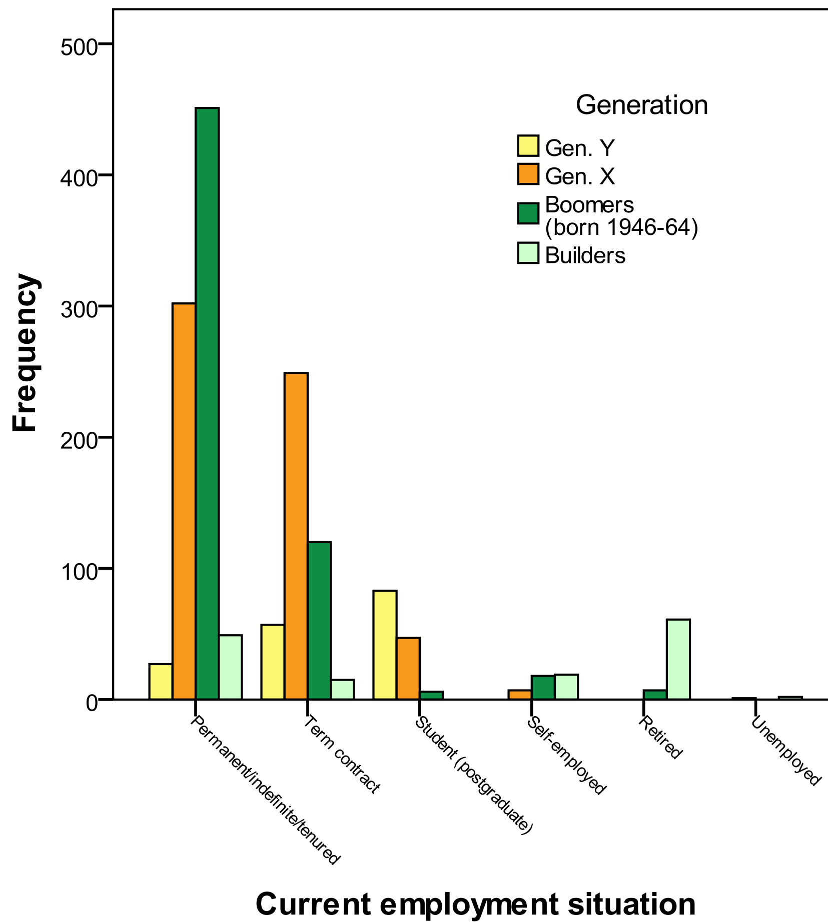
Life Scientist (General)
Anatomist or Physiologist
Biochemist
Biotechnologist
Botanist
Marine Biologist
Microbiologist
Zoologist
Life Scientists not elsewhere classified (nec) into categories e.g. Animal Behaviourist, Parasitologist, Pharmacologist (Non-clinical), Toxicologist (ABS, 2006c).

[8] In the Census (2006) 5,513 scientists were classified as Life scientists; nearly three-fifths (59.0%) worked in hospitals (except psychiatric hospitals) (302 scientists), State Government Administration (682 scientists), Higher Education (862) and Scientific Research Services (1,196).

Employment situation and Generation

Relatively more Boomers were ‘permanently’ employed than scientists in the other generations (Figure 14).

Figure 14. Employment situation x Generation – frequency



Summary ─ demographic description

This study is based on a survey of 1,521 Australia's scientists who lived in all States and Territories of Australia. Nearly sixty per cent (59.3%) of the respondents had either a doctorate degree or higher as their highest completed qualification. Just over half (54.5%) of the scientists had permanent/indefinite/tenured positions and most were employed in physical science professional occupations. Most (69.2%) of the respondents had research-only roles, research and management, or research and teaching roles. Most scientists worked in the Biological sciences (20.6%), Agricultural, Environmental and veterinary sciences (20.3%) and the Medical and health sciences (14.3%). The Medical and health sciences were the only discipline grouping dominated by females. Most of the older scientists were in the Agricultural, environmental and veterinary sciences while most of the younger scientists worked in the Biological sciences. Government was the biggest employer of those in the Agricultural, environmental and veterinary sciences, and both the Government and Higher Education sectors were the employers of most scientists in the Biological sciences.

The respondents represented, as intended, a broad range of scientists in terms of four key demographic characteristics for this study: sex, age, discipline and employer. Thus their experiences and views can be expected to provide an indicative account of aspects of scientists' communication in Australia. The survey respondents represented the population of scientists in terms of sex ratio (61% males: 39% females) and age distribution (from 21 to over 67 years of age). There were, however, relatively more life scientists than medical laboratory scientists, and relatively more scientists from government and universities to be representative of the scientists' population in terms of occupation and employer.

Younger scientists (Generations X and Y), post-graduate students, female scientists and those in the Biological sciences and in Higher education were more likely to be on short-term contracts.

Scientists' Workplace Culture in Australia

This section describes respondents' perceptions of their employer's approach to scientists' communication with the general public. Five questions were used to explore scientists' work culture in relation to communicating with the general public: whether it was part of their job; whether they were expected to communicate and whether they were rewarded or recognised for doing so.

Is communicating part of the job?

When asked, 'Is communicating with the general public part of your job description/duty statement or project requirement?', 27.1% of the 1,494 respondents for whom this question was applicable, said 'Yes' (Table 14).

Table 14. Is communicating with the general public part of your job – frequency

Communication with public part of job?	Frequency	Per cent
No	1006	66.1
Yes	405	26.6
Not sure/don't know	83	5.5
Sub-total	1,494	98.2
Not applicable	27	1.8
Total	1,521	100

For 67.3% of respondents, however, communicating with the general public was not part of their job description, as was the case for the following scientist:

> I don't get paid to speak to the public, and in fact I would get in trouble for doing so. My role is to make discoveries and pursue

research goals, not communicate them through any means other than scientific peer-review publication, and via scientific conferences. [9]

There was no significant association between a scientist's sex and whether a scientist's job included communicating with the public. Significant sources of variation were, however, found for Generation (χ^2 (df = 6, n = 1494) = 26.558, p = 0.000); Discipline (χ^2 (df = 14, n = 1402) = 88.576, p = 0.000) and Employer (χ^2 (df = 12, n = 1470) = 56.464, p = 0.000).

Across the generations, it was the Boomers (33.7%) who were most likely to say that communicating with the general public was part of their job, followed by Gen. X (24.0%), Builders (22.8 %) and Gen. Y (18.2%) (Table 15).

Table 15. Is communicating part of your job x Age (Generation)

	Number (%) within each generation			
Generation	No	Yes	Don't know	Total
Boomers (aged 43-61)	360 (60.6%)	200 (33.7%)	34 (5.7%)	594 (100%)
Gen. X (aged 28-42)	420 (70.1%)	144 (24.0%)	35 (5.8%)	599 (100%)
Builders (aged 62+ in 2007)	101 (74.3%)	31 (22.8%)	4 (2.9%)	136 (100%)
Gen. Y (aged ≤27)	125 (75.8%)	30 (18.2%)	10 (6.1%)	165 (100%)

Across the disciplines, relatively more scientists in the Earth sciences (39.6%), Agricultural, veterinary and environmental sciences (38.2%), and the Biological sciences (26.4%) had communicating with the general public as part of their job description/duty statement or project requirement as detailed, by number and per cent, in Table 16.

[9] Male, 31 years, Medical & health sciences, Hospital

Table 16. Is communicating part of your job x Discipline (No. and %)

Is communicating with the general public part of your job description/duty statement or project requirement?				
	No. (%) within each discipline in decreasing order by 'No' percentage			
Discipline (≥ 50 people)	No	Yes	Don't know	Total
Engineering & technology	78 (82.1%)	13 (13.7%)	4 (4.2%)	95 (100%)
Chemical sciences	78 (82.1%)	14 (14.7%)	3 (3.2%)	95 (100%)
Mathematical sciences	53 (81.5%)	5 (7.7%)	7 (10.8%)	65 (100%)
Physical sciences	119 (72.6%)	27 (16.5%)	18 (11.0%)	164 (100%)
Medical & health sciences	156 (72.6%)	46 (21.4%)	13 (6.0%)	215 (100%)
Biological sciences	214 (69.5%)	81 (26.4%)	13 (4.2%)	308 (100%)
Agricultural, vet. & environment. sciences	178 (58.2%)	117 (38.2%)	11 (3.6%)	306 (100%)
Earth sciences	88 (57.1%)	61 (39.6%)	5 (3.2%)	154 (100%)
Total	964 (68.8%)	364 (26.0%)	74 (5.3%)	1,402 (100%)

In terms of employers, about three-quarters of the scientists employed by Medical research institutes (80%), Hospitals (76.4%), Industry (75.6%) and Universities (73.2%) did not have communicating with the public as part of their job compared with a lower percentage (54.2%) of scientists in State/Territory/Local government departments and agencies (Table 17).

Table 17. Is communicating part of your job x Employer institution/organisation

Is communicating with the general public part of your job description/duty statement or project requirement?				
	No. (%) within each employer type in decreasing order by 'No' percentage			
Type of employer with ≥ 50 scientists	No	Yes	Don't know	Total
Medical research institute	44 (80.0%)	8 (14.5%)	3 (5.5%)	55 (100%)
Hospital	55 (76.4%)	13 (18.1%)	4 (5.6%)	72 (100%)
Industry	62 (75.6%)	19 (23.2%)	1 (1.2%)	82 (100%)
University	353 (73.2%)	93 (19.3%)	36 (7.5%)	482 (100%)
Private consultancy business	33 (66.0%)	16 (32.0%)	1 (2.0%)	50 (100%)
Commonwealth Govt. agency/department	313 (65.8%)	139 (29.2%)	24 (5.0%)	476 (100%)
State/Territory/local Govt. depart. or agency	137 (54.2%)	104 (41.1%)	12 (4.7%)	253 (100%)
Total	997 (67.8%)	392 (26.7%)	81 (5.5%)	1,470 (100%)

Is communication expected by their employer?

In response to the question, 'Is communicating with the general public expected by your employer?' about two-thirds of the 1,470 scientists for whom this question was applicable, answered either 'Yes' or 'Sometimes yes, sometimes no – depends on the issue/project'. This compares with just over a quarter (27.1%) who previously indicated that communicating was a part of their job description/duty statement or project requirement. This means that while communication with the public was not formally part of their job for two-thirds (67.3%) of the scientists, nearly the same per cent (64.4 %) were expected to communicate. This includes 39.3% who were expected to communicate sometimes – depending on the issue/project.

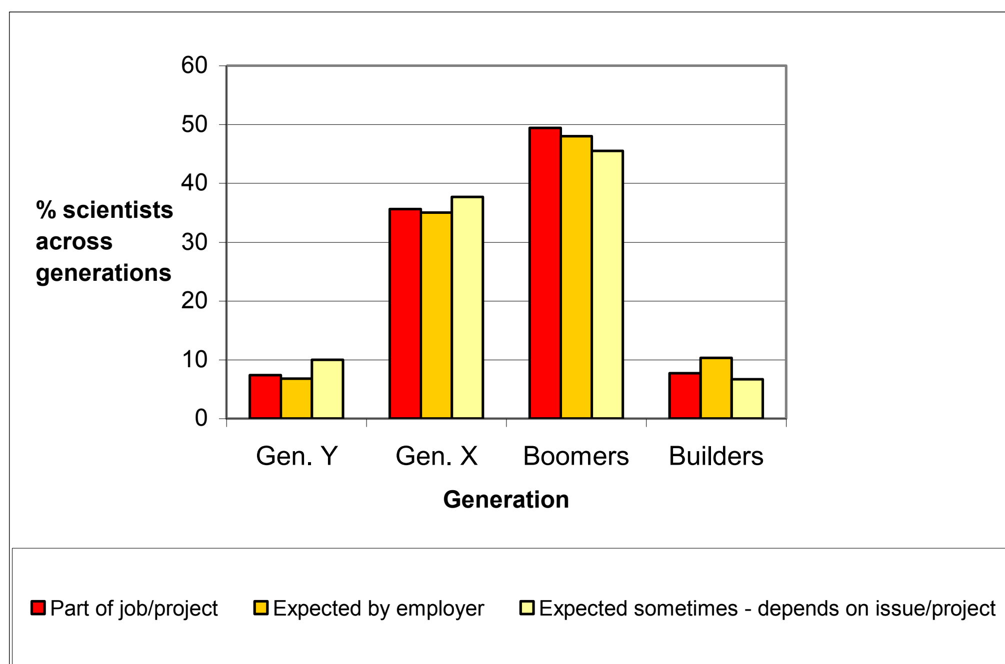
Table 18. Communication expected by employer ─ frequency

Communication expected by employer?	Frequency	Percent	Valid Percent
Sometimes - depends on issue/project	578	38.0	39.3
No	474	31.2	32.2
Yes	369	24.3	25.1
Don't know	49	3.2	3.3
Total	1470	96.6	100.0
Not applicable (missing)	51	3.4	
Total	1521	100	

Slightly more males than females were expected by their employer to communicate with the general public (χ^2 (df = 3, n = 1470) = 12.284, p = 0.006, Cramer's V = 0.091 (effect size is small (Cohen 1988)). Frequencies of male and female scientists are presented in a cross-tabulation table (Appendix 21).

Significant associations were also found between employers' expectations and scientists' Age ((χ^2 (df = 9, n = 1470) = 61.189, p = 0.000). Relatively more Boomers (48.0%) were expected by their employers to communicate than the other generations (Figure 15). A similar trend was found across the generations amongst those scientists who were expected 'Sometimes – depends on issue/project': Boomers (45.5%), Gen. X (37.7%), Gen. Y (10.0%) and Builders (6.7%).

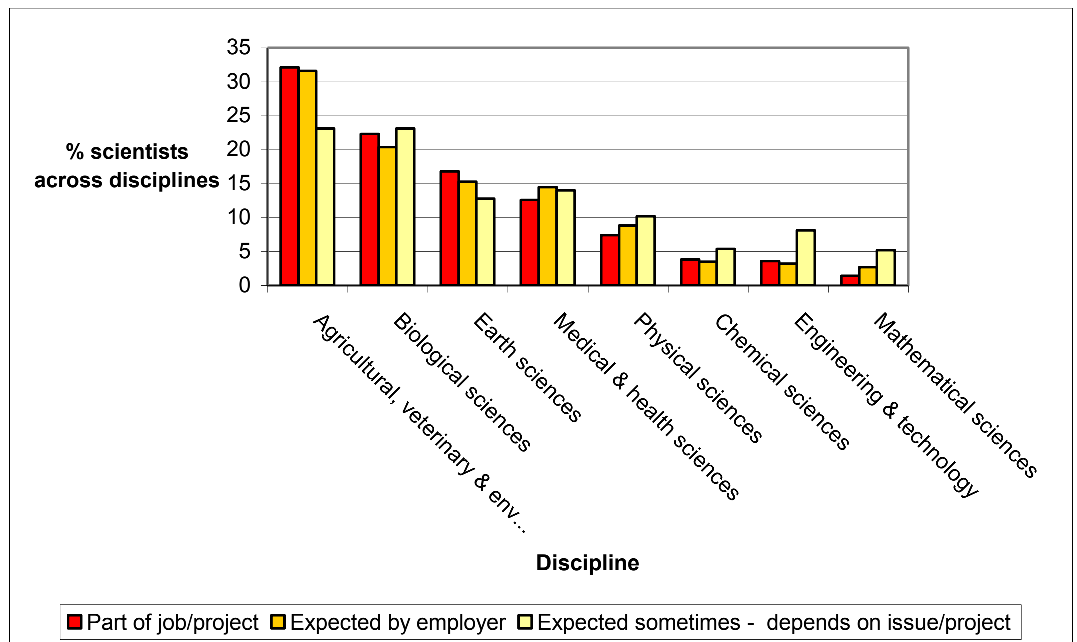
Figure 15. Part of job or expected to communicate x Generation (per cent)



There appears to be a trend that scientists were expected to communicate by their employer as they grew older; whether or not it is a formal part of their job. Whether this trend was associated with greater seniority, increased responsibility or more communication experience was not explored in this study but would be useful to know. Conversely those scientists aged 27 or younger (Gen Y.) were the least expected formally or informally by their employer to communicate with the general public. This group had the highest percentage of scientists who did not know if it was expected. More detailed information is presented in a cross-tabulation table in Appendix 22.

The largest percentage of scientists who were expected to communicate, whether it was their job or not, were those in the Agricultural, veterinary and environmental sciences, Biological sciences and Earth sciences. The smallest percentage of scientists expected to communicate with the general public were those in the Mathematical sciences (χ^2 (df = 21, n = 1379) = 90.392, p = 0.000) (Figure 16).

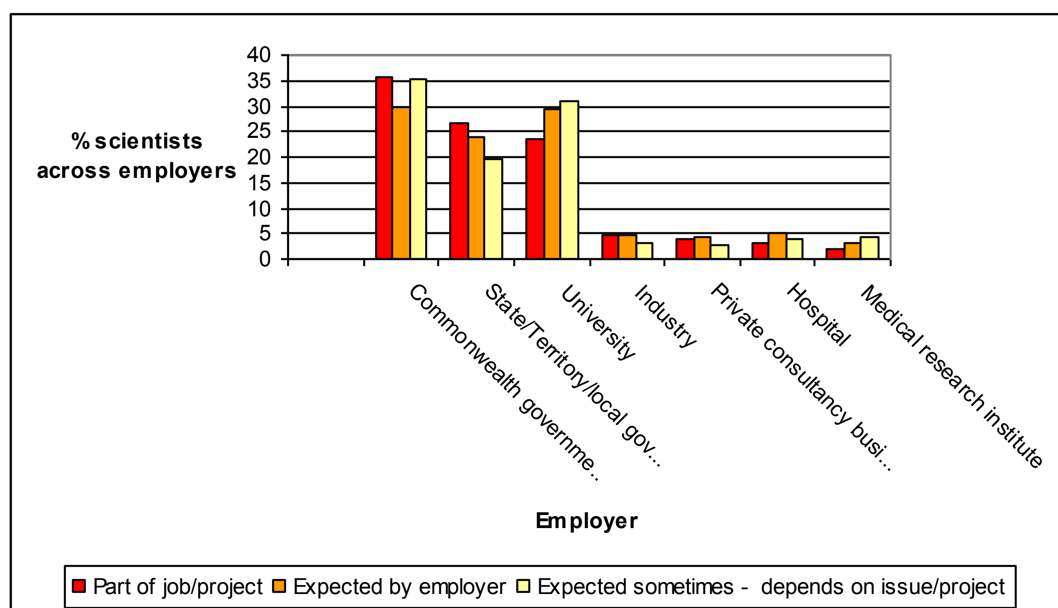
Figure 16. Part of job or expected to communicate x Discipline (per cent)



In terms of employer, higher percentages of those employed by the Government (Commonwealth, followed by State/Territory/Local) and University organisations were expected to communicate, whether or not it was part of their job (χ^2 (df = 18, n = 1447) = 72.629, p = 0.000) (

Figure 17).

Figure 17. Part of job or expected to communicate x Employer (per cent)



Employers' expectations that scientists communicate increased with the age of the scientist. Male scientists, aged over 62, working in the Agricultural, veterinary and environmental sciences and working for State/Territory/Local governments or a Private consultancy business were most likely to be expected by their employer to communicate their specialised knowledge with the general public. Conversely, females aged 27 or younger, working in Engineering and Technology or the Chemical sciences for a Medical research institute or Industry were the least likely to be expected by their employers to communicate (Table 19).

Across the eight disciplines between a third and nearly one half of scientists were expected to communicate at one time or another with the public. There was a greater range amongst those scientists who were not expected to communicate – from a high of 50.5% for those in the Chemical sciences down to 20.1% for

those in the Earth sciences (See Appendix 23). This cross-tabulation shows that relatively more were expected to communicate in the Agricultural, veterinary and environmental sciences and the Earth sciences and less than expected communicated in the Chemical sciences, and Engineering and Technology.

In terms of the differing expectations of the seven employers groupings, relatively more scientists who worked for a State/Territory/Local government department or agency and Private consultancy business were expected to communicate than those employed by a University, Commonwealth government agency/department, Industry, Medical research institute or Hospital. It was scientists employed by Industry who had the greatest percentage (57.3%) of scientists who were not expected by their employer to communicate with the general public. Within Industry or a Private consultancy business, no scientists were uncertain about whether or not they were expected by their employer to communicate with the general public. There was a relatively greater percentage (6.2%) of scientists employed by a University who did not know whether they were expected to communicate by their employer or not. These findings are summarized in Table 19.

Table 19. Summary of employer expectations x Sex, Age, Discipline and Employer (in decreasing order by '%Yes')

	Expected by employer to communicate with the general public								
Sex	No		Sometimes		Yes		Don't know		Total
	No.	%	No.	%	No.	%	No.	%	No
Male	262	29.6	359	40.5	241	27.2	24	2.7	886
Female	212	36.3	219	37.5	128	21.9	25	19.5	
								Total	1470
Age (Generation)	No		Sometimes		Yes		Don't know		Total
	No.	%	No.	%	No.	%	No.	%	No
Builders (aged 62+)	37	32.5	39	34.2	38	33.3	0	0	114
Boomers (aged 43-61)	140	23.6	263	44.3	177	29.8	14	2.4	594
Gen. X (aged 28-42)	228	38.1	218	36.4	129	21.5	24	4	599
Gen. Y (aged ≤27)	69	42.3	58	35.6	25	15.3	11	6.7	163
								Total	1470
Discipline (≥ 50 scientists)	No		Sometimes		Yes		Don't know		Total
	No.	%	No.	%	No.	%	No.	%	No
Agricult., vet. & environment. sciences	65	21.7	125	41.7	107	35.7	3	1	300
Earth sciences	31	20.1	69	44.8	52	33.8	2	1.3	154
Medical & health sciences	80	37.7	76	35.8	49	23.1	7	3.3	212
Biological sciences	109	35.4	115	37.3	69	22.4	15	4.9	308
Physical sciences	63	39.9	55	34.8	30	19	10	6.3	158
Mathematical sciences	25	39.1	28	43.8	9	14.1	2	3.1	64
Chemical sciences	46	50.5	29	31.9	12	13.2	4	4.4	91
Engineering & technology	34	37	44	47.8	11	12	3	3.3	92
								Total	1379
Type of employer (≥ 50 scientists)*	No		Sometimes		Yes		Don't know		Total
	No.	%	No.	%	No.	%	No.	%	No
Private consultancy business	15	32.6	15	32.6	16	34.8	0	0	46*
State/Territory/Local government	51	20.2	112	44.4	86	34.1	3	1.2	252
Hospital	28	39.4	23	32.4	18	25.4	2	2.8	71
Commonwealth government	150	31.8	200	42.5	108	22.9	13	2.8	471
University	160	34	175	37.2	106	22.6	29	6.2	470
Industry	47	57.3	18	22	17	20.7	0	0	82
Medical research institute	18	32.7	24	43.6	11	20.0	2	3.6	55
								Total	1447

Is communication financially rewarded?

The majority of scientists (86%) responded that they were not rewarded financially for their communication with the general public; 6% did not know (Table 20). Of those who were rewarded, the numbers were generally less than 5% within each generation and within each discipline. They were less than 10% for each employer type.

Table 20. Financial reward for communication with the general public – frequency and per cent

Q. 47 Financially rewarded for communication with the general public?		
	Frequency	Percent
No	1306	85.9
Yes	42	2.8
Don't know	97	6.4
Sub-total	1445	95.0
Not applicable	76	5.0
Total	1,521	100

A summary of those who were and were not financially rewarded, and how this varies with scientists' Age (Generation), Discipline and Employer by frequency is tabled in Table 21.

Whether scientists were financially rewarded or not for their communication with the public was found to be significantly associated with their Age (Generation): $\chi 2$ (df = 6, n = 1,445) = 49.103, p = 0.000, Cramer's V = 0.130 (small ─ medium effect) using a Chi-square test for independence. This appears to be mainly attributable to Generation Y because a relatively large number did not know if they were financially rewarded. A more than expected number of Boomers and less than expected number of Generation Y scientists also said that they were not financially rewarded. No significant association was found between scientists' sex and the financial rewarding of communication with the general public ($\chi 2$ (df = 2, n = 1445) = 1.686, p = 0.430). Frequencies, actual and expected, are shown in a cross-tabulation in Appendix 25.

Table 21. Financial reward – within each Generation, Discipline and Employer ─ frequency and per cent

Is communicating with the general public financially rewarded by your institution or organisation? (in decreasing order by '%Yes')							
Generations	No		Yes		Don't know		Total
	No.	%	No.	%	No.	%	No
Gen. Y (aged ?27)	120	77.4	6	3.9	29	18.7	155
Builders (aged 62+)	117	94.4	4	3.2	3	2.4	124
Gen. X (aged 28-42)	523	89.7	17	2.9	43	7.4	583
Boomers (aged 43-61)	546	93.7	15	2.6	22	3.8	583
						Total	1,445
Discipline (? 50 people)	No		Yes		Don't know		Total
	No.	%	No.	%	No.	%	No
Medical & health sciences	184	89.3	10	4.9	12	5.8	206
Chemical sciences	74	85.1	3	3.4	10	11.5	87
Earth sciences	137	92.6	4	2.7	7	4.7	148
Physical sciences	141	89.8	4	2.5	12	7.6	157
Agricult., vet. & environment. sciences	288	96.0	7	2.3	5	1.7	300
Mathematical sciences	53	84.1	1	1.6	9	14.3	63
Engineering & technology	84	91.3	1	1.1	7	7.6	92
Biological sciences	273	91.0	3	1.0	24	8	300
						Total	1,353
Type of employer (? 50 scientists)*	No		Yes		Don't know		Total
	No.	%	No.	%	No.	%	No
Private consultancy business	37	86.0	4	9.3	2	4.7	43*
Industry	67	91.8	3	4.1	3	4.1	73
University	414	86.6	17	3.6	47	9.8	478
Commonwealth government agency/department	418	90.3	11	2.4	34	7.3	463
State/Territory/local government depart. or agency	234	95.5	5	2.0	6	2.4	245
Hospital	68	98.6	1	1.4	0	0	69
Medical research institute	49	92.5	0	0	4	7.5	53
						Total	1,424

Is communication otherwise recognised or acknowledged?

Were there other ways that scientists were recognized or acknowledged for their communication with the general public? One half said ‘No’ and over one-third indicated ‘Yes’ (Table 22).

Table 22. Communication otherwise recognised or acknowledged by employer – frequency

Otherwise recognised or acknowledged	Frequency	Percent	Valid Percent
No	721	47.4	50.0
Yes	544	35.8	37.7
Don't know	178	11.7	12.3
Sub-total	1443	94.9	100
Not applicable	78	5.1	
Total	1,521	100	

Those who answered ‘yes’, were further asked to select from six options. They mainly selected: ‘Verbal recognition/praise/gratitude’, followed by ‘Taken into account for career advancement’ (Table 23). For most, however, this was not the experience, as explained by a university scientist:

> … we are not rewarded/acknowledged for doing so in any of the performance measures. Thus, while the university wants us to do it, we suffer an opportunity loss via not doing other things that are more directly measured[1]

The two options that would arguably be of more immediate direct cost, in terms of time or money to the employers, such as ‘Time in lieu for time spent communicating’ and ‘Remuneration (e.g. cash rewards)’ were rarely used.

[1] Male, 39, Biological sciences, University

Table 23. Reward/recognition/acknowledgement of communication with the general public

How does your institution or organisation reward, recognise or acknowledge your communication with the general public?	No. responses (from 554 scientists)	% of 905 responses	% of 1,521 scientists
Verbal recognition/praise/gratitude	335	37.0	22.0
Taken into account for career advancement	276	30.5	18.1
Written recognition/praise/gratitude	162	17.9	10.6
Time in lieu for time spent communicating	57	6.3	3.7
Other – Please specify	53	5.9	3.5
Remuneration (e.g. cash rewards)	22	2.4	1.4
Total	905	100%	

Analyses to see which scientists were being recognised for their communication in what ways found a significant relationship between scientists' Age (Generation) and whether or not they were rewarded, recognized or/acknowledged for their communication (χ^2 (df = 18, n = 905) = 59.385, p = 0.000) (

Appendix 26). Looking more closely at which age groups had their communication taken into account specifically for career advancement, an

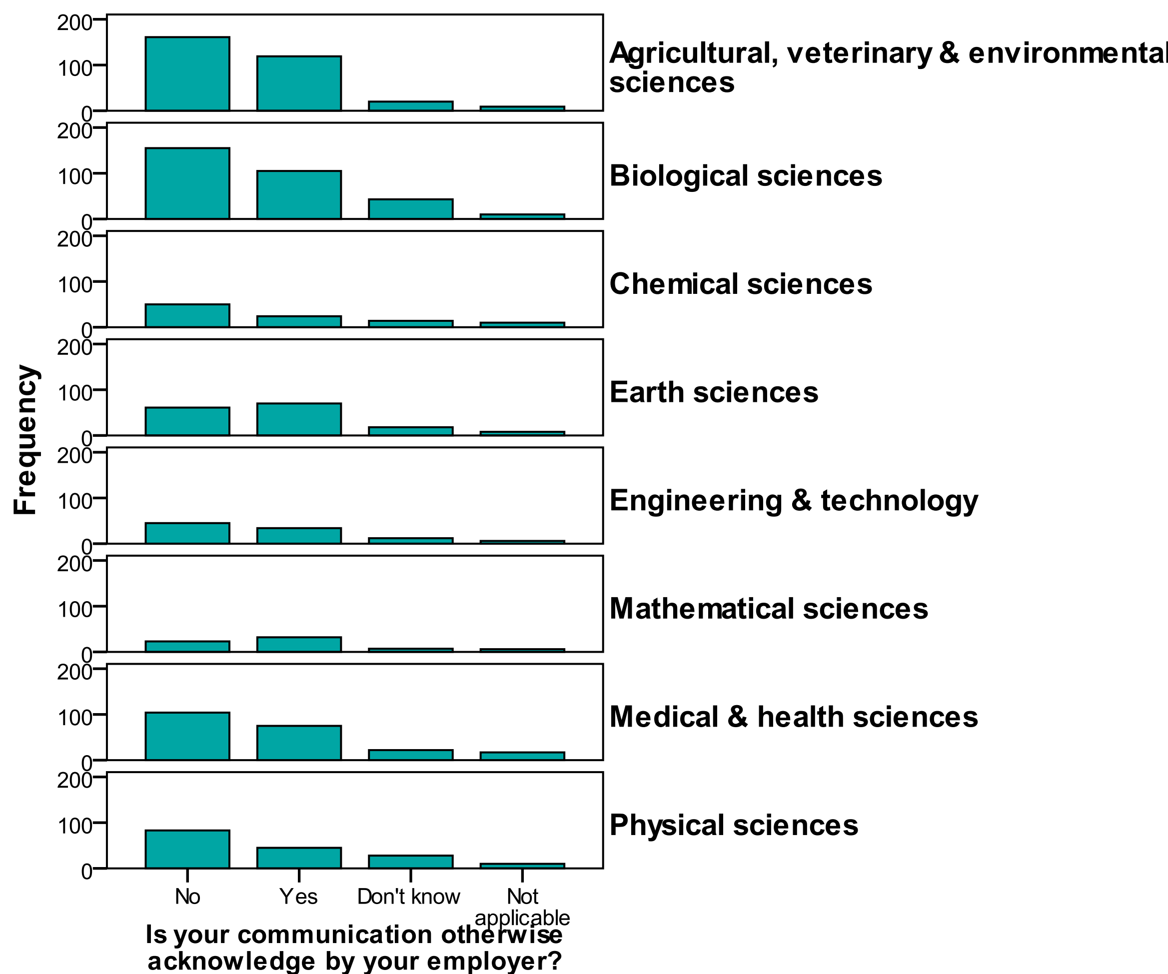
Independent variable	df	N (Responses)	χ^2	p	Chi-square statistic significant at the 0.05 level
Sex	6	905	11.277	0.08	No
Age (Generation)	18	905	59.385	0	Yes
Discipline (≥ 50 scientists)	Assumptions of test not met. More than 20% of cells in table have expected cell counts less than 5				
Employer (≥ 50 scientists)	Assumptions of test not met. More than 20% of cells in table have expected cell counts less than 5				

overall analysis, using Chi-square tests, of scientists' responses to the six

options[2], it was found that relatively more Boomers (20.4% of all Boomers) and scientists in Generation X (19.5% of all Gen X) had their communication taken into account for career advancement than the younger and older generations (Appendix 27). In terms of acknowledgement through verbal recognition, more Builders (28.1%) received verbal recognition, praise or gratitude than scientists in other generations (Appendix 28).

Relatively more scientists in two of the eight disciplines, Earth sciences and the Mathematical sciences, were awarded or recognised for their communication with the general public; as can be seen in Figure 18.

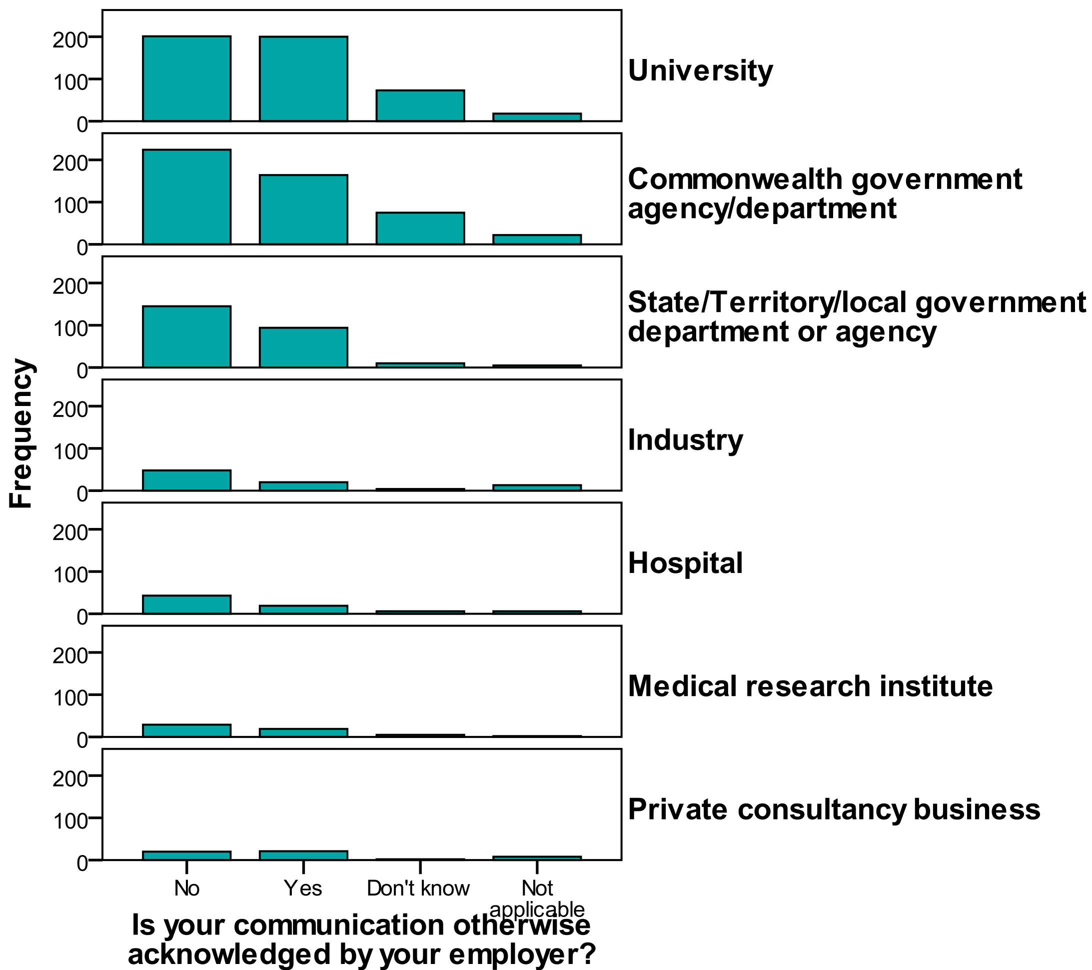
Figure 18. Other organisational recognition of communication x Discipline — frequency



[2] (including 'Other – please specify')

University-employed scientists were relatively more often recognised than those in other institutions or organisations. This variation amongst different employer types (Figure 19).

Figure 19. Communication otherwise recognised x Employer — frequency



Other comments

Sixty-six people wrote about recognition that they felt was not described in option answers offered in Q 49. These are interesting insights into the ways that Australian employers recognise and reward their scientists' communication with

the general public and examples, grouped into four emergent themes, are as follows:

a. Awards and rewards

> Awards: ‘Recent prize for service to School of Physics.’
>
> Funding: ‘Granted scholarship on condition of speaking to students about physics’; ‘Required to give public talks in order to earn money to pay travel expenses for observing [at] conference[s]’; ‘One of my clients pays me for communicating with the public. Others allow me time to do so’.
>
> Travel: ‘More opportunities to travel and present’; ‘Sponsoring attendance to events’
>
> Negative comments: ‘It is a very minor part of career advancement. I think reward is too strong a word…they don’t discourage me, but they don’t acknowledge it unless I’m using my skills to promote the university’; ‘Little or no reward, sometimes gagged’.

b. Workplace recognition

> Employment: ‘Tenure’; ‘This is what I am paid to do’; ‘Part of the job – generally taken for granted’; ‘Part of employment contract’; ‘Written into performance management document’; ‘Part of annual assessment process’.
>
> ‘Recognised as legitimate work activity; ‘[Institution or organisation] values and keeps records on general publications/presentations’, ‘Voluntary work, might be recognised e.g. through institution’s web page etc’; ‘Divisional Communications Officers, sometimes, recognise and make others in the Division aware of public appearances and achievements (hence written gratification [sic] e.g. email’; ‘General thank you email to staff who helped at Open Day’; ‘Mention in staff news and also factor in promotion in regard to service to the community’.
>
> Reports (Annual reports; regular and monthly): ‘Taken into account i.e. recorded, but who knows what for?; Something to do with the annual report, I think’; ‘Category for monthly reporting’.

Training: ‘Courses to say the right thing’.

‘Ambivalent or negative comments: ‘The best that could be said is that I would not have advanced to the position I now occupy had I been less communicative – if anything, my communication efforts tend to be trivialised during annual performance evaluations’; ‘Many managers don’t seem to care’; Bawling out if it goes wrong’; ‘MIGHT!! Be taken into account for career’ advancement’.

c. Professional recognition

Honorary positions: ‘Enables me to continue as an honorary research associate’.

Professional recognition: ‘CEUS [continuing education units] in the professional realm’.

Status: ‘General kudos’; ‘Improves standing within work group which generally sees the better communicators being asked to present more to more important visitors’.

‘Most of the above (except remuneration) apply to the way I am viewed within my own group, but some parts of senior management are not always so receptive’

d. Media contact

‘I am listed as the university’s media contact on certain community issues’.

Summary – Is communicating with the general public part of the job?

For two-thirds of the scientists in this study, communicating with the general public was not part of their job descriptions/duty statement or project requirements although conversely, a similar proportion said that their employers expected them to communicate, depending on the issue. Most (86%) of those who did communicate were not rewarded financially although just over one-third were recognised for their communication in other ways. This was mostly

through verbal recognition, praise or gratitude; followed by being taken into account for career advancement.

Across the four generations, it was the Boomers who were most likely to say that communicating with the general public was part of their job, followed by Gen. X, Builders and Gen. Y. Across eight disciplines, it was those in the Earth, Agricultural, veterinary and environmental, and Biological sciences who were expected by their employers to communicate with the public.

Scientists employed by Private consultancy businesses and State/Territory/Local government agencies were more likely to have communicating with the public as formally part of their job. It was also found that higher percentages of those scientists employed by the Government (Commonwealth, followed by State/Territory/Local) and University organisations were expected to communicate, whether or not it was part of their job. Conversely, it is also interesting to see that about three-quarters of the scientists employed by either Medical research institutes, Hospitals, Industry and a University did not have communicating with the general public (defined as excluding clients) as part of their job descriptions.

It would seem that communication with the general public was not generally part of most scientists' job description, although they were expected to communicate when required by their employer. It was the male Boomers in the Earth sciences, Agricultural, Environmental and veterinary scientists, and Biological sciences working for government who had communicating as part of their job. Employers did not generally recognise or reward scientists' communication with the general public, although when they did, it was more likely to be verbal praise or taken into account for career advancement.

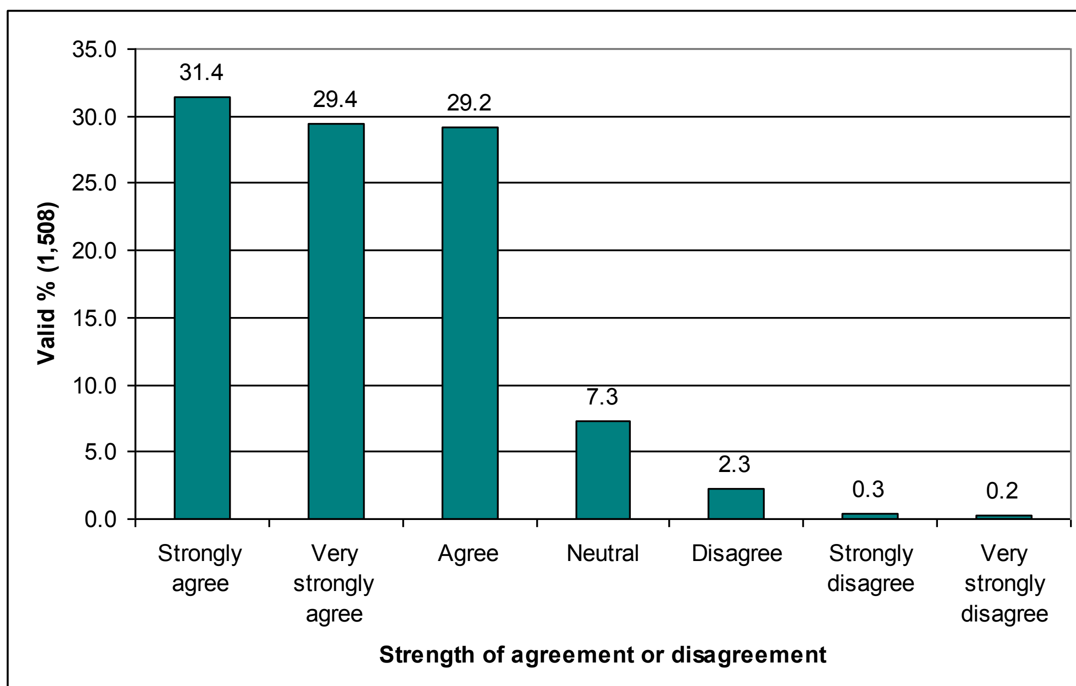
Scientists' Responsibility to Communicate with the Public

This research sought to ascertain whether Australia's scientists believed that, in both the public and private sectors, scientists had a responsibility to communicate with the general public. To elicit their views, they were asked how strongly they agreed or disagreed with the following statement by selecting one option from a 7-point Likert scale:

> 'Scientists, within both the public and private sectors, have a responsibility to ensure the timely communication to the public of research results that are in the public interest'.

The respondents generally agreed that it is a responsibility of scientists to communicate with the general public. Of the 1,508 (99.1%) who had an opinion, most (89.1%) agreed with this statement to some degree, with most (473) strongly agreeing and similar numbers in the other 'agree' categories. Less than 10% were either neutral (110 scientists) or disagreed to some extent (42 scientists). The distribution is graphed in Figure 20.

Figure 20. Scientists' responsibility to communicate – frequency

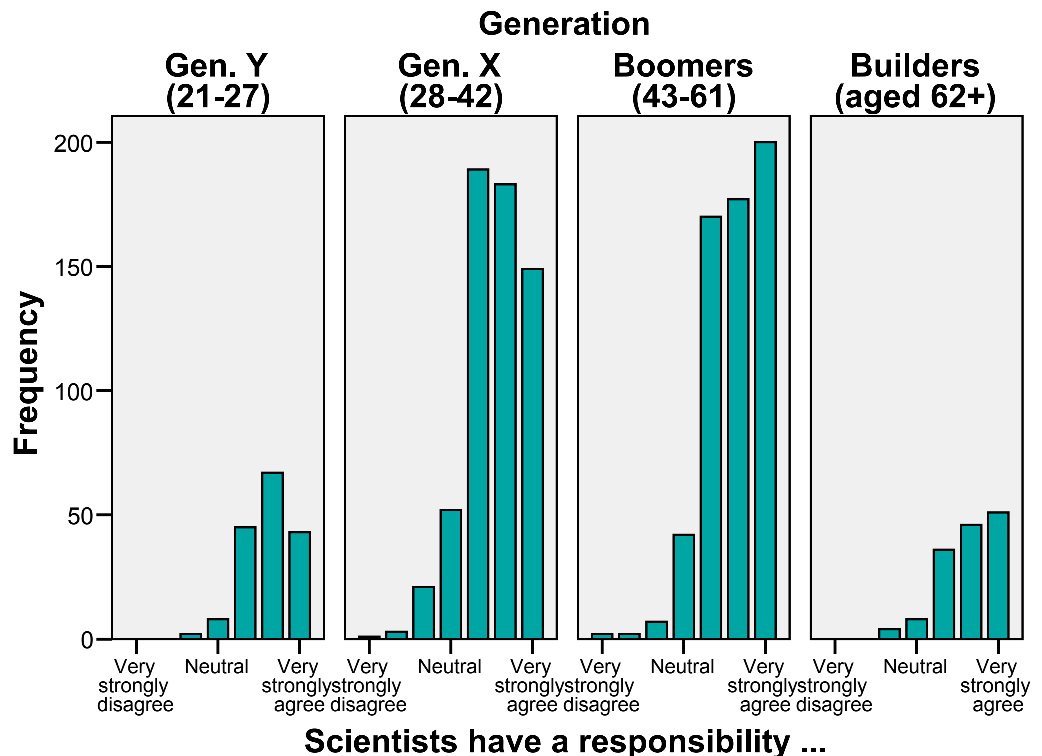


This majority agreement that scientists have a responsibility to communicate appears to have been made despite the complexity of the statement with which they were presented. Some expressed concern about undefined terms or concepts such as 'timely' and 'public interest' but agreed anyway as indicated by the following: 'There are obviously definitional issues with the terms 'timely' and

'in the public interest', but in general I would agree with the sentiment of this statement' (Agree).

The frequency distributions for responses was negatively skewed (skewness = -0.705, kurtosis = .545). Non-parametric analyses[3] were used to identify any significant differences in scores between scientists of different sex, age, discipline and employer type. A Kruskal-Wallis Test revealed a statistically significant difference in agreement scores across the four different age groups. (H(df = 3) = 16.637, P = 0.001) with a mean rank of 814.2 for Builders, 786.3 for Boomers, 778.7 for Gen. Y and 701.2 for Gen. X). Although the median scores were the same (Md = 6 or Strongly agree), scientists in Generation X had the lowest overall scores and differed significantly from the other generations ─ the effect size was small. The distribution of scores, split by generations, is shown in Figure 21.

Figure 21. Scientists' responsibility to communicate – frequency split by Age (Generation)



[3] Transformations did not normalize the distribution.

There were no significant differences in terms of their agreement or disagreement with the statement, between males and females according to a Mann-Whitney Test, and between scientists from different disciplines and working for different types of employer (according to Kruskal-Wallis Tests).

In summary, it was found that irrespective of their sex, age, discipline and employer, Australian scientists in this survey generally agreed that ‘Scientists, within both the public and private sectors, have a responsibility to ensure the timely communication to the public of research results that are in the public interest’.

The following description indicates the broad range of scientists’ beliefs and concerns about which of them, if any, have responsibility to communicate with the general public. This gives insights into the many demands upon and expectations of scientists, juxtaposed against their professional ideals of independence and openness, and the reality of their responsibilities as employees. There were many instances of scientists writing very similar comments to each other and yet having very different strengths of agreement or disagreement that scientists had a responsibility. To illustrate this, the level of scientists’ agreement or disagreement (from ‘Very strongly disagree’ to ‘Very strongly agree’) is included at the end of each comment.

For example there were those who believed that it was the scientists’ choice as to whether they communicated or not with the public.

> It is up to the scientist if they want to contribute to the public interest or not and it may be a matter of opinion as to what will benefit the public interest[4]. (Disagree)

Some were not sure that it was the scientist’s choice:

> There is a responsibility to communicate important results.... Not sure whether the responsibility to communicate it to the public lies with the scientists themselves.[5] (Neutral)

[4] Female, 28, Biological sciences, State/Territory/Local Govt.

A small number of scientists pragmatically commented on their responsibilities to their employer or funders, making it clear that scientists are not the final arbiters of what they communicate and with whom:

> Scientists may have a responsibility but it is their managers need to make it feasible[6]. (Strongly agree)

> Scientists have a responsibility to ensure the timely communication of research results only to their funders. It is up to the funders of the research to decide whether communication of results to the general public is a priority.[7] (Neutral)

Moral or ethical responsibility to society

The following focuses on scientists' beliefs that they have a moral or ethical responsibility to communicate; that others have the sole or partial responsibility, or that scientists have no responsibility. Comments that attribute different responsibilities to scientists working in public and private sectors are also presented. There were those who strongly believed that scientists had a moral or ethical responsibility. Typical comments from scientists (29%) who strongly agreed with this statement were:

> Scientists in the public sector are publicly funded and thus have an obligation to disclose how the public money is spent. Scientists in the private sector probably have more of a moral rather than absolute obligation…[8] (Strongly agree)

> They do have a moral and ethical duty to do this.[9] (Very strongly agree)

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[5] Male, 41, Agricultural, veterinary & environmental sciences, Commonwealth Govt.
[6] Male, 42, Physical sciences, Commonwealth Govt.
[7] Male, 31, Earth sciences, Commonwealth Govt.
[8] Female, 50, Biological sciences, University

[9] Male, 51, Medical & health sciences, Hospital

For topics that affect the whole or a large part of any community e.g. global warming, water usage, pollution etc the people affected have the right to know and should not be kept in the dark by groups with vested interest such as governments and large organisations.[10] (Very strongly agree)

A small number specifically stated that scientists had a responsibility to society, irrespective of the sector which employed them.

… But a scientist should be responsible to the community as a whole, not just the employer.[11] (Agree)

We are part of society and we have a responsibility to society that transcends any obligation to specific employers or funding bodies. Science would not exist without society and we have a duty to contribute. Knowledge is one of the greatest gifts we have.[12] (Very strongly agree)

Other scientists embraced the ideal implicit in the statement because they believed that they were part of a society that had a right to know about issues that affected them:

We should all be informed of that which impacts upon us.[13] (Very strongly agree)

Public have a right to know about science progress, particularly with respect to issues that affect them now or in the future.[14] (Very strongly agree)

The public have a right to know and understand the discoveries we have made and how this will impact their lives. But, we should be

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[10] Male, 51, Physical sciences, Business

[11] Male, 61, Medical & health sciences, Industry

[12] Female, 29, Biological sciences, University

[13] Female, 37, Medical & health science, Business

[14] Male, 53, Chemical sciences, Commonwealth Govt.

> reasonably thorough with our investigations first, however, before we make bold statements. [15](Very strongly agree)

> As a member of the community I want to know the results of research, so that I can make better informed decisions about my own actions.[16] (Strongly agree).

Who owns the research?

Some scientists pointed out that research was owned by whoever funded it, or their employer.

> Due to commercial, political or other confidentiality issues, it is not always possible to communicate results. Most scientists don't own their own results.[17] (Neutral)

> I am paid to respond to government needs and industry not the general public with timely communication.[18] (Neutral)

> Scientists in my area are not encouraged to communicate research results with the public for political reasons, and sometimes commercial confidentiality reasons, even though the results are in the public interest. [19](Disagree)

Others have the responsibility

Then there were scientists who believed that this responsibility did not rest, or rest solely, with scientists (and therefore were more likely to disagree or be neutral about the statement). Some believed that scientists' greater responsibility was to research and publish the findings of their research or that it was simply not their job (Appendix 29).

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[15] Female, 27, Medical & health sciences, University
[16] Female, 46, Science (General), University
[17] Female, 44, Medical & health sciences, Business
[18] Male, 41, Earth sciences, Commonwealth Govt.
[19] Male, 29, Biological sciences, University

> Scientists have to do their jobs, which is to research. Yes, the public needs to be informed of research results, but I am not certain it is up to scientists to spend their time doing this. It is a different skill and it's extremely time-consuming if done well, as it needs to be.[20] (Neutral)

> They have responsibility but only after meeting more important ones including publishing their research in scientific journals, getting industry funds and reporting to funding bodies.[21] (Neutral)

There were others who commented that the responsibility belonged to others, such as the employer, the scientists' managers, the funders, or to professional science communicators:

> While I agree there is a need, to overcome general public scientific ignorance, I do not believe there is a responsibility. That lies with the agencies for which we work[22]… (Disagree)

> This has nothing to do with the key performance criteria for my position, nor is it stipulated within any agreements that I sign to obtain public funding for my research. This is true for the vast majority of scientists. In a broader sense, scientists have a responsibility to perform quality, relevant, and non-fraudulent research, not educate the general public. We are researchers - not teachers.[23] (Strongly disagree)

> The organisations that scientists work for have that responsibility. Not all scientists (perhaps few scientists) have the personal capacity to be effective communicators. Better to have good communication departments that are well supported by the scientist.[24] (Strongly disagree)

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[20] Female, 34, Biological sciences, University
[21] Male, 47, Agricultural, veterinary & environmental sciences, State/Territory/Local Govt.
[22] Male, 45, Chemical sciences, University
[23] Male, 31, Medical & health sciences, Hospital
[24] Male, 46, Information, computing and communication sciences, Commonwealth Govt.

> It is not the scientists responsibility it is the agencies, their management and governments of all levels to communicate the scientists findings effectively.[25] (Very strongly disagree)

By 'good communication departments' and 'the agencies for which we work' in the previous quotes, scientists were referring to professional communicators because, as stated below, they had the time; it was their job; they could provide a broader context, and they had the specialist skills for knowledge brokering:

> Yes, but it can take a lot of time and media communicators who have that as a full time job are needed too.[26] (Strongly agree)

> I think research results should be communicated, but by professionals who can provide the appropriate context.[27] (Neutral)

> Organisations need to employ more (or some) people specialised in knowledge brokering etc rather than putting added roles onto scientists who are employed to develop innovative scientific breakthroughs.[28] (Very strongly disagree)

Several more comments about the need for professional communicators were given, because either not all scientists are good communicators (Appendix 30) or science communicators are needed because scientists do not have the time or the expertise to communicate with the general public (Appendix 31).

Others stated that such responsibility rested with scientists' managers, employers and funders, not the individual scientists themselves (Appendix 32).

> Scientific institutions, rather than individual scientists, have this responsibility…[29] (Strongly agree)

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[25] Male, 31, Earth sciences, Commonwealth Govt.
[26] Female, 40, Biological sciences, University
[27] Female, 34, Earth sciences, Commonwealth Govt.
[28] Female, 43, Biological sciences, Commonwealth Govt.
[29] Male, 34, Engineering & technology, University

> I think the agencies that employ the scientists have this responsibility, preferably by using the scientists as communicators rather than passing through a media filter first.[30] (Agree)

> The organisations that scientists work for have that responsibility.[31] (Strongly disagree)

Part of that responsibility apparently included encouragement, support and reward for communication and the provision of opportunities to communicate. Some went beyond scientists' employers and funders to state that a responsibility was shared with, or belonged to, governments and the media:

> Communicating research results is essential to improving public knowledge and understanding, but it's not the responsibility of scientists alone. There is also a lot of responsibility on Government and media outlets…[32] (Agree)

> It is not the prerogative of scientists to unilaterally decide what information to disseminate. Governments should decide what is in the public interest otherwise anarchy will reign.[33] (Disagree)

> It is not the scientists responsibility it is the agencies, their management and governments of all levels to communicate the scientists findings effectively…[34] (Strongly disagree)

Further quotes are presented in Appendix 33.

Public sector scientists

Many scientists wrote about differing communication responsibilities of scientists within the public and private sectors; principally because of the public funding that the scientists within public sector receive. As a result, there appears

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[30] Male, 44, Agricultural, veterinary & environmental sciences, State/Territory Govt.
[31] Male, 46, Information, computing & communication sciences, Commonwealth Govt.
[32] Male, 33, Information, computing & communication sciences, University
[33] Male, 59, Information, computing & Communication sciences, State/Territory Govt.
[34] Male, 31, Earth sciences, Commonwealth Govt.

to be a strong belief amongst scientists that publicly-funded scientists do have a responsibility to communicate publicly funded research with the general public:

> Government research organisations owe it to the public to communicate their findings.[35] (Very strongly agree)

> The public may contribute money to support science through their taxes; knowledge should be shared so that all can benefit from it if they choose to.[36]

> This is somewhat issue-dependent. But in areas of public-good research, the public needs to be kept informed as they are a key stakeholder (even if they don't realise that they are!).[37] (Agree)

One public servant observed that they make compromises:

> Public servants must walk a fine line between what is best for the public and what is best for one's career.[38] (Neutral)

There were those who believed scientists had a responsibility only if they worked for the public sector, but even then defence and commercial research would not be communicated:

> Public interest is important. Science should be ethical. We should be accountable and transparent, except in areas like defence, but even then to the correct degree.[39] (Strongly agree)

> Communication may be appropriate but not all scientists need to be involved and there are likely to be cases where research results, which may be in the public interest, are still best kept very confidential.[40] (Disagree)

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[35] Male, 45, Biological sciences, Commonwealth Govt.
[36] Female, 50, Agricultural, veterinary & environmental sciences, University
[37] Male, 43, Agricultural, veterinary & environmental sciences, Commonwealth Govt.
[38] Male, 51, Biological sciences, State/Territory Govt.
[39] Male, 38, Agricultural, veterinary & environmental sciences, Business
[40] Male, 67, Engineering & technology, Commonwealth Govt.

Private sector scientists

There were also many who stated that scientists in the private sector do not have such a responsibility, as can be seen from the following quotes, and those in Appendix 34.

> Agree, with considerable qualification in an era of growing emphasis of privately funded research. If the public hasn't paid for it, there is an argument (albeit debatable) that the public has no right to it.[41] (Agree)

> Public sector - yes, strongly agree. Private sector - no, strongly disagree. For better or worse we live in a capitalist society where there is no entitlement to free information from the private sector.[42] (Neutral)

Others referred to the statement as possibly ideal but not always possible in the private sector because of commercial concerns:

> While I agree in general with this statement it seems aspirational in the kind of market-driven competitive climate that exists, particularly in the private sector [43] (Agree)

> Due to the impact of competitors, research results from the private sector cannot always be shared.[44] (Disagree)

> I don't agree with this for scientists in the private sector. If it were just the public sector I'd very strongly agree.[45] (Strongly disagree)

Problems with the public

There were scientists who commented on communicating to a public that does not understand, can be misled, does not care or is not interested:

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[41] Male, 55, Agricultural, veterinary & environmental sciences, University
[42] Male, 53, Earth sciences, Commonwealth Govt.
[43] Female, 64, Social science, humanities & arts (General), Commonwealth Govt.
[44] Female, 40, Agricultural, veterinary & environmental sciences, Industry
[45] Male, 36, Mathematical sciences, University

> Ideally yes - but is often not clear cut, at times new 'research results' increase ambiguity or uncertainty, and statistics are poorly understood by large proportion of the population.[46] (Agree)

> 'Will anyone be interested?' Not all scientific results are newsworthy to the general public and that is why only 'sexy' or 'common interest' results make the popular media.[47](Neutral)

Further quotes are presented in Appendix 35 and scientists' comments and criticisms around the question itself (Appendix 36) and their observations on the meanings of 'timely' (Appendix 37) and 'in the public interest' (Appendix 38) are presented as these also give additional insights into the world in which scientists work today.

Given the critiques that many respondents wrote about certain aspects of the question statement[48], such as asking for a definition of 'timely' and 'public interest' and a lack of distinction between scientists within the public and private sectors, relatively few made any comment related to the implication in the phrase, 'communication to the public' that this responsibility was a one-way communication from the scientists to the public; rather than two-way communication between scientists and the public. Comments that referred to communication as being two-way were:

> To have meaningful social dialogue, up to date information is required.[49]
> (Strongly agree)

> Communication is a two-way process, with responsibilities on both sides.[50] (Agree)

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[46] Male, 43, Engineering & technology, Commonwealth Govt.
[47] Male, 35, Chemical sciences, Commonwealth Govt.

48 'Scientists, within both the public and private sectors, have a responsibility to ensure the timely communication to the public of research results that are in the public interest'.

[49] Female, 40, Agricultural, veterinary & environmental sciences, State/Territory Govt.
[50] Male, 64, retired, Agricultural, veterinary & environmental sciences, Commonwealth Govt.

> In the end the people pay the cost of research whether public or private. Sharing the knowledge is often two-way ─ generates new ideas, new applications.[51] (Agree)

> Again, communication can only take place as a two-way process. As scientists we can want to communicate and have a responsibility to do so, but without an audience there can be no communication.[52] (Neutral)

Scientists' comments are presented in further detail in Appendix 29 ─ Appendix 38.

Section summary - responsibility

It seems that calls for scientists' communication reviewed in Chapter 2 certainly reflect or reinforce scientists' expectations within the culture of science. They also ignore the fact that employers and funders of scientists may disagree.

In summary, an overwhelming majority (89%) of respondents agreed with a statement that scientists in both the public and private sector have a responsibility to ensure the timely communication to the public of research results that are in the public interest. Judging from their comments, more would have agreed had the question been restricted to ask only about scientists within the public sector. Not surprisingly, many commented on the undefined terms in the question itself such as 'timely' and 'public interest'. This overwhelming agreement, however, was found to be irrespective of a scientist's sex, discipline or employer. It was only scientists in Generation X[53] who had a significantly lower level of agreement than those the other generations. They were found to be more likely to 'Agree', than 'Agree strongly' or 'Agree very strongly' with the statement.

Many scientists proffered many reasons for agreeing or disagreeing with the statement, or reservations about agreeing. These comments highlight the

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[51] Male, 59, retired, Agricultural, veterinary & environmental sciences, University
[52] Male, 67, Engineering & technology, University

[53] Generation X was aged 28-42 in 2007

diversity of opinions and concerns amongst scientists about their profession's responsibility and ability to communicate with the public. They also provide insights into scientists' working lives, where their view of their professional responsibility to communicate with the public as a scientist or as member of society, appears to be overridden either inadvertently – they don't have time to communicate for example – or explicitly – because they are prevented by their often conflicting responsibilities to those who directly employ or fund them.

Some scientists wrote about scientific ideals, and the rights of the public to know. Others stated that it was not scientists' job to communicate with the public because scientists have a greater responsibility to research and publish. Some pointed out that not all scientists are good communicators and others that there is a need for professional science communicators because scientists do not communicate well or do not have the time to do it themselves.

A number believed that responsibility rested with employers and funders, scientific community, governments and the media. Many stated that scientists in the private sector do not have a responsibility.

Whether scientists gained any benefit from their communications with the general public is presented next.

The Benefits Scientists Gain from Communicating with the General Public

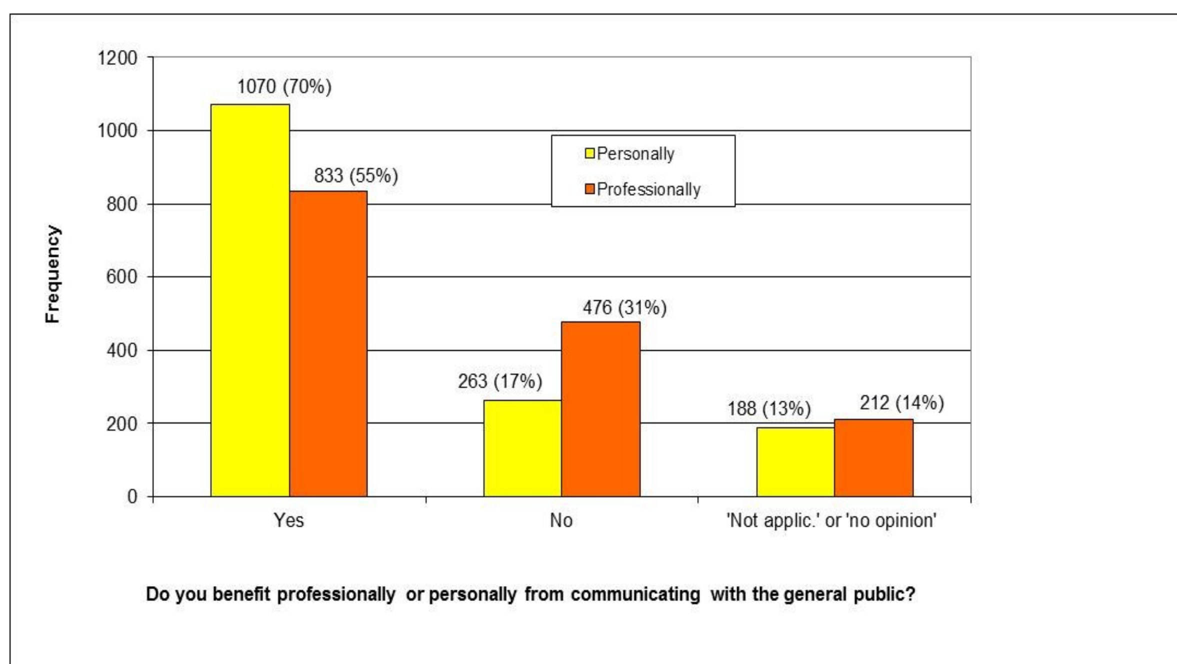
Scientists were asked whether they benefited professionally or personally from communicating their work or specialised knowledge with the general public. They were deliberately asked in two separate questions, rather than one combined question, to elicit a range of responses that included both professional and personal benefits. These benefits were not defined, however, as a purpose of these questions was also to find out what scientists thought the benefits were. The questions focussed on the scientists' own experience and also asked for examples of how communicating with the general public benefited them.

The majority of scientists saw both personal (70% of 1,521 scientists) and professional (55%) benefits from communicating their work or specialised knowledge with the general public (Figure 22).

One scientist, however, could not separate the professional and the personal benefits:

> Public awareness is a necessity when fighting for your share of a very small pie. Can't separate professional from personal (you tend to live this job).[54]

Figure 22. Professional & personal benefits from communicating – frequency of scientists



A retired medical laboratory scientist wrote very humbly about the personal benefit of communication as being, 'A constant reminder of how "the rest of the world" has hopes and fears for what we do'.

Sixty-two per cent of the 1,521 respondents gave 1,886 examples of how they benefited from communicating their work or specialised knowledge with the general public by answering one or both questions. When the scientists' written examples for professional (916) and personal benefits (970) were grouped into

[54] Male, 40, Medical & health sciences, University

themes that emerged from the data, rather than assigning them to existing categories, there was considerable overlap. For example, some scientists assessed an improvement in their communication skills and confidence as a professional benefit, while for others this was a personal benefit. This is not surprising, as neither professional nor personal benefits were defined in the questions, and they flow into each other. The responses to both questions were therefore combined for latter analyses, excluding any duplicate comments. This resulted in 11 broad emergent themes[55] which are listed in decreasing order of frequency of comments:

Positive feelings about themselves, their communication and their work*
Work or personal success
Public understanding/awareness/support for science
Scientists' understanding of their own science or work
Communication skills and confidence (e.g. communication, grant-writing)
Public input into existing and future work or research
Scientists' understanding of the public's needs
Positive feelings (without further explanation of why) *
The good of the organisation or profession or science, society
Duty or responsibility or obligation
Recruitments of science students or scientists
Defence - against the public

The frequencies of these examples are given in Figure 23 and broad descriptions are presented in Appendix 39.

[55] There were 12 emergent themes if positive feelings are separated between those who gave further explanation* and those who did not*.

Table 24. Examples of professional and personal benefits – frequency

12 themes arising from scientists' examples of benefits (1,886)	No. examples of benefits		No.	%
Scientists' communication with the general public improves or contributes to:	Professional	Personal	benefits	of 1,886
Positive feelings about themselves, their communication and their work	9	347	356	18.9
Work or personal success	181	98	279	14.8
(including direct participation or co-operation in research, networking,				
building relationships, impact)				
Public awareness, understanding of, interest in, acceptance, use of or support	172	96	268	14.2
or funding for, science, scientific organisations, scientific research, scientists				
Understanding of their own science or work	135	97	232	12.3
e.g. relevance, different perspective, clarity, gives it a real world context,				
focus, up-to-date, benefits and limitations of science				
Communication skills & confidence	130	95	225	11.9
e.g. communication, communication with other stakeholders, grant-writing				
Public input into existing & future work or research	112	48	160	8.5
e.g. public feedback, two-way communication, new knowledge, new research				
questions, input or direction (excludes direct participation in research)				
Scientist's understanding of publics' needs, requirements, interests, opinions	74	30	104	5.5
Positive feelings (with no further explanation of why)	5	87	92	4.9
The good of the organisation or profession	42	42	84	4.5
or science, society, the community, the environment and other people				
Duty or responsibility or obligation	28	18	46	2.4
e.g. as scientist, public servant, employee or beneficiary of scientific research				
Recruitment of science students or scientists	25	10	35	1.9
Defence against hostile, critical, ignorant, irrational, suspicious or distrustful public	3	2	5	0.3
Total	916	970	1,886	100%

For comparative purposes attempts were made to describe and restrict categories of comments about the benefits within a communication context (e.g. Trench, 2008). These were not found to be useful, however, as the questions for this study were not framed in the same context. Similarly, attempts to further categorise the benefits into motivations or communication stances given in a science communication context (e.g. Trench & Junker, 2001) or – 'why they do it' were not useful either as these did not take into account the benefits of 'work success' or 'positive feelings' which Australia's scientists in this study mentioned so frequently.

Nearly 24% of respondents' examples described positive feelings about themselves, their communication and their work. These positive feelings included satisfaction, enjoyment, fun and self-esteem. Examples of these, given by scientists working in a range of disciplines for different types of employers are as follows:

Satisfaction

Scientists felt satisfaction from having the public interested in their work; from educating and entertaining the public; and from helping the public and promoting their profession.

> A certain satisfaction. Additionally, it is gratifying to see the 'look of sudden understanding' on peoples faces when being told some of the fundamental principles underlying their everyday lives[1]

> By giving the general public enjoyment and for them to find interest in my work is very satisfying and makes the challenges of research become more bearable[2]

> Educating and entertaining people is innately satisfying and encouraging[3]

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[1] Male, 35, Chemical sciences, Commonwealth Govt.

[2] Female, 28, Mathematical sciences, University

A warm fuzzy glow develops. I also like the feeling that I may have been able to help someone personally (either by 'developing their mind' or by explaining a problem to them in a way that can be understood).[4]

Personal satisfaction (from helping to answer queries, correct misconceptions, promote my profession etc).5

Enjoyment and fun:

And it's fun to pick up on some of the enthusiasm that may have been diluted along the way! [6]

Because I enjoy showing the public what I do and how hopefully one day it'll be able to help their lives It also helps me see what I'm doing from their perspective and it motivates me.[7]

I work in an interesting and important area and it's nice to be appreciated - I enjoy the interaction as a contrast to my normal research work, which by definition is detailed and of interest to very few other specialists.[8]

Increased self esteem

Communicating work provides a 'reason to be' and assists with improving self-value.[9]

Gives a sense of acceptance, a reason for striving to achieve breakthrough science for the community; Assists with self esteem issues; Makes your job seem more worthwhile and less mundane.[10]

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[3] Male, 43, Biological sciences, State/Territory/Local Govt.

[4] Female, 46, Medical & health sciences, University

[5] Female, 53, Agricultural, veterinary & environmental sciences, Commonwealth Govt.

[6] Female, 29, Biological sciences, University

[7] Female, 28, Medical & health sciences, Medical research institute

[8] Male, 54, Engineering and technology, Commonwealth Govt.

[9] Female, 41, Agricultural, veterinary & environmental sciences, University

It builds confidence and a self-assurance that I'm doing good in the world.[11]

Other examples are presented in Appendix 40.

To further understand what scientists meant by these positive feelings, the 280 comments that specifically referred to personal benefits and good feelings about themselves and their work, were further grouped into eight emergent categories (Table 25).

Table 25. Personal benefits – categorization of examples of good feelings

Personal benefits - good feelings about yourself and your work	Responses	
	No.	%
Feel good /my work is of value/that I have achieved/feel (job) satisfaction	121	43
Love/enjoy/gives pleasure to explain/talk/teach/share/discuss/nform/about my knowledge/results/work/what I do	66	24
Enjoy/feel good/satisfaction if peoples are/become interested, enthused or appreciate my work/knowledge	33	12
Feel good/satisfaction/pride/self esteem/sense of achievement*	19	6.8
Enjoy/it's good/satisfaction - positive feedback/helping others	11	3.9
Other	9	3.2
Love to share enthusiasm/passion for my work/my area of interest	7	2.5
Enjoy two-way exchange	7	2.5
Fun!	7	2.5
Total	280	100

*to make useful contribution to society through communication/research

A small number of scientists, nearly 5%, described feelings, such as ‘gives me a buzz’ and ‘feels good’ without any further comment on why they felt that way. Thus it is unknown, for example, as to whether they felt good because they enjoyed the process of presenting or because they enjoyed the feedback from the audience – people were interested or enjoyed it – or it validated the usefulness of their work.

A small number of scientists took the opportunity to comment on benefits to their employer rather than themselves:

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[10] Male, 31, Chemical sciences, Commonwealth Govt.

[11] Male, 30 years, Information, computing & communication sciences, Commonwealth Govt.

> General public have no effect on my career path, so there is no benefit in communicating to them in special circumstances, media releases may be attracted to publicise success, but this is not really important to me personally… I don't benefit personally, though my university may see benefits, I can't speak for them.[12]

Analyses were conducted to identify any effects due to Sex or Generation. There were differences between males and females in the frequency of their examples for three benefits. Males gave relatively more examples of benefits that related to their understanding of the public's needs (χ^2 (df = 1, n = 104) = 10.7, p = 0.0011) and work or personal success χ^2 (df = 1, n = 279) = 4.2, p = 0.0404). Females, on the other hand, gave relatively more examples of understanding their own science or work (χ^2 (df = 1, n = 232) = 4.0, p 0.0455).

The younger generations (X and Y) more frequently gave examples of improving their 'Communication skills and confidence' through communication with the general public than the two older generations (χ^2 (df = 3, n = 225) = 14.7, p = 0.0021).

Summary – The benefits of communication

A large number of scientists identified benefits from their communication with the general public. Their 1,886 examples, grouped into 12 emergent themes, gave insights into how such communication improved their work success and their understanding of their own science/work and of the public. The three most frequently identified benefits were 'positive feelings about themselves, their communication and their work', 'work or personal success' and 'public awareness, understanding of, interest in, acceptance, use of or support for science, scientific organisations, scientific research and scientists'.

They also described improvements to their skills and confidence in communicating and increased public input into existing and future research. Most examples described good feelings about themselves, their communication

[12] Male, 25, Engineering & technology, University

and their work and there were significant sex and age differences. For example, males were more outwardly oriented, while females gave more examples of understanding their own science or work. The two younger generations differed from the older two because they wrote more frequently about communication with the public improving their communication skills and confidence in communicating with other stakeholders, and grant-writing.

Personal Importance of Communicating with the General Public

Scientists were asked to indicate how important communicating their specialised knowledge was to them personally on a 7-point Likert scale; with ‘1’ being ‘Extremely unimportant’ and ‘7’ being ‘Extremely important’. The mean score was ‘5.3’ (SD 1.3); between ‘5’ ‘Important’ and ‘6’ ‘Very important’.

Three-quarters of the 1,497 scientists who had an opinion responded that communicating their specialised knowledge with the general public was personally important to them to some degree. (See Table 26).

Table 26. Personal importance of communicating with the general public ─ frequency

Personal importance	Frequency	Per cent
Extremely unimportant (1)	15	1.0
Very unimportant (2)	6	0.4
Unimportant (3)	88	5.8
Neutral (4)	259	17.0
Important (5)	478	31.4
Very important (6)	345	22.7
Extremely important (7)	306	20.1
Sub-total	1,497	98.4
'I have no opinion on this topic'	24	1.6
Total	1,521	100

Mean scores for the 923 males and 598 females (Males = $\bar{x}$ = 5.37, SD = 1.26; Females = $\bar{x}$ = 5.30, SD = 1.30) were very similar and between 'Important' and 'Very important'. Across the generational groups, mean scores ranged from 5.14 (Generation X) to 5.49 (Builders).This difference was found to be significant using a two-way between-groups analysis of variance. Significant main effects were found for Age (Generation) $F(3, 1348) = 4.654$, $p = 0.03$; Discipline $F(7, 1348) = 6.486$, $p = 0.000$ and Employer $F(6, 1348) = 4.536$, $p = 0.000$; however the effect sizes were small (partial eta squared = 0.033 (discipline) and 0.020 (employer)).

There was an effect for age on scientists' attitudes towards communicating their specialized knowledge. Perhaps the oldest generation, the Builders, feel a greater personal responsibility to communicate for the public good. For example, a retired male medical laboratory assistant (over 67 years of age), who used to work for a Medical research institute wrote that it was personally important to him because scientists are 'public servants':

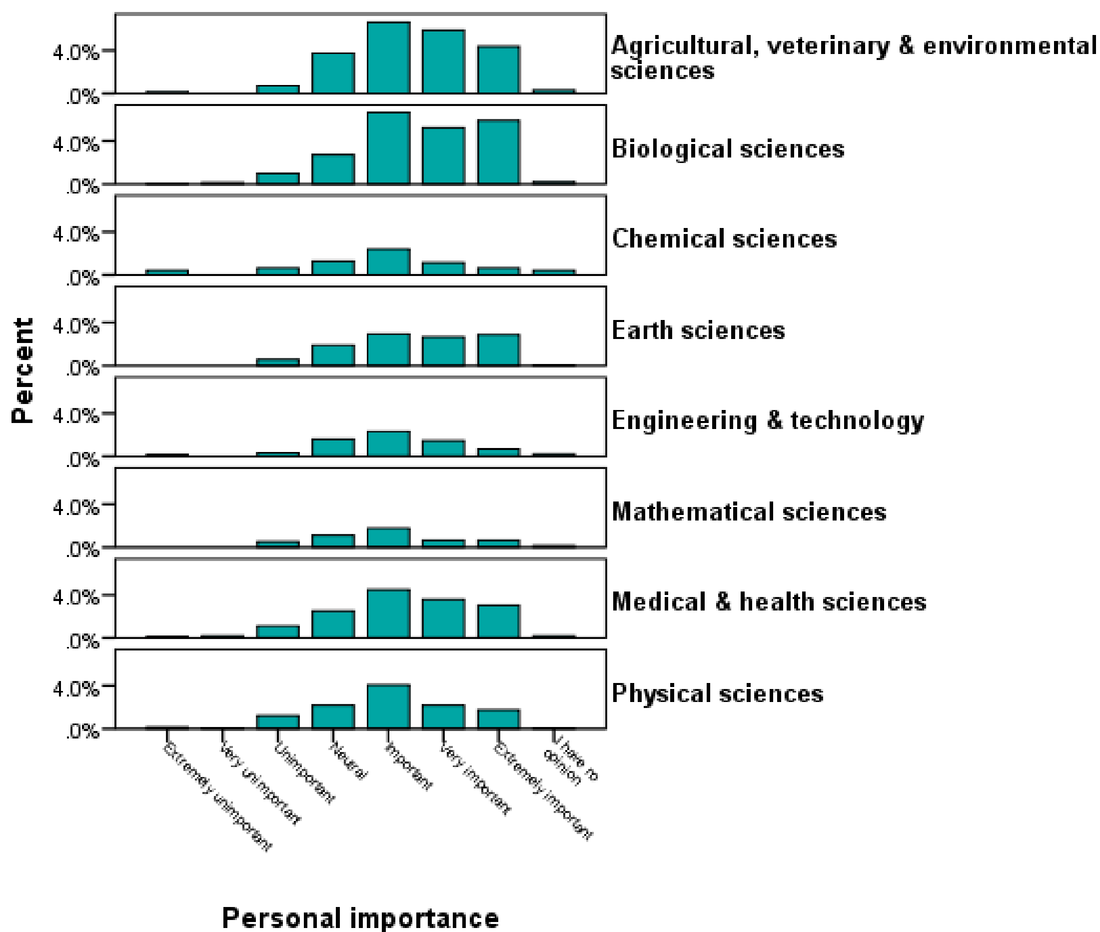
> We are 'public servants' (i.e., our privileged positions doing exciting work that we find a constant enjoyment and challenge is paid for by the public purse), and therefore should communicate with the public on what we do, how we do it, and what the outcomes are.

Another retired male scientist, aged 67, who worked in the 'Mathematical sciences' in a University, stated that:

1. I strongly believe that Science is a part of general culture.
2. Science is currently under siege (e. g. 'creation science')
3. The current shortage of funds for Science is harming the nation.

Across disciplines, scientists more frequently indicated that communicating was personally important to them to some degree as shown in Figure 23 which shows the distribution of their responses split into categories of personal importance.

Figure 23. Personal importance of communicating x Discipline – per cent



Those in the Chemical sciences had the lowest score (4.92) and those in the Biological sciences had the highest mean score (5.56) (Table 27), with ‘4’ being ‘Neutral’ and ‘5’ being ‘Important’.

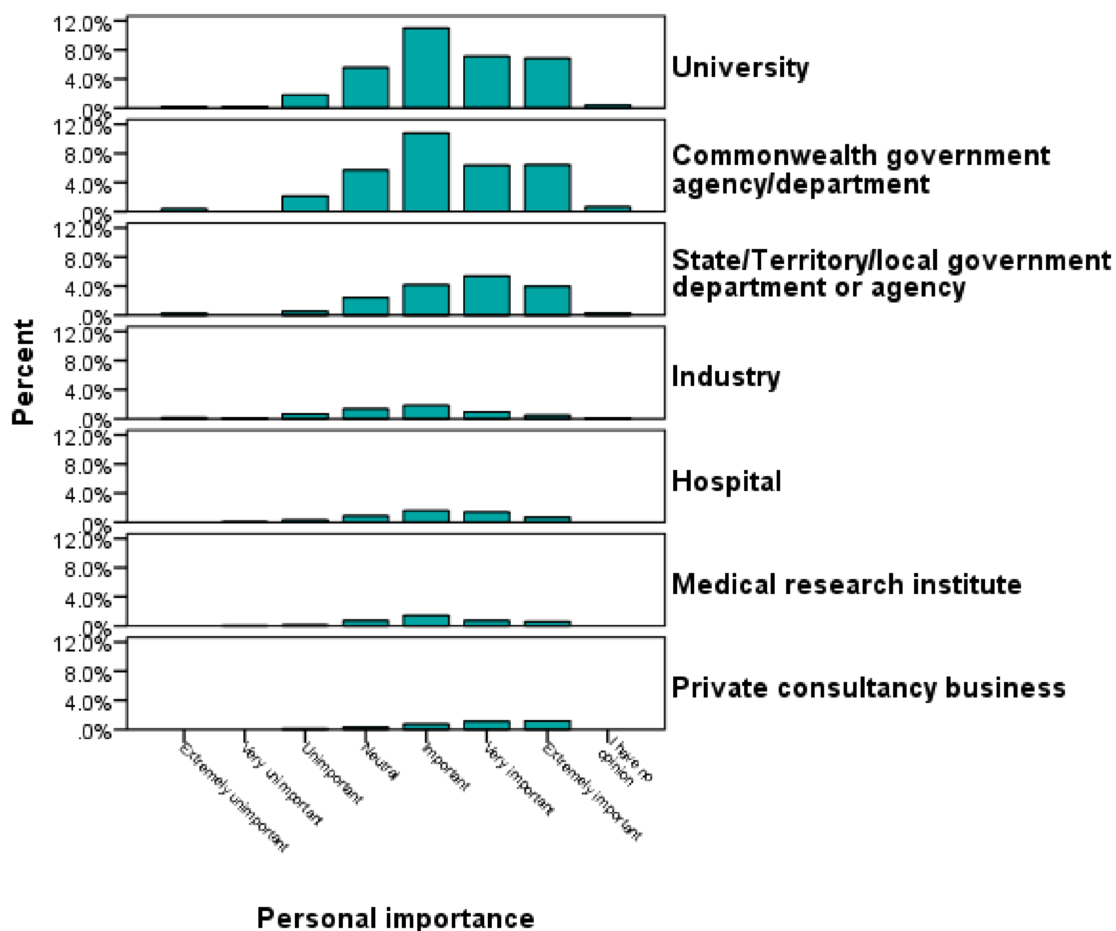
There was a significant but small effect for discipline on levels of personal importance. Scientists in the Biological sciences and Earth sciences had the highest scores for communicating with the general public and Chemical sciences had the lowest. A one-way between groups analysis of variance revealed the significant impact of a scientists’ discipline on their scores of personal importance ($F (11, 1{,}511) = 4.026$, $p = <0.001$). Post-hoc comparisons using the Tukey HSD test indicated that the mean score for scientists in the Chemical sciences was significantly different from those in the Biological sciences, Agricultural, veterinary and environmental sciences and the Earth sciences.

Table 27. Personal importance scores x Discipline

Discipline (≥ 50 people)	N	Mean	SD
Chemical sciences	98	4.92	1.62
Mathematical sciences	68	5.04	1.26
Physical sciences	166	5.05	1.30
Engineering & technology	97	5.09	1.30
Medical & health sciences	218	5.28	1.34
Agricultural, veterinary & environmental sciences	309	5.45	1.18
Earth sciences	157	5.51	1.21
Biological sciences	313	5.56	1.23
Total	1,426	$\bar{x}$ = 5.24	$\bar{x}$ = 1.31

Across employers, communicating with the public was important to most scientists, but more important to scientists working for State/Territory/Local government and a Private consultancy business. The frequency distribution, split by type of employer is presented in Figure 24.

Figure 24. Personal importance of communicating x Employer – per cent



The mean scores for scientists working for different types of employer, ranged between 'Neutral' to 'Very important'. Scientists in Private consultancy businesses had the highest scores[13] ($\bar{x}$ = 5.80 'Important' — 'Very important'). (See Table 28)

Table 28. Personal importance scores x Employer

Type of employer institution/organisation with ≥ 50scientists	N	Mean	SD
University	492	5.36	1.23
Commonwealth government agency/department	485	5.30	1.31
State/Territory/local government department or agency	254	5.57	1.27
Industry	85	4.72	1.46
Hospital	74	5.20	1.17
Medical research institute	55	5.20	1.16
Private consultancy business	51	5.80	1.13
Total	1496		

Post-hoc comparisons using the Tukey HSD test indicated that the mean score for Industry ('Neutral' — 'Important', $\bar{x}$ = 4.72 SD = 1.5) was the lowest across the employer types, with the exception of the Medical research institute grouping ($\bar{x}$ = 5.20 SD = 1.2), but the effect size was small (partial eta squared = 0.020).

Irrespective of a scientist's employment situation (that is whether a scientist was a postgraduate student, on a term contract, 'permanently' employed, or retired) most felt that communicating with the general public was at least 'Important'. Exceptions were the 44 self -employed scientists because half of them responded that communicating with the general public was 'Extremely important' as well as the relatively high percentage of the 67 scientists who were retired. Only six (9%) said that communicating their knowledge was personally unimportant to them. Appendix 41 shows these frequencies and expected values in a cross-tabulation.

A two-way between-groups analyses found significant differences (although small) for Age (Generation) (F(df = 3, 1348) = 4.654, p = 0.003) , Discipline (F(df = 7, 1348) = 6.486, p = 0.000) and Employer (F(df = 6, 1348) = 4.536, p = 0.000), but not for Sex, with the exception of a significant interaction with Generation. Relatively more males in the Boomer generation selected 'Extremely important' (F(3, 1348) = 2.969, p = 0.31); the effect size was small (partial eta squared = 0.007 (Appendix 42).

Personally communicating with the public was of relatively less importance to respondents in Generation X, the Chemical sciences and employed by Industry.

More than 1,000 scientists gave explanations of why it was personally important or unimportant to them. For example, those for whom communicating was important, often described the benefits to themselves, their profession and society. Emergent themes arising from these comments demonstrated that it was important to them because they wanted to:

either correct misconceptions or demystify science

recruit students and scientists into science and particular science fields

attract support & funding for their own research

share valuable information for people to know and use

inform people so that they could participate in democracy and make informed decisions

For those who were neutral, a number wrote about what hindered them from communicating with the public: that communicating with the general public was either important but they are not the ones to do it, that their knowledge was too specialised to be useful, significant, relevant, understood, or interesting, or that their findings were too tentative to communicate publicly. Some said that they would like to but did not have the time.

The minority (7%) for whom communicating was unimportant, often described a work environment where communication with the general public was either not necessary, desired, or an option. For example, it was not part of their job or there was no benefit for them because it was not part of their research aims, or contributed to their advancement. Some were prevented by contracts or legislation or agreements from communicating publicly or it was the job of others such as more senior scientists or supervisors, or science communicators,

or funders. There were those for whom it was more important to talk to clients, collaborators, scientific peers, government and other funders or industry. Others believed that the public would not understand because they did not have the math level required or technical background, or that the public were not interested.

Summary ─ personal importance of communicating

Three-quarters responded that communicating their specialised knowledge with the general public was personally important to them to some degree. It was unimportant for just 7.2%. It was equally important to males and females, but relatively more important to Boomers and Builders, and most important to those in the Biological sciences and those who worked for private consultancy companies. Regardless of whether scientists were postgraduate students, on a term contract, 'permanently' employed, or retired, however, most felt that communicating with the general public was important to some degree. Most selected 'Important', even those who had retired, and especially those who were self-employed.

Scientists' Communication Activities

This section describes scientists' communication activity during the 12 months (2006─2007) prior to the survey. The description is presented in terms of what scientists' communicated, how they communicated and how often they communicated their specialised knowledge with the general public.

What did scientists communicate?

Those 1,288 (98%) scientists who had communicated with the general public in the previous 12 months were asked to select from 11 options what they had communicated[14].

[14] 26 scientists who had communicated did not respond to this question.

More than 70% of the respondents communicated about their own work (findings, applications and/or potential benefits) and about their specialised area of knowledge. One-third communicated outside their specialized area of knowledge while one in four communicated about the wider ethical and social implications of their research findings (Table 29).

Table 29. What did scientists communicate with the general public?

Which of the following did you communicate with the general public?	Responses	
	N	Per cent*
Your work - findings, applications and/or potential benefits	931	72.3
Your own specialised area of knowledge	902	70.0
Careers in science	503	39.1
Science - the benefits of science/value of scientific knowledge	502	39.0
Science - its relevance to everyday life	487	37.8
Science - the scientific process and/or the nature of science	482	37.4
Science - the enjoyment and excitement of doing it	452	35.1
Scientific knowledge or issues **outside** your specialised area	428	33.2
Science - its uncertainty/ambiguity/limitations	354	27.5
Your work - limitations of research findings	329	25.5
Your work - wider ethical and social implications of research findings	313	24.3
Other - Please specify	35	2.7
Total	5,718**	443.9

* Valid n = 1,288

** Respondents could select more than one option

Thirty-five people wrote comments about communication topics not included as options in the question. They were the following:

> Critical thinking, scepticism and educational benefits
>
> Political and economic impact of science and science policy
>
> Social impacts of scientific knowledge
>
> The links between art and science, and the complementary nature of the processes involved
>
> Public involvement in science
>
> Regulatory issues

Two people said that they communicated about the nature of science:

> That the media exaggerate and incorrectly portray science

> Science - the hard, tedious and mundane aspects of research-usually to counter the exaggerated and over-glorified ‘popular’ notion portrayed in the popular press and movies

Three communicated about funding for scientific research and scientists' relatively low pay:

> Lack of funding for basic scientific research
>
> How poorly funded scientific research is in Australia, and how uncertain a scientist's job is, and that you are better having no education and driving a dump truck on a coalmine for three times what a normal scientist gets paid!
>
> Working conditions for scientists

There were also those who communicated about particular issues:

> Benefits of science to natural resource management
>
> Issues on and related to agriculture biotechnology and the debate created by the anti-Biotech groups
>
> Energy production/global warming
>
> The ramifications of climate change and what we should be doing to minimise the effects and risks.

How did scientists communicate?

How respondents communicated their specialised knowledge with the general public in Australia was explored through 19 questions (Q19-Q37). Of the 1,521 respondents in the survey, 1,494 answered the questions 19-36. Twenty-seven people did not answer all the questions because two questions were (accidentally) not made compulsory: (Q23 an interview on talk-back radio (17 did not answer) and Q. 31 'Informal discussions with members of the general public in situations not listed above (12 did not answer). The most frequent communication between scientists and the public occurred through informal discussions, followed by scientists responding to questions from the general public via email, letter or telephone.

Looking specifically at the five top ranking communication activities in decreasing order of frequency, two-thirds of the scientists had informal discussions with the general public[1]. Just over half responded to questions from the general public and just under half had spoken with students and/or teachers at schools/colleges or elsewhere[2]. A similar number had provided information (text, images, audio, video) for the Internet (including a personal webpage) and two in five had spoken at meetings, workshops, or symposiums specifically intended to inform the general public (Table 30). Some commented that communicating face-to-face as a way to control the accuracy of the information made available to the public, as can be seen from the following:

> I work for the Government and most of the public's only understanding of what is done by the Government in a regulatory or health policy manner is via the media. The media's perspective of

[1] Only 4.7% (70) of scientists communicated through 'informal discussions with the general public' and in no other way.

[2] Of those who had communicated with schools, 34.4% were employed by universities; 26.3% were from Commonwealth science or research agencies and 18.8% were from State/Territory/Local government departments or agencies.

> anything can be quite skewed and inaccurate. I have found that if I talk to people about what is currently happening about particular issues they may get a more realistic viewpoint.[3]

In summary, respondents communicated through a mixture of formal situations, such as through enquiries from the public, speaking with students and teachers, and at public meetings; and informal situations, such as conversations with family, friends and acquaintances. It is interesting to note that the five most frequent communication activities did not include the media.

[3] Female, 39, Commonwealth public servant, Administration

Table 30. Communication activity with the general public undertaken at least once in the past 12 months ─ frequency

	Communication activity	At least once in 2006-2007	% respondents to question
Q. 31.	Informal discussions with the general public (in situations not listed [elsewhere in this section])	1008	66.8
Q. 30.	Responding to questions from the general public via email, letter or telephone	806	53.0
Q. 28.	Speaking with students and/or teachers at schools/colleges or elsewhere	703	46.2
Q. 33.	Providing information (text, images, audio, video) for the Internet (including personal webpage)	688	45.2
Q. 24.	Speaking at meeting, workshop, symposium or similar specifically intended to inform the general public	610	40.1
Q. 19.	An interview for a national, [regional] or local newspaper	467	30.7
Q. 32.	Working with schoolteachers (including writing educational materials)	379	24.9
Q. 25.	Participating in a meeting or event specifically intended for two-way communication	358	23.5
Q. 20.	An interview, monologue or panel discussion on radio	343	22.6
Q. 27.	Speaking at an institutional open day for the general public	317	20.8
Q. 26.	Speaking at a field day for the general public	305	20.1
Q. 35.	Writing for publication in the national, [regional] or local press (Including 'Letters to the Editor')	208	13.7
Q. 21.	An interview on television	201	13.2
Q. 34.	Writing for a popular science magazine	196	12.9
Q. 29.	Speaking at science centres/museums with the general public	146	9.6
Q. 23.	Speaking on talk-back radio	145	9.6
Q. 22.	An interview for a popular science magazine e.g. 'Australasian Science', 'Cosmos', 'New Scientist'	141	9.3
Q. 36.	Writing a book for the general public	95	6.2
Q. 37.	Other - Please specify (80 people wrote comments - often explanatory regarding previous answers)	80	
	207 (13.6%) scientists did not communicate through any of the 18 communication activities offered		

How often did they communicate?

Most (86%) of the respondents had communicated at least once with the general public over the previous 12 months while 14% did not select any of the options.

Specifically looking at the media however, it was communication via the newsprint media, through an interview for a national, regional or local newspaper that was the most frequent method of communication. This was for just under one third of all scientists. This was followed in decreasing order of frequency by an interview, monologue or panel discussion on radio (22.6% of the respondents were heard on radio at least once in the last 12 months); writing for publication in the national or local press (including' Letters to the Editor') (13.7%) and an interview on television (13.2%). Further details (frequencies and percentages of respondents) for each of the communication activities are presented Table 31.

Table 31. Scientists' communication – frequency in decreasing order for 2 — 10 times

Communication activity	Frequency over past 12 months (2006—2007)					Total no. respond. to question
	None	Once	2-10 times	>10 times	Summary — at least once	
Informal discussions with the general public (in situations not listed [elsewhere in this section])	501	70	621	317	1008	1509
Responding to questions from the general public via email, letter or telephone	715	128	459	219	806	1521
Providing information (text, images, audio, video) for the Internet (including personal webpage)	833	185	376	127	688	1521
Speaking with students and/or teachers at schools/colleges or elsewhere	818	263	342	98	703	1521
Speaking at meeting, workshop or similar specifically intended to inform the general public	911	208	325	77	610	1521
An interview for a national, [regional] or local newspaper	1054	183	233	51	467	1521
Participating in a meeting or event specifically intended for two-way communication	1163	131	188	39	358	1521
Working with schoolteachers (including writing educational materials)	1142	178	162	39	379	1521
An interview, monologue or panel discussion on radio	1178	138	160	45	343	1521
Speaking at a field day for the general public	1216	145	139	21	305	1521
Writing for publication in the national, [regional] or local press (Including 'Letters to the Editor')	1313	71	122	15	208	1521
Speaking at an institutional open day for the general public	1204	189	114	14	317	1521
An interview on television	1320	107	83	11	201	1521
Writing for a popular science magazine	1325	109	78	9	196	1521
Speaking on talk-back radio	1359	63	67	15	145	1504
Speaking at science centres/museums with the general public	1375	69	60	17	146	1521
An interview for a popular science magazine e.g. 'Australasian Science', 'Cosmos', 'New Scientist'	1380	88	51	2	141	1521
Writing a book for the general public	1426	79	14	2	95	1521
Other - Please specify (80 people wrote comments - often explanatory regarding previous answers)						80
207 (13.6%) scientists did not communicate through any of the 18 communication activities offered						
		<1521 responded because question w as not made compulsory				

Note: The top six ranking activities are shaded green. The two questions for which less than 1,521 scientists responded because the questions were (accidentally) not compulsory are shaded blue.

Frequency distribution of communication activity

To gain an overview and enable further analyses of how much scientists communicated, a 'communication (total) score' was calculated for each scientist by adding up the values assigned to each of their responses by frequency for each of the 18 questions (Appendix 43). This approach was described in the 'Research Design and Methods' chapter and the categories are repeated in Table 32.

Table 32. Scores for communication frequency options

Frequency options to questions 19–36	Score for frequency response	% scientists
No	0	13.6
Once	1 (low)	3.4
2-10 times	2 (medium)	52.4
>10 times	3 (high)	30.6

The total communication activity score for respondents to 18 questions could potentially range from 0 – 54 (18 questions x maximum score of 3). The distribution, however, ranged from 0 – 43 with a mean of 8.5 ± SD 8.0 and was positively skewed towards '0' (skewness = 1.369; kurtosis = 1.920). The median score was 6.0. Just over 30% had high scores (between 11 – 43), half (52.4%) had medium scores and 17% had low scores (0 –1) with 3.4% communicating once and 13.6% not communicating at all. To enable parametric statistical analyses the data were transformed by taking the square root of the score for communication activity (total) score. Thus the score ranged from 0 – 7 with a mean of 2.5 ± SD 1.5 and the data's positive skew was reduced to 0.032; kurtosis = -.403. The median score was 2.5. A summary table of how much scientists communicated with the mean scores (√total) of the communication scores by sex, age, discipline and employers is presented in Table 33.

Table 33. Summary of communication activity (√total) mean score

Demographic	No. of scientists	Mean comm. activity score	SD
Sex			
Female	598	2.3	1.4
Male	922	2.6	1.5
Total	1520	x̄ = 2.5	x̄ = 1.5
Generation			
Gen. Y (age ≤ 27 in 2007)	167	2.0	1.3
Gen. X (age 28 – 42)	605	2.2	1.4
Boomers (age 43 – 61)	602	2.8	1.5
Builders (age 62+)	146	2.9	1.6
Total	1520	x̄ = 2.5	x̄ = 1.5
Discipline with ≥50 scientists			
Chemical sciences	98	1.9	1.5
Mathematical sciences	68	2.0	1.4
Engineering & technology	97	2.1	1.4
Medical & health sciences	218	2.2	1.5
Physical sciences	166	2.3	1.4
Biological sciences	313	2.7	1.4
Agricultural, veterinary & environmental sciences	309	2.9	1.4
Earth sciences	157	3.0	1.5
Total	1426	x̄ = 2.5	x̄ = 1.5
Type of employer institution/organisation with ≥50 scientists			
Hospital	74	1.8	1.4
Industry	85	1.8	1.4
Medical research institute	55	1.9	1.4
University	492	2.5	1.4
Commonwealth government agency/department	485	2.5	1.5
State/Territory/local government department/agency	253	2.9	1.4
Private consultancy business	51	3.1	1.4
Total	1495	x̄ = 2.5	x̄ = 1.5

Total (out of a possible 7.3) communication activity score (summed for 18 activities & transformed by square root). Valid n = 1,520.

Significant differences were found between how much scientists communicated. Males communicated more than females. An independent –samples t-test was conducted to compare the communication activity (√total) scores for males and females. There was a significant difference in scores for males ($\bar{x}$ = 2.65, SD = 1.51) and females, $\bar{x}$ = 2.30, SD = 1.40; t (1347.2) = 4.57, p = 0.000 (two-tailed). The magnitude of the differences in the means (mean difference = 0.346, 95% CI: 0.20 to 0.50) was very small (eta squared = 0.014). Expressed as a percentage, only 1.4% of the variance in communication activity (total) is explained by sex.

The two older generations communicated more than the younger ones. A one-way between groups analysis of variance was conducted to explore the impact of age (divided into four 'generations on communication activity (√total) scores. Post-hoc comparisons using the Games-Howell test indicated that the mean scores for Builders and Boomers were significantly different from Generation X and Generation Y. There were no significant differences, however, between the Boomers and Builders; and Generation X and Generation Y. As the Levene's homogeneity of variance assumption was violated, the Welch test was used. This showed a difference in communication activity (total) scores for the four generational groups (Welch F(3, 427.31) = 29.55, p = 0.000). The effect size, calculated using eta squared, was 0.05 – medium (Cohen, 1988).

Frequency of communication was also associated with Discipline. Those in the Chemical sciences for example communicated significantly less than those in the Biological, Agricultural, veterinary and environmental, and Earth sciences. A one-way between groups analysis of variance was conducted to explore the differences between disciplines for communication activity (√total) scores.. Post-hoc comparisons using the Tukey HSD test indicated, for example that the lowest mean score: which was for Chemical sciences was significantly different from Biological sciences, Agricultural, veterinary and environmental sciences and Earth sciences. There were differences in communication activity (total) scores for the eight disciplinary groupings (F (7, 1418) = 13.84, p = 0.000). The effect size, calculated using eta squared, was 0.06 (medium)

With the highest mean score, scientists in the Earth sciences communicated significantly more than those in the Physical sciences, Medical & health sciences, Engineering & technology and Chemical sciences.

There were no significant differences between scientists' scores within the three disciplines with the highest means: Biological sciences, Agricultural, veterinary and environmental sciences, and Earth sciences. Nor was there a difference between those five disciplines with the lowest means scores: Chemical sciences, Mathematical sciences, Engineering & technology, Medical & health sciences and Physical sciences.

Post-hoc comparisons using the Tukey HSD test indicated that the employer with the highest mean score (Private consultancy business) was not significantly different from the government (Commonwealth and State/Territory/Local) government department or agency. University employers were significantly different from all other employers with the exception of Commonwealth government agency/departments. The employer with the lowest mean score: Hospital was not significantly different from Industry and Medical Research institute.

A one-way between groups analysis of variance to explore the impact of Employer institution/organisation on communication activity (√total) scores found difference in communication activity (total) scores for the seven employer groupings: $F(6, 1488) = 13.65$, $p = 0.000$. The effect size, calculated using eta squared, was 0.05 (medium).

Significant interactions were found for Age, Discipline and Employer, but not Sex. There was, however, a significant interaction between Sex and Age (Generation) using a two-way between groups analysis of variance. The interaction effect between sex and age was statistically significant, $F(3, 1383) = 3.72$, $p = 0.011$; the effect size (calculated using partial eta squared) was small (Partial eta = 0.008) and this was due to Boomer males communicating more than Boomer females. This was identified using an independent-samples t-test T test to compare the communication activity scores for males and females. The only significant difference between the sexes occurred within the Boomer generation and females; $t(600) = 3.08$, $p = 0.002$ (two-tailed) and the

magnitude of the differences in the means (mean difference = 0.41, 95% CI: 0.148 to 0.670) was very small (eta squared = 0.006).

For each of the 18 communication activities, Chi-Square tests for independence were conducted to identify effects of sex, age discipline and employer upon how they communicated. Scientists differed on the basis of their sex for 10 of the 18 activities listed (Table 34). However Cramer's V values indicated that the effect sizes for all were small to very small and therefore the differences between the sexes for these activities, are of little practical importance (Pallant, 2007, p. 263).

For Age (Generation), there were 13 significant associations with communication activities. For discipline, there were eight out of 18 activities that were significantly associated. For discipline, the effect size was small to medium for all of these, and the highest Cramer's V value, for example, was 0.195: 'an interview, monologue or panel discussion on radio (Q 20). For this radio activity it was found, for example, that more scientists in Agricultural, veterinary and environmental sciences, Biological sciences and Earth sciences communicated than expected.

Looking at associations between employer and communication activities and more specifically at Cramer's V values, all effects for those (9) that were significant, were found to be small to medium, with the largest effect (Cramer's V value of 0.164) being for 'responding to questions from the general public by email, letter or telephone'. For this activity, scientists in Private consultancy companies, Universities, Commonwealth and State/Territory/Local departments or agencies communicated more than expected. The significance values are presented in Table 34.

For the purposes of this thesis, it is therefore noted that there were significant interactions between how respondents communicated and their generation, discipline and employer. The details of what this meant in terms of each of the 18 communication activities is beyond the scope of this research.

Table 34. Differences between communication activities x Sex, Age, Discipline & Employer

Significance of differences between frequencies for communication activities	Pearson Chi-Square test for independence			
	Sex	Age (Generation)	Discipline	Employer
Q. 19 an interview for a national, [regional] or local newspaper	<0.001	<0.001	<0.001	<0.001
Q. 20 an interview, monologue or panel discussion on radio	<0.001	<0.001	<0.001	<0.001
Q. 21 an interview on television	<0.001	ANM	ANM	ANM
Q. 22 an interview for a popular science magazine e.g. 'New Scientist'	ANM	ANM	ANM	ANM
Q. 23 speaking on talk-back radio	<0.001	<0.001	ANM	ANM
Q. 24 Speaking at a meeting, workshop etc. specifically intended to inform general public	P = 0.003	<0.001	<0.001	<0.001
Q. 25 participating in a meeting/event specifically intended for two-way communication	NS	<0.001	<0.001	<0.001
Q. 26 speaking at a field day for the general public	NS	P = 0.001	ANM	ANM
Q. 27 speaking at an institutional open day for the general public	P= 0.031	P = 0.016	ANM	ANM
Q. 28 speaking with students and/or teachers at school/colleges or elsewhere	N.S.	P = 0.029	NS	P = 0.001
Q. 29 speaking at science centres/museums with the general public	P = 0.026	NS	ANM	ANM
Q. 30 responding to questions from the general public by email, letter or telephone	<0.001	<0.001	<0.001	<0.001
Q. 31 informal discussions with members of the general public (in situations not elsewhere specified)	N.S.	P = 0.016	<0.001	P = 0.013
Q. 32 working with schoolteachers (including writing educational materials)	N.S.	<0.001	P = 0.024	<0.001
Q. 33 providing information (text, images, audio, video) for the Internet (including your own personal webpage)	NS	<0.001	P = 0.001	<0.001
Q. 34 writing for a popular science magazine	P = 0.030	ANM	ANM	ANM
Q. 35 writing for a publication in the national, [regional] or local press	<0.001	<0.001	ANM	ANM
Q. 36 writing a book for the general public	ANM	ANM	ANM	ANM

NS = Variation is Not Significant ANM = Assumptions of statistical test not met.
Note: For Q25 regarding participation in a two-way communication event, the percentage of expected counts less than 5 was 21.4% and therefore slightly greater than the assumption that these counts should be less than 20%. Therefore the Pearson Chi-Square test may not be reliable but certainly warrants further investigation

Examples of 'Other' Communication Activities

For those 80 people who wrote comments in answer to Q. 37 'Other – please specify', most referred either to communication methods that had already been generally asked about in the previous 18 questions (e.g. 'organised annual public lecture on mathematics'), or communication with those not defined as the general public for this research, such as scientific colleagues, collaborators, clients, policy makers. For example, a number of scientists referred to writing articles for industry and educational journals, industry and professional association newsletters, stakeholder publications (e.g. for primary producers and farm advisers, and fact sheets) and in one case, 'responding to questions from people outside my discipline e.g. chemists, geologists'.

Some different examples of how scientists had communicated with the general public were given, however, and these highlight the many ways that scientists communicate with this audience. Examples of face–to–face opportunities included: ‘After dinner speaker for Rotary’, ‘creating planetarium shows’, ‘talks to the University of the Third Age’, ‘launches of art and science communication activities’ and ‘giving regular brief botanical talks to volunteer guides at a botanic garden’.

Interviews for different purposes were given such as ‘interview for women’s lifestyle magazine’, ‘long interview with a person planning to write a book’ and ‘interview for a careers magazine intended for Yr 11-12 students’,

Examples of written science communication included, ‘regular climate commentary for a regionally distributed news-sheet’, ‘community newsletters’ and ‘inputs to Australian defence magazine’

Television examples included ‘TV documentary – 50 mins’ and ‘Gardening Australia’ [a weekly ABC television program]’ and ‘interview with a production company for a documentary’.

Several wrote about communication via digital media such as ‘recording a podcast interview for public downloading’, and ‘participating in educational DVD about biotechnology’. Online examples included ‘Wikipedia articles’, ‘contributing each month to “Bonzer”, a monthly on-line magazine for 5+ years’ and ‘writing biographical memoirs for the Australian Academy of Science’.

Two scientists wrote about ‘press releases’ and one in particular wrote about a very successful, ‘press release on satellite tracking of frigate birds [that] was published by over 90 newspapers globally’.

Two scientists wrote about working with journalists to ensure accuracy: ‘Editing for accuracy stories written by journalists for the general public’, ‘…responded to queries from the ABC Quantum team re. the work of [a scientist]’.

One scientist wrote about informal discussions with family and friends about science and research: ‘especially why research is required, its potential and impact on community’, and another talks ‘extensively to people about science i.e. in the pub in small communities, to taxi drivers, to politicians, when it is of relevance and appropriate, and if they are receptive’.

Another took the opportunity to comment on his lack of success in reaching a wider audience: ‘Several attempts were made to communicate to a wider audience, but these did not result in publication or have any effect’.

Scientists’ communication activities, work culture and views

Those who communicated more frequently were more likely to have communicating as part of their job, or were recognised or rewarded for their communication. Also, those scientists for whom communicating their knowledge was personally more important were found to communicate more frequently too.

Those who did not have communication in their job description did not tend to communicate with the general public. Of those 197 scientists who did not communicate at all, most (88.3%) did not have communication with the general public as part of their job. Fifty-five percent of those who had medium communication scores did have communication as part of their job description/duty statement or project requirement. This can be seen in a cross-tabulation (Appendix 44). There was a significant association[1]: χ^2 (6, n = 1493) = 111.298, p = 0.000, Cramer’s V = 0.193 (medium effect), between how much scientists communicated, and whether or not communicating with the general public was part of their job.

There was also a significant association between the percentage of scientists who communicated more and those for whom communication was recognised or acknowledged: χ^2 (6, n = 1442) = 112.878, p = 0.000, Cramer’s V = 0.198 (medium effect). For example, scientists who communicated most, (that is those with medium (66.9%) or high (63.6%) communication activity scores), were also those whose communication with the general public was recognised or acknowledged. Amongst those who had low communication activity scores (none or low), the largest groupings of scientists (51-53%) were those who were

[1] Chi-square test for independence (Pearson Chi-Square)

not recognised or acknowledged. A cross-tabulation is presented in Appendix 45.

The data for 'Personal importance' and 'Communication activity' with the general public were strongly skewed. Therefore a non-parametric statistical technique, Spearman's Rank Order Correlation (rho) was used to examine the relationship between seven personal importance categories (from 'Extremely unimportant (1)' to 'Extremely important' (7)) and four communication score categories (from None (1) to High (3)[2].

A significant, medium[3] strength, positive correlation was found between 'Personal importance' and 'Communication score (categories)'; rho = +0.41, n = 1496, p = 0.000, with higher levels of personal importance associated with higher levels of communication activity. Personal importance explained 16.1% of variance in the respondent's score on communication.

The strength of the relationship was stronger and 'large'[4], (rho = +0.513, n = 1496, p = 0.000) when the communication activity (total) score[5] was used and this explained 26.3% of the variance in the respondent's score.

Section summary – scientists' communication

Most (86%) of the respondents had communicated at least once with the general public over the previous 12 months. Within the context of this study, the majority (52%) had a medium score and nearly one-third (31%) had a relatively high score, for their overall communication. About 14% had no communication with the public at all, while 3% communicated once (categorised as 'low' communication activity).

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[2] Those 24 scientists who had no opinion for this question and one scientist who had a maximum communication score were treated as 25 missing values in the analysis.

[3]According to Cohen pp. 79-81 (Cohen, 1988).

[4] According to Cohen pp. 79-81(Cohen, 1988) .

[5] This communication (total score) variable ranged from 0 – 43.

When they communicated, most scientists (over 72%) communicated about the findings, applications and/or potential benefits of their own work, or specialised area of knowledge (70%). To a lesser extent they communicated about a range of related topics, such as careers in science, the benefits of scientific knowledge, its relevance to everyday life, the scientific process and the enjoyment and excitement of doing it. Interestingly, one third communicated about scientific knowledge or issues outside their specialised area. The least number of scientists, or about one in four, communicated about the limitations (25.5%) or wider ethical and social implications of their research findings (24.3%).

Scientists were found to communicate through a mixture of informal and formal situations. For example, in decreasing order, 67% had communicated through informal discussions[6], 53% had responded to questions from the general public during the course of their work and 46% had spoken with students and teachers[7], or provided information for the Internet (45%). Forty per cent spoke at meetings, workshops, or symposiums specifically intended to inform the general public. In terms of the media most scientists (31%) had communicated though an interview for a newspaper, rather than speaking on the radio (23%) or an interview on television (13%) for example. More than half of the scientists (56%) had not communicated via the media and of those who had, most (20%) communicated only once or twice. Face-to-face communication (82%) was much more frequent than communication via the Internet (45%) or media (44%).

Respondents communicated more frequently with the general public when communicating their knowledge was part of their job, recognized or acknowledged, and more personally important to them. How scientists communicated was found to differ significantly on the basis of their sex, age, discipline and employer for a number of the 18 communication activities.[8] For

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[6] Only 4.7% (70) of scientists communicated through 'informal discussions with the general public' and in no other way.

[7] Of those who had communicated with schools, 34.4% were employed by universities; 26.3% were from Commonwealth science or research agencies and 18.8% were from State/territory government departments or agencies.

[8] All had a medium effect size with the exception of sex which had a very small effect size.

example Builders and Boomers communicated more than Generations X and Y; scientists within the Earth sciences, Agricultural, veterinary and environmental sciences, and Biological sciences communicated more than those in the Chemical sciences. Those who worked for a Private consultancy business, State and Commonwealth government departments and agencies, or a University communicated more than scientists in Industry, a Hospital, industry or Medical research institutes.

Hindrances to Scientists Communicating with the General Public

Scientists were asked if anything hindered them from communicating in the way they would like with the general public. Fifty-five per cent of those who had an opinion (1,301) said 'Yes'[9] (See Table 35).

Does anything hinder you from communicating...?	Frequency	Valid per cent
Yes	715	55.0
No	586	45.0
I have no opinion on this topic	127	
Not applicable	93	
Total	1,521	

Table 35. Hindered to communicate – frequency

When asked to describe what hindered them, 691 scientists gave more than eight hundred examples such as:

[9] This summary excluded those scientists for whom this question was not applicable (93 or 6.1%) and those who had no opinion (127 (8.3%).

> It is not part of my role to be a science communicator and I have no training as such. Also I don't have delegated authority to speak in public. That and I don't like public speaking.[10]

This data were sorted into emergent themes, and then categorised into smaller groupings. A further categorisation grouped the responses into the same categories used in a later question ─ about what would help scientists ─ so that the answers to both questions could be compared.

The sources of these hindrances, divided into four broad emergent themes, were, in decreasing order of frequency for the examples, the scientists' workplace, factors external to the workplace, scientists' personal characteristics and the scientific culture.

Most (58%) examples concerned hindrances in the scientist's workplace (which included their particular work/project). One in five scientists wrote about the 'Lack of time to organise it, prepare for it, and present it'. This was the most frequently expressed hindrance for scientists in all organisations. They also described the sensitivity of the research that they were working upon, a lack of opportunity to communicate, and critical peers as workplace hindrances.

Factors external to the workplace (22% of comments) included the public's lack of scientific knowledge, and public perceptions or expectations of science and scientists. Disappointment in and distrust of the media, and media disinterest in science were other hindrances external to the workplace along with government politics and policies. Personal characteristics such as a lack of self-confidence or skills to communicate with the general public or 'Lack of a certain outgoing personality' accounted for 17% of the comments. Hindrances caused by aspects of the scientific culture (3%) included recognition of the difficulty of communicating to those without a scientific knowledge. Together with 'time', most of the examples related to heavy workloads and employer practices and policies, rather than personal hindrances or factors external to the workplace.

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[10] Male, 42, Chemical sciences, Commonwealth Govt.

Workplace

The most frequent hindrances written about by scientists appeared to rest with the workplace as opposed to their own personal characteristics or factors that are arguably external to the workplace control such as commercial considerations, politics, media, national security, the public or technicalities of science. These workplace hindrances included lack of time, heavy workloads, the low priority of communication with the public, the opportunity cost of communicating, sensitivity of research, and critical peers. Aspects of the workplace culture that hindered scientists' communication included censorship, management spin and lack of opportunity. Examples of these comments are presented below with lack of time being the most frequently stated hindrance

Lack of time

Twenty-one per cent of all comments about hindrances related to time and most scientists simply wrote either 'time' with no further explanation, or commented on their heavy workload and other commitments and demands. A few others commented further to say that communicating with the general public was not a priority – it competed with time after work time or did not contribute to their advancement – or that the process of communicating took time (finding opportunities, the work to do it and opportunity cost or time to be trained in communication and to practice it).

For example:

> …Lack of preparation time to produce high quality presentations. I note that presenting to the public takes even more thought and effort than an ordinary research presentation. [1]

> Time, time, time. There have been several instances I would like to have responded to articles, or letters to the editor, in the local newspaper, but my work duties absorb too much time to be able to develop a careful, reasoned, response.[2]

The following quotes give insights into the pressures and priorities in scientists' workplaces that translate into a lack of time for communicating with the general public:

> Lack of time for this type of activity in a highly competitive research environment. This work is not rewarded and therefore it is seen as 'extra' and a community service to do this - but may interfere with my research productivity.[3]

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[1] Male, 34, Physical sciences, Hospital
[2] Male, 45, Chemical sciences, University
[3] Female, 52, Medical & health sciences, University

> Time - huge pressure to apply for funding and produce results and publications, public communication seems less essential than the research and scientific communication.[4]

> I do not have time to communicate to the general public. As a research scientist on fixed term appointments I have to work 25 hours/day 8 days/week on research, publication, funding applications, graduate student supervision, report-writing, networking, and assessing grant applications. There is no scope for talking to the public, even though I would like to.[5]

One respondent commented on the need for science communicators because scientists are so busy: 'Most scientists I think are just extremely busy with the pressures of research and obtaining funding to have time to organize communication with the general public, which is why PR people are needed'.[6]

Heavy workload

University scientists spoke about their heavy workloads:

> My workload is also extremely heavy ... just today I have been approached to go to a school, but may not be able to do it because I'm drowning. [7]

> Too many other calls on my time. Modern academia is very unforgiving in its teaching and admin load, leaving research for 'spare time' and communication after that![8]

A State Government employee also spoke about having more administration as well as research:

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[4] Female, 29, Biological sciences, University
[5] Female, 51, Physical sciences, University
[6] Female, 30, Medical & health sciences, Business
[7] Female, 33, Physical sciences, University
[8] Female, 40, Chemical sciences, University

> So busy doing our job (research) plus the increasing amount of admin work we are required to do (as our admin people are continually reduced) and communication with industry/funding people makes communication to the public a low priority.[9]

Low priority of communication with the public

For some, communicating with the general public was either not a priority or a very low one for them and/or their employers:

> My managers and I do not see it as high priority. My job is primarily to do research which benefits client groups (growers, farm advisers, research funding bodies), and to communicate the results to these clients.[10]

> Time. My employer does not provide me with any time to speak to the general public. I am only encouraged to speak to clients[11].

Commercial concerns also hindered some organisations:

> Caution as to loss of IP (has happened to me before). Funding bodies and employer do not really value communication to the general public, more so to our industry people[12].

Opportunity cost of communicating

Some talked about the opportunity cost of communicating with the public:

> Simply that we are not rewarded/acknowledged for doing so in any of the performance measures. Thus, while the university wants us to do

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[9] Female, 34, Agricultural veterinary & environmental sciences, State/Territory/Local Govt.
[10] Male, 56, Agricultural, veterinary & environmental science State/Territory/Local Govt.
[11] Female, 35, Agricultural, veterinary & environmental science, State/Territory/Local Govt.
[12] Female, 34, Agricultural veterinary & environmental sciences, State/Territory/Local Govt.

> it, we suffer an opportunity loss via not doing other things that are more directly measured.[13]

A Commonwealth government scientist said that she did not have the opportunity because:

> Despite working for the 'Public Service', the public seem to come last in any efforts made by our organisation to communicate the science it does.[14]

She added that the effort is focussed on:

> - Peers in the Mining industry, and their bosses - to increase exploration, to keep the government of the day happy
>
> - Ministers - selling ourselves to keep the money coming to our organisation
>
> - Peers in academia - the only ones interested in whatever science our staff manages to find time to do.
>
> - School students - the workforce of the future (and they only get to hear from specialist Education Officers, mostly ex-teachers) the rest of the staff get no practice at dealing with students[15]

Sensitivity of research

Scientists wrote about being hindered by the public or political sensitivity of their research, such as the use of water or pesticides, animals for research, health-related research, forestry, fire weather research, which discouraged communication.

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[13] Male, 39, Biological sciences, University
[14] Female, 50, Earth sciences, Commonwealth Govt.
[15] Female, 50, Earth sciences, Commonwealth Govt.

Poor or negative public perception of agriculture in use of water or pesticides[16]

Sometimes feel that (as scientists) we need to be guarded about what we say given the possibility for liability or 'someone to take things the wrong way'. (Especially since my research field is health-related).[17]

Employment agency does not promote active independent transfer of information to the general public. Forestry debate is so polarised that it is impossible to contribute without distortion of the information.[18]

Limited time and unwillingness to be part of hostile argument.[19]

Critical peers

Although most scientists commented on hindrances linked with their employers and managers, a few commented on their peers who were either critical of those who communicated at all, or were critical of those who communicated publicly without knowing the subject. For example:

…I am cautious in this regard having heard a significant number of stories in recent years about scientists who have said unpopular or unwelcome truths in public spaces and been punished both professionally and personally for their candor - not by the public, but by their professional colleagues or employing organizations or by government.

My view is that being seen as a communicator with the public is a positive disadvantage to people in their career. It is usually described

16 Male, 59, Agricultural, veterinary & environmental sciences, Commonwealth Govt.

17 Female, 26, Agricultural, veterinary & environmental sciences, University

18 Male, 59, Biological sciences, Commonwealth Govt. research agency

19 Female, 38, Engineering & technology, University

> (behind people's backs) as being a 'media tart', and delays promotion. This is particularly true for women scientists[20]

Workplace culture

The next most frequent response (one-in- six descriptions or 16.2%) concerned hindrances within the workplace (including the requirements of specific projects): its culture, legislations, policies, approval processes and protocol requirements, sensitivities, characteristics, and responsibilities.

One scientist observed wariness amongst older scientists in senior management about 'communicating with the outside world' for example:

> I sometimes get the impression that some parts of senior management (particularly the older generation) are not particularly comfortable with the idea of us communicating with the outside world, and/or are not tolerant of the inevitable occasional encounter that doesn't go well.[21]

Others talked about protocols that stipulate that only senior managers are permitted to speak with the media:

> I work for government who have decided that only senior managers should talk to the press, also aware I can get into trouble if I say the wrong thing (this has happened, got ticked off...for saying something that was true in a newspaper article)[22]

> Older (more experienced) scientists are approached preferentially (although they know little about the work taking place in the lab on a daily basis).[23]

For others, it was more than just an impression:

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[20] Male, 67+, Retired medical laboratory scientist
[21] Male, 36, Earth sciences, Commonwealth Govt.

22 Female, 53, Environmental sciences, State/Territory/Local Govt.

[23] Male, 28, Biological sciences, University

Yes we are gagged by protocols. Whatever one has to communicate goes through several seniors and management staff to approve the content and context of what you are allowed to say.[24]

Many organisations have protocols for communication with the public which require screening or clearance by management first:

My State Government agency requires all communication with the public be screened through media officers. The hassle involved in getting permission to speak is often not worth the effort.[25]

A retired medical laboratory scientist, who had worked in a medical research institute, wrote about his Board's concerns about errors or controversy. In doing so, he probably described the concerns of senior management in many types of employer organisations, with the possible exception of universities, about uncontrolled communication with the public:

Not applicable now that I have 'retired', but certainly when I was in full time (senior) employment the answer would have been 'yes'. My Board was always worried that the consequences of one error or controversial statement would outweigh hundreds of good experiences.

Some scientists were prevented by protocols from commenting on politically sensitive issues or government policy:

I'm on a 1 year renewable appointment....which means that I am always cautious of speaking on topics which are related to my specialist area which might be seen by the powers that be as criticising government policies[26].

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24 Male, 63 Agricultural, Veterinary and Environmental Sciences, State/Territory/Local Govt.

25 Female, 36, Biological sciences, State/Territory/Local Govt.
25 Male, 54, Agricultural, veterinary & environmental sciences, Commonwealth Govt.

26 Female, 33, Physical sciences, University

> Occasional political interference by my departmental executives and State politicians. I have in the past been threatened with dismissal if I spoke out on a particular sensitive subject, but I have so far ignored such threats by speaking out as a private citizen not affiliated with government. My Public Sector Union would have backed me were dismissal to have still occurred.[27]

> The very real constraint that I must be extremely careful not to upset my political masters, my professional clients (esp. fellow agencies who part fund my work) and the agency I work for. It is very difficult not to be able to directly comment on public policy when your research results clearly show that current policy is inadequate[28].

Censorship

Censorship was specifically mentioned by Government employees (both Commonwealth and State/Territory/Local):

> The issue isn't communication it's censorship and freedom of opinion. In my government department, every official public communication is vetted through a media liaison officer, and has to be approved by the CEO of the Department. The key concept of scientific training and knowledge is truth and independence, so why are senior bureaucrats the given the power of veto?[29]

> Agency censorship in broad sense of discouraging all but senior executive from speaking in major fora and allowing more junior staff only to speak informally and under guidance from senior management[30].

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[27] Male, 55, Earth sciences, State/Territory/Local Govt.

[28] Male, 50, Biological sciences, Commonwealth Govt. on term contract

[29] Male, 40, Biological sciences, State/Territory/Local Govt.

[30] Female, 40, Biological sciences, Commonwealth Govt.

> There is increasing pressure on scientists of a censorship or self-censorship nature.[31]

Management spin

Management spin (or marketing depending on your perspective), rather than science communication, was believed to be their employer's requirement according to some government employees:

> The moronic attitude to employment contracts and intellectual property that pretty much excludes anyone who knows anything about a topic from making public comment on it. We are really only permitted to communicate spin. We are not permitted to discuss or debate or even present fact unless approved as politically or commercially beneficial.[32]

Lack of opportunity

Nine per cent of hindrances concerned lack of opportunity to communicate. Scientists wrote that they were limited by employer, opportunities were rare, that they were not often asked, or it was not their job to seek them, or it was not often that they had something to communicate.

> …Opportunity to talk to the general public is the problem. I have only addressed a community group once in the last 4 years. I would willingly do more but need the opportunity…[33]

Others wrote that opportunities to communicate have to be sought and that they had difficulties finding their own opportunities or they did not have access or contact or support with media, a specialised or general public, or they were not sure how to go about it. Others commented on the lack of opportunity or that the time it takes to find opportunities and that this was time that they did not have.

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[31] Male, 62, Biological sciences, Commonwealth Govt.

[32] Male, 41, Agricultural, veterinary & environmental sciences, State/Territory/Local Govt.

[33] Male, 67+,

Factors external to the workplace

Scientists gave examples of hindrances to their communication that were outside their workplace such as the media, politicians and the public. For example, some scientists commented on the media's desire for 'breakthrough' stories and journalists' lack of understanding about the nature of research:

> Also most journalists reporting on science do not have a science background and do not appreciate or understand what they could be reporting on. With the exception of Cosmos magazine the standard of reporting on science in Australia is dismal with an emphasis on 'breakthroughs' rather than informing the public of the long years of research it takes to achieve a so called 'breakthrough'[34].

A male scientist, over 67, commented on politicians' views of science as a hindrance:

> The general public appears to be indifferent to science and technology. …I also do not believe politicians have any appreciation either and I suspect this might be because too many of them come from a legal or non-industrial background….[35]

Other scientists stated that the public hindered their communication because people had negative views of particular scientific research; from disinterest to fear.

> When one mentions the words 'cancer' and 'radiation' in the same introductory sentence, many people are already recoiling in horror and fear.[36]

One scientist pointed out pragmatically that people were less interested in science that does not affect them:

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[34] Female, 30, Medical & health sciences, Industry
[35] Male, 67+, Engineering & technology, Private Consultancy Business

[36] Female, 43, Physical sciences, Hospital

> Public usually interested in things that directly affect them (a cure for cancer will elicit interest but the elimination of a plant disease will elicit yawns).[37]

Some believed that the stereotypical public image of scientists and academics was a barrier to their communication:

> …The image of the scientist as confined to the ivory tower, having no knowledge, skill or interest in `the real world', typically bumbling and useless outside of their specialty, is something that has to be overcome every time we communicate with the public. It is a barrier to people listening or taking the subject seriously.[38]
>
> A common prejudice that science is boring, irrelevant or evil[39]

Another seemed to resent the style of communication they believed was required to engage the audience:

> Seem to need a 'song and dance' act to get the public to understand or be interested in some aspects of science.[40]

Personal characteristics

Their own personal characteristics were hindrances for some, and these represented 17% of respondents' comments.

> My own anxiety. My desire to make the subject appealing and attractive.[41] …

Others said they lacked confidence or presentation skills:

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[37] Male, 39, Biological sciences, Business

[38] Male, 36, Mathematical sciences, University

[39] Male, 52, Engineering & technology, Industry

[40] Male, 39, Biological sciences, Industry

[41] Male, 34, Physical sciences, Hospital

> Self confidence, not in my area of expertise. Being an introverted personality, I lack the public confidence to be more 'extroverted' on this.[42]

Others were simply not interested in communicating with the public:

> I am more interested in the technical side of science than the PR side.[43]

Scientific culture

Three per cent of comments referred to the culture of science which was the smallest grouping amongst the four major hindrance themes. Scientists generally recognised the difficulty of communicating specialist knowledge to a non-specialist audience:

> Sometimes hard to simplify the topic enough to be understood.[44]

> Struggle making topic matter relevant and available to all levels.[45]

> Sometimes the research is too difficult to understand without a science degree or further education.[46]

> The largest difficulty is the gap in knowledge between scientists and the general public. It is hard to remember that the general public is often poorly informed on many issues and so there is the danger of talking over their heads, but one does not want to over simplify things and risk talking down to them.[47]

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[42] Male, 48, Engineering & technology, Commonwealth Govt.
[43] Male, 39, Biological sciences, Industry

[44] Male, 45, Biological sciences, Medical research institute

[45] Male, 25, Chemical sciences, University

[46] Female, 29, Medical & health services, Medical research institute

[47] Male, 30, Biological sciences, University

Others talked about the difficulty of translating scientific information for the general public and the lack of a forum in which to do so:

> Go to conference - and listen to the shit that is talked about. Now how do we translate this into publicly digestible form. Where is the forum? Could say more, but must do some work.[48]

One scientists seemed to be commenting on the nature of science and lack of direct relevance of most science to people's lives.

> Most science isn't high impact.[49]

The next section concerns the differences found between the hindrances scientists encountered, on the basis of their sex, age, and employer.

Hindrances – the effect of Sex, Generation, Discipline and Employer

Significantly more females (χ^2 (df = 1, n = 93) = 20.7, p < 0.0001) than expected described personal characteristics or circumstances such as lack of confidence as hindering them in their communication in the way they would like with the general public (See Appendix 46). Significantly more males than expected (χ^2 (df = 1, n = 314) = 4.0, p = 0.0455) wrote that they were hindered by workplace or employer resources, culture, requirements, approvals, policies or practices. Observed and expected values for males and females, and the results of chi-square analyses for all hindrance themes are presented in Appendix 47 .

There were three significant generational effects on hindrances to communication. More Generation X and Y scientists than expected wrote about being hindered by the public's views and reactions (χ^2 (df = 3, n = 59) = 14.0, p = 0.003). Generation X and Y scientists were more likely write about being hindered by the public's lack of scientific knowledge, or their views on particular scientific issues:

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[48] Male, 43, Medical & health sciences, CRC
[49] Male, 39, Biological sciences, Industry

> The fact that few people have the basics to understand. It's very difficult to explain things when the basics are not known...[50]

> A large proportion of my research required animal testing of antimalarial drugs. When presenting to the public I have to delete any reference to my use of animals as the public do not understand the importance of animal research or the stringent ethics that we must abide to. Their opinions are swayed by media attention and opinions to animal research. For open days in the university that I work, I have to take down any of my research posters that reference the use of animals so that I do not offend anyone from the public. It would be wonderful if animals did not have to be used for research, however what most of the public do not understand or think about is that if we didn't test on animals what other model would we use, humans? Thus I feel that public opinion of this model of testing prevents me from presenting the true nature of my research, which is often most disappointing as we are helping society as a whole.[51]

More than the expected number of Boomers (χ^2 (df = 3, n = 190) = 13.1, p = 0.004) wrote that they were hindered by time, and more than expected number of scientists from Generation X (χ^2 (df = 3, n = 62) = 8.3, p = 0.040) described lack of opportunity (Appendix 48). Although these hundreds of comments about hindrances were written by scientists from different disciplines, the number for each discipline category was too small for further statistical analysis.

Within any one of the seven employer categories, the most comments were made about time. Most examples of hindrances were given by scientists in universities (34%) and Commonwealth Government agencies and departments (32%), followed by those in State/Territory/Local government department and agency (20%). Those working for the Government for example, wrote more

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[50] Female, 23, Biological science, Commonwealth Govt., Gen. Y

[51] Female, 25, Medical & health sciences, University, student (postgraduate), Gen. Y

comments about being hindered by policies and protocols. Those employed by a University wrote more often about lack of time (See Table 36).

Table 36. Hindrances x Employer – frequency of examples

If anything hinders you from communicating in the way you would like with the general public, please describe	Employer									%
Hindrances	Uni.	Med.Inst.	C. Govt	Priv.consult.	St./Ter. Govt	Industry	Hospital	Sub-total	Total	of 822
COMMERCIAL, legal & confidential considerations*	11	1	14	3	5	5	0	39	**39**	**4.7**
MEDIA - Perceptions & experience	13	1	11	0	6	1	1	33	**33**	**4.0**
PERSONAL characteristics or circumstances (lack of confidence, knowledge, motivation or fear)	27	7	30	1	15	6	6	92		
Lack of communication skills & training (science, media, general)	13	0	5	0	4	2	3	27		
Lack of experience or practice	7	2	4	1	1	1	2	18	**137**	**16.7**
POLITICS**	6	0	10	2	20	1	1	40		
National Security or Higly Classified			7					7	**47**	**5.7**
PUBLIC - Perceptions & experience of public(s) views , reactions & interests (e.g. lack of interest)	29	1	15	0	9	7	3	64	**64**	**7.8**
SCIENCE culture, language, practice, content (difficult to simplify or communicate)	8	2	6	2	7	3	0	28	**28**	**3.4**
WORKPLACE culture, requirements, sensitivities,characteristics, approvals, policies, responsibilities										
Culture and circumstances(Other) e.g. lack of direction or policies from management	4	0	9	0	2	0	0	**15**	15	1.8
Cost, limitied benefit or negative aspects of communicating	3	0	4	2	1	0	0	**10**	10	1.2
Lack of Funds or Payment or resources for communication activities	11	0	5	5	6	0	0	**27**	27	3.3
Lack of help, encouragement, interest, reward, appreciation or recognition of effort involved	9	1	10	1	5	1	0	**27**	27	3.3
Lack of Opportunity***	15	2	14	4	6	2	0	**43**	0	0.0
Lack of opportunity****	15	1	5	4	2	2	1	**30**	73	8.9
Not part of my job or someone else's responsibility in organisation	4	0	8	0	7	0	0	**19**	19	2.3
Workplace - Policies, legislation, contracts or regulations, restrictions, sensitivities, positions or reluctance	6	3	36	0	25	4	2	**76**		
Workplace - Approval processes or protocols - need, time and effort and knowing when to do it and what to do	3	0	17	0	16	1	1	**38**		
Workplace - Issue - Sensitivites or lack of clarity related to particular ISSUES or subjects (not specifically security or politics)	2	1	12	0	3	0	1	**19**	**133**	**16.2**
Workplace - Time or opportuntiy cost to organise it, prepare for it, and present it								**0**		
Workplace - Time - (no further explanation)	43	1	16	2	10	4	4	**80**		
Workplace - Time - Heavy workload - other work commitments demands on time	24	1	9	1	11	1	2	**49**		
Workplace - Time - Not a priority or competes with time after work time or doesn't contribute to advancement	9	1	9	1	5	0	0	**25**		
Workplace - Time - The process of communicating takes time*****	7	0	5	0	2	0	2	**16**	**170**	**20.7**
Other - not sure how to categorise including being hampered by science communicators	3	0	1	0	1	1	1	**7**	**822**	**100.0**
Total	**272**	**25**	**262**	**29**	**169**	**42**	**30**	**829**		

* e.g. contracts, Codes of Conduct, industry regulations

** e.g. political sensitivities, implications, impacts (employer, government, industry, funders, client & unstated) or policies

***e.g. limited by employer.opportunities rare - not often asked, not my job to seek them/not often have something to communicate

****e.g.have to be sought,difficulties finding own opportunities or no access, contact or support with media, specialised or general public or forum or not sure how to go about it

***** e.g. finding opportunities, the work to do and opportunity cost or time to be trained and practice

Lack of time was the most frequent hindrance for two-thirds (67/100) of the scientists who worked for a University; and workplace policies, legislation, contracts, regulations, restrictions, sensitivities or reluctance and related issues were the most frequently given hindrances by almost one in four (61/252 examples) scientists working for Government organisations (both Commonwealth (14%) and State/Territory/Local (10%)). These workplace policies and similar issues were found to be much less of a hindrance to scientists in a University (2%) than those in Government.

For Commonwealth Government agency scientists, the emergent theme with most comments (14% or 36/252) was ‘Workplace policies, legislation, contracts or regulations, restrictions, sensitivities, positions or reluctance’. The following statement by a Commonwealth employee exemplifies the hindrances imposed by a workplace position on public comment about government policy:

> The very real constraint that I must be extremely careful not to upset my political masters, my professional clients (esp. fellow agencies that part fund my work) and the agency I work for. It is very difficult not to be able to directly comment on public policy when your research results clearly show that current policy is inadequate.[1]

Further examples, written by scientists of the hindrances they have encountered are grouped into emergent themes and presented in Appendix 49.

Summary ─ hindrances to communication

Just over half (55%) of respondents were hindered in communicating in the way they would like with the general public. When asked to describe the hindrances, most (58%) examples related to workplace workloads and employer practices and policies, rather than personal hindrances, aspects of the scientific culture or factors external to the workplace such as the media. The most frequent hindrance was the lack of time (21% of comments); followed by other

[1] Male, 50, Biological sciences, Commonwealth Govt. on a term contract.

hindrances (16.2% of examples) within the workplace or the workplace culture. Nine per cent concerned lack of opportunities to communicate.

There were differences between males and females, with more females than expected describing personal characteristics such as lack of confidence, lack of knowledge, lack of motivation, or fear hindering them. Males were more likely to be hindered by their workplace policies, legislation, contracts or regulations, restrictions, sensitivities, positions or reluctance.

Significant generational difference indicated that the younger generations (X and Y) were hindered by their perceptions and experience of the public. Generation X was also hindered by lack of opportunities and Boomers were hindered by lack of time to organise, prepare and present to the general public.

There were differences in the frequency of particular hindrances identified by scientists employed in different types of institutions/organisations. Working for the Government, scientists wrote more comments about being hindered by policies and protocols for example, while those in universities wrote more often about lack of time.

Areas for Improvement to Facilitate Better Communication

Scientists were asked, ‘If you want or have to communicate with the general public, what, if anything would help you most to communicate in the way you would like? There was no restriction on how many of the 19 answer options the scientists could select, and on average they chose between 3 ─ 4 options. This may reflect that, to some scientists, the options appeared similar or overlapping such as ‘Specific training to communicate science’, ‘Training in media skills’ and ‘Training in general communication/presentation skills’. Table 37 presents the number of responses for each option and the number of cases or respondents (by per cent) who selected each option.

Of the 96.1% of scientists who selected from the 15 ‘help most’ options or suggested their own (0.9% or 46 scientists); the top six ‘help most’ options in decreasing order by percentage of responses (12.4 ─7.9%), were ‘Time for communication’; ‘Communication experience/opportunities to communicate’, ‘Specific training to communicate science’, ‘Training in media skills’, ‘Support (encouragement, recognition) from management for my communication

activities' and 'Help from professional science communicators' represented. For a very small percentage this question was not applicable (1.3%) or they had no opinion (1.3%) or did not need help (1.3%). What would help scientists most was found to differ significantly with their Sex, Generation, Discipline and Employer. Significant differences were found for all four independent variables across the 17 'help most' options using a Multiple Response Pearson Chi-Square Tests: Sex ($\chi2$ (df = 16, n = 1,521) = 130.54, p = 0.000), Generation ($\chi2$ (df = 48, n = 1,521) = 387.59, p = 0.000), Discipline ($\chi2$ (df = 112, n = 1,521) = 355.30, p = 0.000) and Employer ($\chi2$ (df = 96, n = 1,521) = 621.14, p = 0.000).

Table 37. What would help scientists most to communicate – frequency

	Responses		
What would help most?	N	Per cent	Per cent of cases
Time for communication	672	12.4%	44.6%
Communication experience/opportunities to communicate	533	9.8%	35.4%
Specific training to communicate science	494	9.1%	32.8%
Training in media skills	457	8.4%	30.3%
Support (encouragement, recognition) from management for my communication activities	433	8.0%	28.8%
Help from professional science communicators	430	7.9%	28.6%
Funds for my communication activities	366	6.7%	24.3%
Training in general communication/presentation skills	349	6.4%	23.2%
If it was part of my job description/duty statement	271	5.0%	18.0%
Less secrecy due to politics (government)	249	4.6%	16.5%
Less secrecy due to intellectual property concerns	235	4.3%	15.6%
Less secrecy due to politics (institutional/organisational)	229	4.2%	15.2%
Less secrecy due to commercial confidentiality	222	4.1%	14.7%
Different employer public comment policy	180	3.3%	12.0%
Not applicable	72	1.3%	4.8%
No help needed	68	1.3%	4.5%
I have no opinion on this topic	68	1.3%	4.5%
Less secrecy due to national security concerns	59	1.1%	3.9%
Other - Please specify	46	0.8%	3.1%
Total	5,433	100.0%	360.8%

Note: These results are broad descriptors. For example, 'Time for communication' could mean, according to respondents comments made about hindrances, that people are experienced and know how much time it take to prepare, or that it is not a priority for them, or their employer when compared with other demands on their time.

Sex

There were significant differences between males and females for eight of the 16 'What would help most' options offered[1]. Women were more likely to select 'Specific training to communicate science' ($\chi2$ (df = 1, n = 1,521) = 35.668, p = 0.000), and 'Communication experience/opportunities to communicate' ($\chi2$ (df = 1, n = 1,521) = 33.404, p = 0.000), and the effect sizes were small-medium. These analyses showed that females were also more likely to select the training and support options than were the males. The effect was small for 'Training in media skills' ($\chi2$ (df = 1, n = 1,521) = 20.794, p = 0.000), 'Help from professional science communicators' ($\chi2$ (df = 1, n = 1,521) = 13.433, p = 0.000), and 'Training in general communication/presentation skills' ($\chi2$ (df = 1, n = 1,521) = 13.368, p = 0.000). It was very small for 'Support (encouragement, recognition) from management' ($\chi2$ (df = 1, n = 1,521) = 35.668, p = 0.000). The males were more likely to select 'No help needed' $\chi2$ (df = 1, n = 1,521) = 9.921, p = 0.002) and 'Different employer public comment policy' ($\chi2$ (df = 1, n = 1,521) = 5.989, p = 0.014) although the size of the effect was very small. The frequency distribution for selections made by males and females is shown in Appendix 50. The analyses are summarised in Appendix 51 and simplified in Table 38.

[1] (excluding 'Not applicable', 'I have no opinion on this topic' and 'Other – please specify').

Table 38. 'Help most' options & significant associations with Sex

Help most' options (8/16) for which there were significant (p ≤ 0.05) associations with Sex	Sex	
	Male	Female
Specific training to communicate science		☼
Communication experience/opportunities to communicate		☼
Training in media skills		☼
Help from professional science communicators		☼
Training in general communication/presentation skills		☼
No help needed	☼	
Support (encouragement, recognition) from management		☼
Different employer public comment policy	☼	

Key : More likely to select 'Yes' for this option	☼

Age (Generation)

Table 38 and Appendix 52 show that there were significant differences between the generations for 13 of the 16 'what would help most' options[2] For example, the Boomers selected more frequently than the other generations: 'Time for communication' $\chi 2$ (df = 3, n = 1,521) = 38.146, p = 0.000). The younger generations (X and Y) selected more often than expected 'Specific training to communicate science' $\chi 2$ (df = 3, n = 1,521) = 85.361, p = 0.000) and 'Communication experience/opportunities to communicate' $\chi 2$ (df = 3, n = 1,521) = 84.801, p = 0.000),, 'Training in media skills' $\chi 2$ (df = 3, n = 1,521) = 36.313, p = 0.000) and 'Training in general communication /presentation skills'[3] $\chi 2$ (df = 3, n = 1,521) = 35.181, p = 0.000). Their desires were identical with one exception; Generation X was more likely to select 'Different employer public comment policy' than expected $\chi 2$ (df = 3, n = 1,521) = 15.512, p = 0.000). Otherwise both generations selected the following options as helping them most. These options were all about training, opportunity, support and pragmatically, if it was formally part of their job.

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[2] Excluding 'Not applicable', 'I have no opinion on this topic' and 'Other – please specify'.
[3] The effect size for the four options was small-medium.

Specific training to communicate science

Communication experience/opportunities to communicate

Training in general communication/presentation skills

Less secrecy due to intellectual property concerns

Help from professional science communicators

If it was part of my job description/duty statement

Support (encouragement, recognition) from management

Funds for my communication activities

Funds for my communication' was an option selected by all but the Builders, but the effect size of the significance of this difference was very small.

Scientists in Generation X and Y, unlike the two older generations, were more likely to select 'Less secrecy due to intellectual property concerns' although the effect size was small. 'Funds for my communication' was selected by all but the Builders $\chi 2$ (df = 3, n = 1,521) = 10.226, p = 0.000) but the effect size was very small. These analyses are presented in Appendix 52 and a summary in simplified form is presented in Table 39.

Table 39. ‘Help most’ options & significant associations with Age (Generation)

Help most' options (13/16) For which there were significant associations ($p \leq 0.05$)	Age (Generation) Gen Y. (aged 21—27)	Gen. X (aged 28—42)	Boomers (aged 43—61)	Builders (aged 62+)
Specific training to communicate science	☼	☼		
Communication experience/opportunities to communicate	☼	☼		
No help needed			☼	☼
Time for communication			☼	
Training in media skills	☼	☼		
Training in general communication/presentation skills	☼	☼		
Less secrecy due to intellectual property concerns	☼	☼		
Help from professional science communicators	☼	☼		
If it was part of my job description/duty statement	☼	☼		
Less secrecy due to politics (government)			☼	
Support (encouragement, recognition) from management	☼	☼	☼	
Different employer public comment policy		☼	☼	
Funds for my communication activities	☼	☼	☼	
Key : More likely to select 'Yes' for this option	☼			

Discipline

Table 40 and Appendix 53 show significant disciplinary differences between scientists' selections for nine out of 16 'What would help most' options. Of these, the following four had the largest effect size, which was small-medium. All four were concerned with less secrecy due to political (government and institutional) and commercial (commercial confidentiality and intellectual property) considerations:

Respondents from three of the eight disciplines: Agricultural, veterinary and environmental sciences, Biological sciences and Earth sciences were more likely to choose 'Less secrecy due to politics (government)' ($\chi 2$ (df = 7, n = 1,426) = 69.565, p = 0.000). Scientists from four disciplines selected 'Less secrecy due to institutional/organisational politics' more frequently than expected ($\chi 2$ (df = 7, n = 1,426) = 44.893, p = 0.000). They worked in the Agricultural, veterinary and environmental sciences, Biological Chemical, Earth sciences, and Engineering and technology sciences. Commercial confidentiality was more of a concern for scientists in the Chemical, Engineering and technology, and Medical and health sciences ($\chi 2$ (df = 7, n = 1,426) = 55.125, p = 0.000), while 'Less secrecy due to intellectual property concerns' was selected by respondents in the Agricultural, veterinary and environmental sciences, Chemical, Engineering and technology, and Medical and health sciences ($\chi 2$ (df = 7, n = 1,426) = 47.673, p = 0.000).

Scientists within five disciplines (the exception of those in the Mathematical sciences, Medical and health sciences, and Physical sciences), were more likely to select 'Different employer public comment policy' ($\chi 2$ (df = 7, n = 1,426) = 16.175, p = 0.024). For those respondents in the Mathematical sciences 'Less secrecy due to national security concerns' was the only option they were more likely to select ($\chi 2$ (df = 7, n = 1,426) = 24.061, p = 0.001).

Further results of the Chi-square analyses showing those options for which there were significant differences between the numbers of selections are presented in Appendix 53. It is beyond the scope of this thesis to explore further these disciplinary differences in the need for secrecy, but it is worthy of further study to understand why this is so.

Table 40. 'Help most' options & significant associations with science disciplines Key: More likely to select 'Yes'

Help most' options (9/16) with significant ($p \leq 0.05$) associations with Disciplines	Science disciplines with ≥ 50 people(8)							
	Ag., vet. & environmental	Biological	Chemical	Earth	Engineer. & technol.	Math.	Medical & health	Physical
Less secrecy due to politics (government)	☼	☼		☼				
Less secrecy due to commercial confidentiality			☼		☼		☼	
Less secrecy due to intellectual property concerns	☼		☼		☼		☼	
Less secrecy due to politics (institutional/organisational)	☼	☼		☼	☼			
Less secrecy due to national security concerns			☼		☼	☼		☼
Funds for my communication activities	☼	☼						☼
Different employer public comment policy	☼	☼	☼	☼	☼			
Support (encouragement, recognition) from management	☼	☼		☼				☼
Training in media skills	☼	☼					☼	

Employer

Table 41 and Appendix 54 show significant differences between the seven employer types for 12 ‘help most’ options, with small-medium effect sizes for six of them. For example, scientists employed by government (both Commonwealth and State/Territory/Local) were found to be more likely to want a ‘‘Different employer public comment policy’ ($\chi2$ (df = 6, n = 1,496) = 98.701, p = 0.000).

Four of the six options with the largest effect concerned less secrecy. Government scientists (all levels of government) and those employed in Private consultancy companies, who probably had government clients, wanted less secrecy due to government politics ($\chi2$ (df = 6, n = 1,496) = 135.525, p = 0.000). ‘Less secrecy due to politics (institutional/organisational)’ was also selected by more than expected by scientists working for government at all levels ($\chi2$ (df = 6, n = 1,496) = 59.563, p = 0.000). ‘Less secrecy due to national security concerns’ was more likely but not only, selected more frequently by scientists employed by a Commonwealth government agency/department ($\chi2$ (df = 6, n = 1,496) = 62.016, p = 0.000) . ‘Less secrecy due to commercial confidentiality’ – was found to most help scientists employed by a Commonwealth government agency/department, Industry, or a Private consultancy business ($\chi2$ (df = 6, n = 1,496) = 57.183, p = 0.000)

‘Funds for my communication activities’ was selected by more than expected numbers of scientists employed by a University, State/Territory/Local Governments and Private consultancy businesses ($\chi2$ (df = 6, n = 1,496) = 39.725, p = 0.000). This last result partially concurs with the finding of the 2006 United Kingdom survey of scientists from universities for whom funding was an issue with their public engagement (Trench & Junker, 2001).

Looking at other associations between employer and ‘what would help scientists most’, respondents employed by a Hospital were more likely to select ‘Communication experience/opportunities to communicate’ than expected, and to select only this option as to what would help them most ($\chi2$ (df = 6, n = 1,496) = 18.372, p = 0.005). On the other hand, scientists employed by the

Commonwealth agencies and departments were more likely to select most (8 out of 12) options. Whether this greater desire for help is linked to their higher percentage of permanent or indefinite employment is a subject for another study. The results from Chi-square tests for independence (Pearson Chi-Square) showing significant differences are presented in Appendix 54.

Amongst those who selected 'Less secrecy due to national security concerns' most (47 of 60) but not all, were employed by Commonwealth government agencies or departments. A small number were employed in universities, State/Territory/Local Government and Industry. The frequencies are shown in Appendix 55. Less secrecy, for various reasons such as government politics, appears to be more of an issue for those scientists who worked for Government agencies and in a University.

Table 41. 'Help most' options & significant associations with different types of employer

What would help you most' options (12/16) for which there were significant ($p \leq 0.05$) associations	Type of employer institution/organisations ≥ 50 scientists (7)						
		Government					
		Commonwealth	State/Territory/local			Medical	Private consultancy
	University	agency/department	department or agency	Industry	Hospital	research institute	business
Less secrecy due to politics (government)		☼	☼				☼
Different employer public comment policy		☼	☼				
Les secrecy due to national security concerns		☼					
Less secrecy due to politics (institutional/organisational)		☼	☼				
Less secrecy due to commercial confidentiality		☼		☼			☼
Funds for my communication activities	☼		☼				☼
Support (encouragement, recognition) from management	☼	☼	☼				
Less secrecy due to intellectual property concerns		☼		☼		☼	☼
Time for communication	☼		☼				☼
Communication experience/opportunities to communicate	☼				☼	☼	
If it was part of my job description/duty statement		☼	☼	☼			
Help from professional science communicators	☼					☼	

Key : More likely to select 'Yes' for this option

Summary – what would help scientists most?

The top ranking six 'help most' options selected by scientists in decreasing frequency of responses were 'Time for communication'; 'Communication experience/opportunities to communicate', 'Specific training to communicate science', 'Training in media skills', 'Support (encouragement, recognition) from management for my communication activities' and 'Help from professional science communicators'. Scientists' desires for help varied significantly with their Sex, Age (Generation), Discipline and Employer.

Males were more likely than females to select 'No help needed' and 'Different employer public comment policy', while females were more likely to select the training and support options such as 'Specific training to communicate science' and 'Communication experience/opportunities to communicate'.

There were many significant generational differences. For example, the younger scientists wanted communication training to communicate science, media skills, and general communication/presentation skills. Many of the Boomers, by comparison, either did not need help, or simply wanted time for communication.

There were also many disciplinary differences found between scientists: for nine out of 16 'help most' options. Scientists from five of the eight disciplines wanted different employer public comment policies. The exceptions were those in the Mathematical sciences, Medical and health sciences, and Physical sciences. For those scientists in the Mathematical sciences,' Less secrecy due to national security concerns' was the only option they were more likely to select than was expected. Less secrecy due to politics (government and institutional), commercial confidentiality and intellectual property concerns emerged as a source of significant variation between the disciplines. For example 'Less secrecy due to commercial confidentiality' was selected by more than expected scientists from the Chemical, Engineering and technology, and Medical and health sciences.

Significant employer differences were found for 12 options. Those six that had the largest effect included the four 'less secrecy' options due to politics (government and institutional), commercial confidentiality and intellectual property, different employer public comment policy and, as a small-to- medium

strength effect, 'Funds for my communication activities'. Scientists from universities, State government and private consultancy business were more likely to want funds for their communication activities. Less security due to national security concerns was a significant source of variation between employers because more than statistically expected numbers of scientists from Commonwealth government agencies and departments selected this option.

Summary ─ Communication Differences due to Scientists' Sex, Age, Discipline and Employer

The following section is a brief synthesis of the significant differences found between scientists' communication with the general public on the basis of their Sex, Age (Generation), Discipline and Employer. These have already been presented in this chapter in greater detail, but as there are so many, they have been summarised in to enable easier comparisons of the results between scientists' views. These concern four aspects of scientists' communication with the general public: personal importance, professional responsibility, self-assessed communication skill, hindrances to communication and what would help most (Table 42).

Between the four age or 'generation' groups, statistically significant differences existed for all four aspects of scientists' communication explored in this study:

Personal importance of communicating
Scientists' responsibility to communicate with the general public
Hindrances from communicating in the way they would like
What would help scientists to communicate?

With regard to scientists' working in different discipline and for different employer[221], personal importance and what would help scientists most to communicate were significant sources of variation.

[221] There was a statistically significant effect for employer $F(6, 1348) = 4.536$, $p = 0.000$; however the effect size was small (partial eta squared = 0.033 0.020 (employer)).

Table 42. Summary ─ Significant differences between scientists' communication x Sex, Age, Discipline & Employer

Communication with the general public	Sex (2)	Generation (4)	Discipline (8)	Employer (7)
Scientists' responsibility	X	✓	X	X
Personal importance of communicating	X	✓	✓	✓
Hindrances from communicating in the way they would like	✓	✓	─	─
What would help scientists to communicate	✓	✓	✓	✓

✓ = Significant differences found
X = No significant differences found
─ = analyses not conducted at this level

Respondents' age, divided into four generational groups, affected all aspects of scientists' communication examined. Significant differences were found for 10 of the 16 associations between respondents' characteristics (Sex, Generation, Discipline and Employer) and their views on four aspects of their communication with the general public (a scientists' responsibility, personal importance of communicating, hindrances and what would help most).

Sex

Males and females generally agreed that it was personally important to them to communicate their specialised knowledge with the public. Females identified different kinds of hindrances to their communication and described personal characteristics or circumstances such as lack of confidence as hindering them in their communicating in the way they would like with the general public. Males were more likely to be hindered workplace or employer resources, culture, requirements, approvals, policies or practices.

There were also distinct patterns of difference between males and females regarding what would help most to communicate with the general public. Females wanted more training to communicate science and communication experience and opportunities to communicate than males. To a lesser extent, more males selected the option 'No help needed' or wanted more freedom to communicate as they selected 'Different employer public comment policy' more often than women.

Generation

Respondents' age was a source of difference between their views and experiences of communication with the general public. Generation significantly affected all the aspects examined:

scientists' responsibility
personal importance of communicating
communication activity
hindrances from communicating in the way they would like
what would help them most to communicate
rewards and recognition.

For example, scientists differed in their agreement with the statement about scientists' responsibility to ensure the timely communication to the public of research results that are in the public interest. The oldest (Builders) scientists agreed most strongly, followed by Boomers and Generation Y. Generation X had the lowest overall score, on average selecting 'agree' rather than 'strongly agree' and this was found to differ significantly from the other three generations.

Respondents ranked the personal importance of communicating with the general public between important and very important and the differences between the generations were found to be statistically significant. Although important to scientists irrespective of age, the importance was found to increase with age. The oldest scientists, the Builders, scored the personal importance of communicating their specialised knowledge with the public the most highly. The younger generations (Y and X) had the lowest scores with scientists in Generation X (aged 28─42 in 2007) having the lowest mean score of all. This age difference may be explained in part by the pressures on younger scientists to conduct research, secure funding and build their scientific credibility as discussed in Chapter 5.

There was, however, an interaction effect between sex and generation that was statistically significant although the effect size was small. More males than expected in the Boomer Generation selected 'Extremely important' when asked about the personal importance of communicating with the general public. Why this is so, is beyond the scope of this study but warrants further investigation.

The factors that hindered scientists from communicating with the general public were found to be often linked with a scientist's age and their responsibilities in the workplace. These varied with circumstances; such as whether they wanted to communicate, had the opportunity, or it was their job to communicate but more than expected Generation X scientists described a lack of opportunity to communicate and more than expected Boomers wrote that they were hindered by time – no doubt the lack of it.

Significant differences were found between generations for more than three-quarters of the 15 'what would help most' options offered in the questionnaire. For example the Boomers selected 'No help needed', or 'Time for communication' along with, to a lesser extent, 'Less secrecy due to politics (government)', 'Support (encouragement, recognition) from management' and 'Different employer public comment policy' more often than the other gnenerations. The younger scientists (Generations X and Y) were identical with one exception; Generation X was more likely than Generation Y to select 'Different employer public comment policy'. The options selected in common were all concerned with communication training, opportunity, support and pragmatically, if it was formally part of their job. 'Funds for my communication' would apparently help scientists within the three younger age groupings but not the oldest scientists; most of whom were also formally retired.

As previously stated, Builders and Boomers were found to communicate with the public more than Generations X and Y. These generations were also found to be more likely to have their communication taken into account for their career advancement than scientists in the older and younger generations. The older respondents (Builders) were also more likely than the younger generations to be thanked verbally rather than rewarded in other ways.

Discipline

Irrespective of their discipline, respondents generally agreed that their profession, across both public and private sectors, had a responsibility to communicate to the general public. In all other respects examined, however, a scientist's discipline or field of research was found to significantly affect their experiences, views of, and needs for, communication with the general public.

It was found, for example, that there were significant differences between respondents from different disciplines as to whether communicating with the general public was formally part of their job description/duty statement or project requirement. Those in the Earth sciences and Agricultural, veterinary and environmental sciences communicated most; they were more likely to have communicating with the general public as formally part of their job; they were more likely to be expected by their employer to communicate with the general public; assessed themselves as being more skilled (e.g. well-skilled) and it was personally more important to them to communicate with the general public than scientists in the other disciplines.

By contrast, respondents in the Chemical sciences communicated least among the eight disciplines. Significantly fewer in the Chemical sciences had communicating with the general public as part of their job and for half of them such communication was not expected by their employer. Perhaps then it is not surprising, that the personal importance of communicating specialised knowledge with the general public was found to be lowest for these scientists.

New insights emerged when scientists' 'help most' selections were examined to see if there were any relationships with their discipline. Significant disciplinary differences between respondents were found for more than half the number of 'What would help most' options. The four options that had the largest effect size between disciplines were all concerned with less secrecy, due to government and institutional politics and commercial-in-confidence and intellectual property concerns. For example, respondents in five of eight disciplines were more likely to select 'Different employer public comment policy' than statistically expected. (Conversely, those in the other three; Mathematical sciences, Medical and health sciences, and Physical sciences, did not choose this option more often than statistically expected).

Scientists in Agricultural, veterinary and environmental sciences selected all options more frequently than expected with the exception of 'Less secrecy due to national security concerns' and 'Less secrecy due to commercial confidentiality'. Conversely, scientists in Mathematical sciences chose only one option more often than expected: 'Less secrecy due to national security concerns'.

Less secrecy due to both commercial confidentiality and intellectual property concerns was selected by more than expected numbers of scientists in the Chemical sciences, Engineering and technology sciences and Medical and health sciences.

In terms of funds, significantly more scientists in the Agricultural, veterinary and environmental sciences, Biological and Physical sciences wanted funds for their communication activities. Training in media skills was wanted by significantly more than expected in the Agricultural, veterinary and environmental sciences, Biological and Medical and health sciences.

Employer

Significant differences were found in this study between different types of organisations as to whether communicating with the general public was actually part of scientists' job descriptions or project requirements. For example, respondents employed by State/Territory/Local government departments or agencies, were significantly more likely to have communication with the public as part of their job description than those scientists working for Medical research institutes, Hospitals, Industry or a University.

Of those who said that communicating with the general public was not part of their job, most worked in a Medical research institute, Hospital, University or for Industry.

Scientists who worked for government agencies and departments described more hindrances than those who worked in the private sector. Scientists' comments suggest that in publicly-funded organisations such as universities and statutory authorities such as CSIRO, many scientists apparently expect to be able to communicate with the general public but then find that they can not.

Some scientists in government were frustrated when they prevented or hindered by politics and commercial considerations. Others are very clear about what was expected by their government employers, and it was not communication with the general public. For example, scientists working for government (both Commonwealth and State/Territory/Local) emphasised the primary importance of their clients, compared with the general public.

Significant differences were found between employment sectors in terms of how much scientists communicated with the general public. Scientists in Private consultancy business and State/Territory/Local government departments or agencies communicated most; those employed in a Hospital, Industry and Medical research institute communicated least. It was also personally more important to scientists in Private consultancy businesses than those in Industry or a Medical research institute.

Across all seven types of employers, the most frequently expressed hindrances, by one in five scientists, concerned lack of time. There were differences in the frequency of particular hindrances identified for different types of institutions/organisations. For example, those respondents working for the government wrote more comments about being hindered by policies, protocols and politics for example, while those in universities wrote more often about a lack of time hindering them from communicating with the general public.

Overall, 57% of all comments about hindrances, related to the workplace: its culture, requirements, sensitivities, characteristics, approvals, policies, responsibilities. The most frequent comments related to time.

Amongst the seven employer categories, most comments about hindrances were made by scientists in universities and Commonwealth Government or State/Territory/Local government departments/agencies. This may be because scientists within these government departments and agencies communicate more frequently with the public and therefore have more experience to draw upon when describing the hindrances they encounter. It was found in this study that there were significant differences between how much scientists working for different types of employers had communicated in the previous year. The scientists who had communicated the most worked in a ‘Private consultancy business’ or for a ‘State/Territory/Local government department or agency’. Further analysis would confirm this but is beyond the scope of this thesis.

Chapter Summary

This chapter presents the findings that address this study’s six research questions. They are based upon the views and experiences of 1,521 self-selected Australian scientists who participated in the 2007 survey ‘Australia’s scientists

and science communication'. This large, national data base was found to represent Australia's scientists on the basis of their sex and age distributions.

The results show that a large majority of the survey respondents agreed that scientists have a responsibility to communicate with the general public. Such communication was also found to be personally important to most scientists. These feelings of professional responsibility and personal importance existed in spite of scientists' workplace cultures where communication with the public was not, in general, formally included as part of their jobs, or recognised or rewarded when it occurred. Nearly three-quarters of the scientists surveyed said that it was not a part of their job description/duty statement or project requirement. It seems, however, that while employers did not generally allocate time or payment for scientists to communicate, they did expect their scientists to communicate when required.

Respondents identified many benefits from communicating with the general public. These included positive feelings about themselves, their communication and their work such as satisfaction, enjoyment and self-confidence; and their work and personal success such as direct public participation or co-operation in research, networking and relationship-building.

This study found that most scientists had communicated with the general public and that the frequency of this communication tended to be medium for most or about half of the scientists. Of those who did communicate at least once, most communicated their specialised knowledge though informal discussions, answering questions from the public through their job, providing information though the Internet; speaking with students and teachers or speaking at public meetings.

More than half of those surveyed were hindered in their communication with general public. Most examples of hindrances concerned the priorities, policies and practices of their employer organisations. For example, just over a third of these identified time – the lack of it to organize, prepare and present their communication with the general public – as a major hindrance. Workplace policies and sensitivities were a particular issue for those employed in Commonwealth and State/Territory/Local Government agencies and departments. Another finding of this research concerning the Government

(Commonwealth and State/Territory/Local) sector was a relationship between scientists' communication activity and hindrances and needs: the more that scientists communicated, the more hindrances they encountered and the more help they wanted.

Those respondents who wanted or had to communicate with the general public, wanted time, opportunities, experience, and training to communicate more effectively. Support (encouragement, recognition) from management and help from professional science communicators were the next most frequently selected options. Interestingly less secrecy and different employer public comment policies were identified by scientists employed by Government, both Commonwealth and State/Territory/Local, as helping their communication with the public.

Important findings were the significant differences in respondents' views about aspects of communication associated with their sex, age, discipline and type of employer.

In the next chapter, the findings described above are further discussed.

CHAPTER 8. DISCUSSION

This chapter discusses how the findings of this survey of scientists address six research questions about scientists' views and activities around communication with the general public. This research aimed to help scientists in Australia to be more effective in their communication with the public by providing a reflection of what their peers think and do about communicating with the general public. In common with the few national surveys conducted elsewhere, it was designed to establish whether scientists themselves believe they have a responsibility to communicate with the general public; whether it is personally important to them; what they do to communicate; what hinders and what would help their communication practice.

Within the field of science communication, this national survey is the first of its kind in Australia to seek the views and describe the communication activities of such a large number of Australian scientists. It traverses the country and gathers the views and experiences of scientists across a number of disciplines (8) and employer types (7). This survey differs from the very few published Australian surveys and studies of scientists' communication because the participants were not restricted to scientists within a particular discipline or research field such as immunology (Charlesworth, et al., 1989); health and medical research (Shewan, et al., 2005) or particular employers such as universities (Turpin & Deville, 1995) and research agencies within the Commonwealth Government sector (Gascoigne & Metcalfe, 1997; Turpin & Deville, 1995). The questionnaire was not concerned with scientists' communication about particular science issues such as climate change, but instead sought their opinions about aspects of science communication in general. It also differs from other Australian surveys because of its larger number of participants (1,521 scientists from every State and Territory of Australia).

Compared with previous Australian surveys, this study's communication focus was much broader than the mass media (Australian Science Media Centre & Australian Science Communicators, 2007; Gascoigne & Metcalfe, 1997;

Metcalfe & Gascoigne, 2009) or publications (Christensen & Jacomb, 1992), because it included these as well as organised meetings such as seminars, in addition to informal discussion with the public. This survey also differs from others nationally and internationally with similar aims because of its broad, inclusive definition of 'scientist' in terms of qualifications and role. It included those with tertiary qualifications over a wide age range of employment situations; irrespective of whether they were employed, retired or unemployed, and irrespective of whether they had research, management, operational, education or administrative roles.

In this study there was no synonymous use of the terms 'scientist' and 'researcher' as has occurred in other studies and engineers were deliberately excluded in the sampling strategy. In this, it differed from some key surveys elsewhere which deliberately sampled both scientists and engineers such as People Science and Policy Pty Ltd (2006), Nielsen (2007) and MORI (2001). This survey also differs from the few other national surveys conducted this century because of a different definition of the term 'general public' than, for example, that used in the United Kingdom survey (People Science and Policy Ltd., 2006).

The questionnaire incorporated some question and answer options from the 2001 survey of scientists in the United Kingdom (MORI, 2001b) to enable some general comparison of results. Subsequent nation-wide surveys conducted in the United Kingdom (People Science and Policy Ltd., 2006), Sweden (Vetenskap & Allmanhet, 2003) and Denmark (Nielsen, et al., 2007) have also drawn upon the MORI (2001) survey.

This chapter is divided into six sections; each discussing research findings in terms of one of the six research questions. For simplicity of reading, percentages have been rounded up or down to the nearest whole integer. It ends with a comparison of Australia's scientists with scientists elsewhere.

Do Scientists Think That it is Their Responsibility to Communicate with the General Public?

Scientists have been told by eminent peers, scientific and political leaders, and by scientific organisations (Bodmer, 1985; Brown, 1971; Carr, 2008c; FASTS,

2006; International Council for Science Committee on Freedom and Responsibility in the Conduct of Science, 2010; Lane, 1997; Leshner, 2005b; The Royal Society, 2006b; Wolfendale, et al., 1995) that they have a duty or responsibility to communicate with the general public. Research indicates that most scientists agree, including those in this study where 89% agreed that scientists, 'within both the public and private sectors, have a responsibility to ensure the timely communication to the public of research results that are in the public interest'. This confirms findings of earlier studies in the United Kingdom such as MORI (MORI, 2001b) where 84% agreed that 'Scientists have a duty to communicate their research and its implications to the non-specialist public' (MORI, 2001b, p. 21) and in Sweden (Vetenskap & Allmanhet, 2003). The latter found that eight out of ten Swedish researchers believed that dialogue with the public was an obligation of every researcher (Vetenskap & Allmanhet, 2003).

These differ, however, from the findings of a more recent survey of scientists in the natural sciences and engineering sciences in Denmark universities where less than half (43%) thought that scientists ought to handle the universities' obligation to report knowledge about scientific methods and results, while 54% preferred for the responsibility to 'be placed elsewhere' (Nielsen, et al., 2007, p. 6).

Scientists in this study generally agreed that scientists have a responsibility to communicate with the general public, both in terms of the importance of scientific knowledge for society and the right of society to know. There were those who believed that this responsibility 'transcends any obligation to specific employers or funding bodies' while others believed that only publicly-funded scientists had a responsibility to communicate publicly funded research. A minority said that those within the private sector had a greater responsibility to their employer or funder. There were those also who pointed out that scientists are not always in a position to choose with whom they communicated, because they do not own their own research results. Other comments made it clear that scientists think that there are others who have or share responsibility, such as governments, the media and scientists' employers and funders.

Do Scientists Believe That There Are Benefits from Communicating with the General Public?

This research aimed to find out if scientists identified any benefits for themselves from their communication with the general public. It builds on the limited qualitative research over the last decade that describes such benefits in Australia (Gascoigne & Metcalfe, 1997; Metcalfe & Gascoigne, 2009) and the United Kingdom (Burchell, et al., 2009; MORI, 2001b; People Science and Policy Ltd., 2006). In this current study, 62% of scientists volunteered examples of how they benefited.

The majority of scientists answered that there were both personal and professional benefits from communicating their work or specialised knowledge with the general public. The following are the broad 'benefit' categories that describe and group the scientists' examples:

Positive feelings about themselves, their communication and their work
Understanding of their own science/work
Understanding of the public
Skills/confidence (e.g. communication, grant-writing)
Work success
The good of the organisation/profession/science/society
Public understanding/support

Although any one of these general benefits may not surprise researchers in the science communication field, the totality of them presented a much more positive picture of scientists' experiences than has generally been painted in the literature. The most frequently described professional benefits from communication with the public were those that contributed to or improved:

'scientist's work or personal success'
'public understanding/support'
'scientist's understanding of their own science/work'.

Unprompted, most scientists in this study gave examples of a wide range of positive feelings when they described the benefits. When asked specifically to give examples of personal benefits, by far the most frequent examples (46%) were of positive feelings. When all examples of both professional and personal benefits were combined, nearly one in five scientists described positive feelings.

Little quantitative research has been conducted to identify, explore and discuss the value of scientists' positive feelings about themselves, their communication and their work in the context of their communication with the public. There have been descriptions of scientists' positive feelings about their work, rather than their communication, that include words such as 'satisfaction', 'passion', 'excitement'. Less often described, however, are scientists' feelings about communicating their knowledge with others, although such descriptions have occasionally appeared in the literature (e.g.Martin-Sempere, et al., 2008; Wolfendale, et al., 1995). Researchers more often comment on the converse; that scientists themselves do not wish to discuss their feelings and would rather project a dispassionate image of themselves as the objective scientist to enhance their status and reputation as a source of advice about their 'specialist knowledge of certain areas of technical and esoteric matter' (Cook, et al., 2004). 'Emotions and beliefs linked with society's changing issues …are not often part of scientists' public image' (Yankelovich, 2003, online). This perception of the emotionless public image of a scientist is part of the culture of science which moulds scientists' communication, as was illustrated in Chapters 3 and 4. There is, however, a suggestion that this could be changing as younger scientists with different values who are motivated by personal satisfaction and enjoyment, rather than a sense of duty, move into positions of seniority (Martin-Sempere, et al., 2008; Yankelovich, 2003).

This strong finding of this current study ─ that many scientists perceive positive feelings about themselves, their communication and their work, as a benefit of their communication with the general public ─ has seldom been explored in the literature in a science communication context. Nor has the importance of these intrinsic positive emotions gained though communication with the general public been identified as contributing to scientists' job satisfaction through alignment with their personal values.

As discussed in previous chapters, it has long been appreciated that scientists are often very passionate about their work. Their reticence, however, to use their emotions to enhance their presentations and their scientific arguments may be inhibiting scientists from being more effective communicators. As this research shows that many scientists have positive feelings about their communication

with the public, and it is generally known that scientists often feel passionate about their work, the question remains: why do scientists feel constrained in showing emotion, a trait commented upon by authors such as Ziman (1998)? Are scientists confusing the need for a disinterested and emotionally neutral conduct of research as described by Merton and others, with the objective, unemotional delivery of results to maintain the credibility of their knowledge and themselves? Is this style of delivery reinforced by critical peers? Are scientists deliberately undermining the effectiveness of their communication with the general public by limiting the affectiveness of their delivery? When in doubt, maybe scientists moderate their style of presentation to ward off critical peers, rather than appeal to an appreciative public. If so, they may be unaware of the cost, because, to paraphrase John Maxwell's oft-quoted advice about good leaders, '…good [scientists] understand that people do not care how much you know until they know how much you care' (Maxwell, 2007, p. 304).

Perhaps the surprising aspect of this research finding is not that scientists enjoy sharing their knowledge and communicating with and learning from their fellow humans, but rather, that this intrinsic aspect of scientists' communication with the general public is not more frequently part of the discourse about scientists' communication within the context of science communication research and practice.

This current research also yielded further insights about what scientists mean by 'personal satisfaction' when referring to their communication with the public. For example, they described satisfaction as arising from having the public interested in their work; from educating and entertaining the public; and from helping the public and promoting their profession. Research findings also demonstrated the overlap between 'personal' and 'professional' benefits. For example, one of the emergent benefit themes was 'Communication skills and confidence e.g. communication, communication with other stakeholders, grant-writing': 130 examples of this were identified by the respondents as a professional benefit, and 95 examples were identified as a personal benefit. Similarly, examples of benefits that related to, 'The good of the organisation or profession or science, society, the community, the environment and other

people' were identified by respondents in 42 examples as professional benefits and in an equal number as personal benefits.

This study found, however, that irrespective of their age, scientists generally did not differ in the number of examples of personal and professional benefits they gave, including 'Duty or responsibility or obligation'. There was one exception. A larger number of younger scientists than expected (in Generation Y and Generation X) gave examples of how communication with the general public improved or contributed to their 'Communication skills and confidence'. In summary, this study revealed that scientists themselves identify a broad range of professional and personal benefits from communicating with the general public. It also revealed that for at least half of the scientists in this study, these many benefits are not realised because of hindrances to communication within their workplace.

Is Communication with the General Public Personally Important to Scientists?

While 89% of scientists in this study agreed that scientists had a responsibility, relatively fewer (75%) but still a sizable majority, said that communication of their specialised knowledge was personally important to them to some degree, despite the relatively little that they communicated with the general public. These findings confirm those where UK researchers were asked about the relative importance of their science communication. The authors concluded that, 'Many researchers regard communicating science as an important thing to be done, although not always as important as other tasks (People Science and Policy Ltd., 2005, p. iv).

More than 1,000 scientists in this current study gave explanations of why communicating their specialised knowledge with the general public was important or unimportant to them. Those for whom communicating was important, however, often took the opportunity to describe their motivation to benefit themselves, their profession and society. A synthesis of their comments demonstrates that communicating with the public enabled these scientists to:

attract support and funding for their own research
recruit students and scientists into science and particular science fields

correct misconceptions or demystify science

share valuable information for people to know and use

inform people so that they could participate in democracy and make informed decisions

These personal reasons corroborate the findings from the UK study where the respondents were asked why they thought scientists and engineers generally engage with the non-specialist public (People Science and Policy Ltd., 2005, p. iv; 2006a).

Most scientists had communicated with the public more than once in the previous year and there was a large, positive correlation between how important scientists thought communicating was and how much they communicated. The personal importance of communicating their specialised knowledge was found to explain 26% of the variance in the respondents' scores for communication activity. This association was similar to a key finding of the *Survey of Factors Affecting Science Communication by Scientists and Engineers* (The Royal Society, 2006a, p. 10).

What Do Scientists Currently Do to Communicate with the General Public?

Most respondents had communicated more than once with the general public in the previous months, but often not much more than once. In general, they appear to have communicated infrequently, reactively or as required by their employer. It would also seem that much of their communication may 'go under the radar', certainly of those leaders discussed in the Chapter 2 who call for scientists to communicate with the general public. Much of scientists' one-to-one, and face-to-face communication would be unrecorded and unreported and yet this is how most scientists most frequently communicate with the general public, if not those who communicate the most. For example this study shows that scientists communicate through a mixture of informal and formal situations: informal conversations (67%); or through inquiries from the public via email, letter or telephone through their work (53% ; speaking with students or teachers (46%); providing information (text, images, audio, video) for the Internet (including personal web pages) (45%); or speaking at meetings, workshops, symposiums or similar events specifically intended to inform the general public (40%).

Relatively fewer scientists communicated with and through the media compared with more direct communication between scientists and the public. The most frequent media communication was through the print media (an interview for a national or local newspaper) – this was the sixth most frequent form of communication.

Looking at communication activity with the general public, males communicated more than females and older scientists (Boomers and Builders) more than younger scientists. Findings elsewhere in this study suggest why. Older scientists were more likely to state that communicating with the general public was personally important; were more likely to have communication with the public as part of their job, expected to communicate by their employers, and have more opportunities to communicate and, perhaps not surprisingly, communicated more frequently than younger scientists. Comments made by respondents also indicated that senior scientists are preferred organisational representatives, and control, to some degree, the communication with the general public. These findings are similar to those of Jensen (2011) in France, Kreimer, Levin, & Jensen Kreimer (2011) in Argentina and the UK study by People, Science and Policy Ltd. (2006).

There were also variations in how often scientists communicated that related to their differing disciplines and employers. Scientists who communicated their scientific knowledge were more frequently found to work in the Biological sciences, Agriculture, veterinary and environmental sciences, and Earth sciences. They were also more likely to work for a Private consultancy business, a State/Territory/Local Government or Commonwealth government agency or department

Conversely scientists who communicated relatively less with the general public were more likely to be female and members of the younger generations (Y and X), and working within the Chemical sciences, Mathematical sciences, Engineering and technology, Medical and health sciences, and Physical sciences, and employed by Industry, a Hospital or Medical research institutes. Significant differences were found between scientists in different disciplines and their communication activity. For example scientists in the Chemical sciences

communicated least; and those in the Earth sciences and Agricultural, veterinary and environmental sciences communicated most.

Does Anything Hinder Scientists from Communicating with the General Public?

Fifty-five per cent of scientists in this study were hindered from communicating with the general public in the way that they would like. Many of the large number of hindrances they described indicate the dilemmas they face in a scientific career where increased collaboration, commercialization, competition and short-term-contracts silence their communication with the public which supports them.

Arguably many of these hindrances in the workplace can be traced back to the decline in public funding for science in Australia and elsewhere since the 1970s (Cutler, 2008; Department of Innovation Industry Science and Research, 2009; Goodell, 1977). This has led to greater competition for jobs for scientists and funding for research, a greater accountability to funders through more frequent reporting; and more short-term contracts for scientists, as was evident in this study, all of which lead to a lower priority and less time for non-research activities for both scientists and their employers. Scientists, especially those just beginning their careers face job uncertainty and lack of a clear career structure (Bennet, et al., 2005; Borthwick & Murphy, 1998; Marceau & Turpin, 2007a; Wills, 1998). These factors encourage them to focus on the jobs they were paid and trained to do, and minimize any risk to their professional credibility by incurring the disapproval of their peers or employer (Burchell, et al., 2009; Cribb, 2011; Gascoigne & Metcalfe, 1997; People Science and Policy Ltd., 2006a; Weigold, 2001).

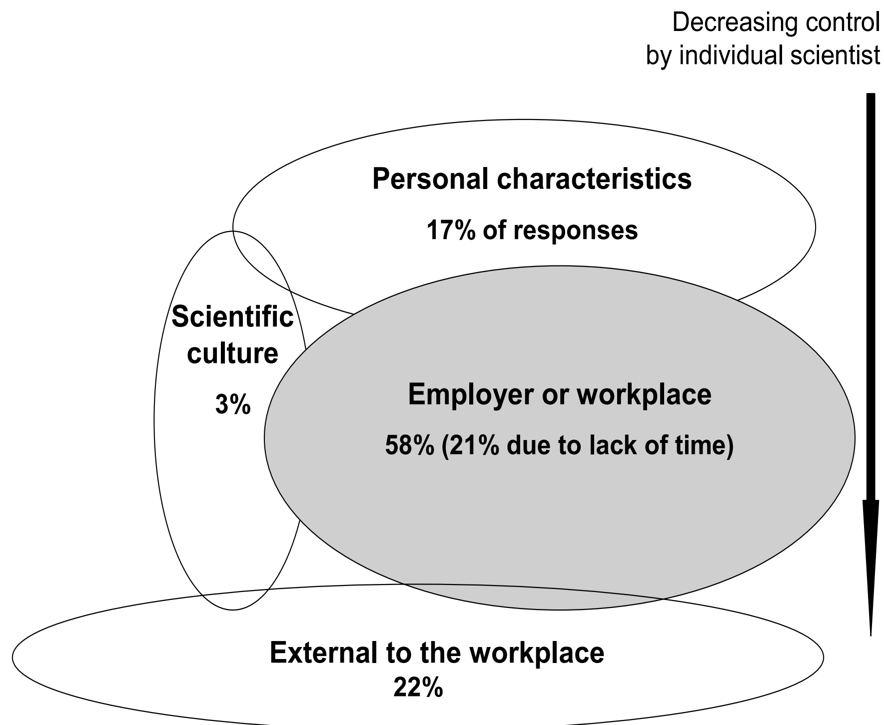
Leaders who call for scientists to communicate with the general public seem to be oblivious to the hindrances to such communication that scientists encounter in their workplaces. For example, in this study, communication with the public was not formally part of their job description, duty statement or project requirement for 66% of the scientists. Nevertheless an almost similar number (62%) were expected by their employer to communicate when required. It was found, however, that if communication with the public was part of their job,

scientists were more likely to communicate. For example, across the four age groupings, the Boomers were more likely to have communication with the public as part of their job and they communicated more than the younger scientists.

Despite these expectations of the leaders and employers of scientists, research has shown that most scientists are not trained to communicate with the public, and face personal and professional risks from doing so if they do not protect national or commercial, corporate and political secrets (European Communities, 2007; Small & Mallon, 2007; The Government-University-Industry Research Roundtable, 1997; Ziman, 2000). Already constrained by the 'rules' designed to protect and enhance the reputation of the science profession, these are overlaid by workplace protocols and policies put in place to protect and enhance the reputation of scientists' employers. Overall, 58% of all comments about hindrances, related to the workplace: its culture, requirements, sensitivities, characteristics, approvals, policies, responsibilities. The most frequent comments related to time, followed by policies or protocol requirements and lack of opportunity to communicate. There were significant differences due to sex and age for all three hindrance categories.

These workplace cultures and practices hindered scientists much more than their own personal characteristics or other factors beyond workplace control such as commercial considerations, government politics, the media, national security, or the disinterest or misconceptions of the public. Figure 25 shows the broad emergent themes from scientists' comments. It is ordered by decreasing control by the scientist.

Figure 25. Hindrances – broad emergent themes from scientists' comments



Time, or more specifically the lack of it, to communicate with the general public, was scientists' most frequently-cited hindrance. This reflects that communication with the general public is generally not part of a scientist's job or otherwise recognized or rewarded. One in five of all comments described time as a hindrance and amongst these relatively more were made by scientists in both the Boomer generation and in universities. Previous research has also shown that scientists identify a lack of time as a constraint to their communication, as well as the relatively low priority given to public communication compared with the need to prepare formal publications, grant proposals and report back to funding bodies (MORI, 2001b; People Science and Policy Ltd., 2006a). Heavy workloads are an issue too, as others have observed that scientists do not have enough time to do what they are trained and employed to do, let alone communicate with the public (Edmeades, 2009a; Gascoigne & Metcalfe, 1997; People Science and Policy Ltd., 2006; Peters, et al., 2008;

Rothwell, 2002). This study sought to delve a little deeper in to what scientists meant by time and a synthesis of the emergent themes from their comments suggest two broad categories. The first was comprised of those who lack time because communicating with the public is a low priority and this includes those scientists who have insights into how much time it can take to be trained, identify opportunities, prepare and practice for it, and then do it. The second encompasses those who lack time because communicating with the general public would never be a priority because it competes with their personal time after work or does not contribute to their advancement.

The next most frequently described hindrances (one in six descriptions) were also concerned with the workplace: its culture, legislations, policies, approval processes and protocol requirements which either censored communication or acted as disincentives.

An important finding of this study was that scientists, especially females and younger scientists of both sex, were hindered by a lack of opportunity. One in eleven descriptions of hindrances concerned the lack of opportunity to communicate. Some, for example, wrote that they were limited by their employer because they were less experienced. This is a Catch-22 where they are not given the opportunities to gain experience in communication, because they are not experienced. This finding shows that despite the hierarchical culture of science where scientists, in general, expect the more senior, and more often male, scientists to communicate with the public for a whole range of valid reasons (Anderson, et al., 2002; Jensen, et al., 2008; People Science and Policy Ltd., 2006), that others, particularly those in Generation X, want the opportunity too.

This study showed that there are significant differences due to employers in the hindrances experienced by scientists. It contributes to the research conducted in Australia and elsewhere, which previously described the cultural differences between industry and academia (Bitmead, 1997; Robbins & Johnston, 1976).

In summary, Australian scientists have made it very clear that most of the hindrances to their communication with the general public occur in their workplaces. This means that their employers and funders, the scientific departments, and research and funding agencies, have the power to improve the

culture and practice around scientists' communication with the general public. As long as scientists have no time or opportunity to communicate, and when they do, they encounter onerous approval processes, it is unlikely that the current situation of infrequent communication between scientists and the public will change.

Are There Areas for Improvement?

The final research question addressed by this study asked, 'Are there areas for improvement to facilitate communication between scientists and the general public based on what scientists selected would help them most to communicate in the way they would like?' Information was sought through a question that asked, 'If you want or have to communicate with the general public, what, if anything, would help you most to communicate in the way you would like?' Scientists were presented with 15 options. Most scientists selected 2 — 4 options.

Of the more than 95% of scientists who selected from the 15 'help most' options, the following options represent the top six in decreasing order by percentage of responses:

> 'Time for communication',
>
> 'Communication experience/opportunities to communicate',
>
> 'Specific training to communicate science',
>
> 'Training in media skills',
>
> 'Support (encouragement, recognition) from management for my communication activities'; and
>
> 'Help from professional science communicators'.

The majority response was for 'time' and this is consistent with the frequency of unprompted answers that scientists wrote about what hindered them. This finding is similar to those from other studies over the last decade (Anderson, et al., 2002; Edmeades, 2009b; Gascoigne & Metcalfe, 1997; MORI, 2001b; People Science and Policy Ltd., 2006).

This research contributes new evidence of the importance of scientist's sex, age discipline and employer in determining their needs for help to communicate with the general public. The fact that women more than men indicated the desire for more help with their communication through training (to communicate science,

in media skills and general communication/presentation skills), communication opportunities and support (encouragement and recognition) from management may be a function of the gender inequality that exists for women in science in terms of status, rewards, retention and advancement (Caprile, et al., 2008; Fox, 2001; Ledin, et al., 2007; National Science Foundation (Division of Science Resources Statistics), 2004; Servon & Visser, 2010; UNESCO, 2007). The significant differences found between scientists of different generations for 13 of the 16 'what would help most' options may reflect the strongly hierarchical character of science (Martin W. Bauer & Jensen, 2011; Fox, 2001; Kreimer, Levin, & Jensen, 2011, p. 45) or the differing responsibilities and increased experience that invariably come with age in the career of a scientist. For example, younger scientists wanted more training, more experience and opportunities to communicate and older scientists (aged 43 ─61) either did not need help, wanted more time or different employer public comment policies.

Certainly in this study there was a definite trend with age as to which scientists had communicating with the public as part of their job and were expected by their employer to communicate with the general public. Older scientists were in the age group that was most often paid and expected to communicate with the general public; those scientists aged 27 and younger were the least paid or expected to communicate. It may help explain why a relatively large percentage of the younger scientists (Generation Y) did not know whether their institution or organisation financially rewarded such communication. Perhaps communication with the general public was not discussed as much with the youngest scientists who were expected to focus on research and securing funding grants. Given that the Boomers were the ones, along with the Builders, who were found to communicate most, and that they would be more likely than the Builders to be subject to employer's policies and practices, this finding is not surprising. Boomers wanted not only more time, but more support (encouragement, recognition) from management, and less constraint due to public comment policies and secrecy due to government politics as well. The Boomers were also more likely, than the other generations, to select 'No help needed'.

‘Funds for my communication activities’ was selected by more than expected numbers of scientists employed by a university, State/Territory/Local Governments or private consultancy businesses. This last result partially concurs with the finding of the 2006 United Kingdom survey of scientists from universities for whom funding was an issue with their public engagement (Trench & Junker, 2001).

New insights into the hindrances that scientists face in their particular workplace emerged when scientists’ ‘help most’ selections were examined to see if there were any relationships with their discipline. The four options that had the largest effect size between disciplines were all concerned with less secrecy, due to government and institutional politics and commercial-in-confidence and intellectual property concerns. In terms of funds, significantly more scientists in the agricultural, veterinary and environmental sciences, biological and physical sciences wanted funds for their communication activities. Training in media skills was selected by significantly more than expected in the agricultural, veterinary and environmental sciences, biological and medical and health sciences.

In summary, therefore, this research provides new and strong evidence that to facilitate scientists’ communication with the general public, scientists’ sex, age, discipline and employer should be taken into account as they have a significant influence upon scientists’ needs.

Australia’s Scientists – Comparison of their Views and Activities Internationally

Direct comparison between results from this and other surveys, regarding similarly-worded questions about communication activities and views is limited because of different explicit or implicit definitions of such basic concepts such as ‘scientist’, ‘general public’ and ‘communication’. For example, the definition of a scientist in this study was very broad and self-determined. The sample populations differed from those surveyed elsewhere which were often focussed only on scientists working in universities or other higher education institutions, and excluded scientists who were retired.

The representativeness of sample populations across scientific disciplines and employer sectors often varied significantly too. For example recent surveys of scientists in the United Kingdom (People Science and Policy Ltd., 2006) and Denmark (Nielsen, et al., 2007) focussed only on those in universities. The earlier United Kingdom study (MORI, 2001b) and this current study aimed to sample scientists across government, industry and universities.

How the questionnaire data was categorised into discipline and employer groupings for analysis invariably differs from other surveys as well. For example, in this study they were based upon to the Australian Bureau of Statistics categories for employer (ABS, 2006a, 2006b), and discipline and research fields (ABS, 1998, 2006a, 2006c). The age groupings by four generations were based on a generational description, partly based on trends in Australian birth rates, developed by an Australian research company (McCrindle Research, 2006).

Nevertheless, similarities were found between the activities and views of scientists in Australia and overseas; particularly those in the United Kingdom. This is another example of the international culture of science that crosses political and geographic borders. For example, scientists in Australia agreed with scientists in the United Kingdom (MORI, 2001a, 2005b; People Science and Policy Ltd., 2006; The Royal Society, 2006b) and Denmark (Nielsen, et al., 2007) that scientists have a responsibility to communicate with the general public (The Royal Society, 2006b). This current study did not, however, specifically explore whether scientists believed they had the main responsibility, unlike the MORI (2001b) study.

For both Australian scientists and UK academic scientists there was a positive relationship between how much they communicated and how personally important communication with the general public was to them. This finding about personal importance implies for the Australian scientists that they were exerting a personal choice about how much they communicated with the general public, given that it was a low priority for most employers. More research would be needed to confirm whether they communicate on a voluntary basis in their own time.

It was found that, in common with the academic scientists and engineers in the United Kingdom, the majority of scientists had communicated at least once during the previous year. In 2007 more than four out of five of the respondents in this study had communicated at least once with the general public over the previous 12 months. By comparison, the MORI study found that just over half of scientists participated in communication with the general public within the previous year (MORI, 2001b, pp. 4-5). This increased to 75% of those surveyed in the UK in 2005 (The Royal Society, 2006a, p. 10) who had taken part in at least one science communication or public engagement activity in the last year. Despite the fact that the UK and the current study sampled different groupings of scientists and asked about different publics, this result indicates that relatively more scientists were communicating with the general public in Australia. This may be due to the large percentage of Australian scientists in the disciplines of the biological, agricultural, veterinary and environmental sciences and earth sciences who responded to the survey. Other differences were that this current study used a narrower definition of public; it excluded policy makers for example; but had arguably, a broader definition of communication because it included informal discussions.

It is difficult to conclude whether scientists in Australia communicated more or less than scientists in other countries for reasons discussed elsewhere in this chapter. Perhaps the most similar surveys of scientists communication with the general public were, however, the *Survey of Factors Affecting Science Communication by Scientists and Engineers* (2006) and *Scientists and science communication: A Danish survey* (Nielsen, et al., 2007). In Denmark many more scientists and engineers had used the Internet for personal and university homepages (70-80%) (ibid., p. 7) compared with scientists in Australia (45.2%). A similar percentage (56%) of Australian scientists, compared with UK scientists and engineers (63%) undertook low-medium levels of activity. More Australian scientists, however, communicated frequently, with 31% who communicated more than 10 times per year, compared with 11% in the UK study (The Royal Society, 2006a, p. 10). There were also relatively fewer (13%) scientists in this Australian study who did not communicate with the general public at all, compared with 26% of the UK academics who were described as

inactive in the year previous to the 2006 study (The Royal Society, 2006a, p. 10). The listed activities from which scientists could choose differed, however, and were broader in this Australian study. For example they included 'informal discussion with members of the general public' and responding to public inquiries through their work.

The United Kingdom survey found a strong, positive relationship between three levels of public engagement activities undertaken by scientists and their perceived importance of public engagement on a five-point Likert scale (The Royal Society, 2006a, p. 10). This relationship was generally confirmed by this study which indicated a medium strength, positive correlation between four levels of communication activity and 'Personal importance' categories on a seven-point Likert scale.

For the majority of Australian scientists, communicating their specialised knowledge with the general public was not part of their job and this situation is similar to that found in the United Kingdom for science and engineering academics (People Science and Policy Ltd., 2005; The Royal Society, 2006a).

Hindrances were found in common between scientists in Australia and elsewhere. For example, lack of time for communication was a big hindrance for one in five scientists in Australia, as was the need to spend more time on research.

The People, Science and Policy survey for The Royal Society reported that institutional attitudes were a barrier to scientists' communication with the general public which was regarded 'as being on the outer margins of the objectives of most institutions. It is thought to be something that is nice to see happening but is rarely driven by the institution' (People Science and Policy Ltd., 2005, p. 7).

Research findings from the United Kingdom support the findings of this Australian study: it is the workplace culture that hinders scientists most in their communication with the general public.

The next chapter will briefly describe the conclusions, implications and limitations of this study. Recommendations to improve communication practice and research will also be made.

Note

Just as this thesis was being finalised for submission, a collection of papers describing scientists' public engagement activities was published in *Public Understanding of Science* in January 2011 to describe the extent to which bench scientists had become involved in public engagement activities since the Bodmer Report in 1985 (Martin W. Bauer & Jensen, 2011, p. 3). Bauer and Jensen (2011) stated that, 'There are very few studies that assess the level of activities among scientists' (p. 5).

In this collection, papers described scientists' public outreach in France (Jensen, 2011), dissemination practices in Spain (Torres-Albero, et al., 2011), popular science writing by academics across 13 countries including Australia (Bentley & Kyvik, 2011), 40 European research institutions (Neresini & Bucchi, 2011), and popularisation activities and motivation of 1,198 scientists in Argentina (Kreimer, et al., 2011). These are a valuable contribution to the paucity of published research about scientists' activities, their motives and the influence of institutional factors.

Jensen (2011) concluded from his studies of thousands of French CNRS researchers that included statistical analyses of the influence of dissemination activities on their promotions, that, 'dissemination activities are *not* [original emphasis] bad for scientists' careers'. 'They are not very good either' (Jensen, 2011, p. 34). In a previous paper that reported on the same population of French scientists, it was stated that 'scientists active in dissemination are also more active academically. However, their dissemination activities have almost no impact (positive or negative) on their career' (Jensen, et al., 2008, p. 527).

CHAPTER 9. CONCLUSIONS AND RECOMMENDATIONS

This chapter summarises the research findings and presents the conclusions and implications of this study. Limitations of the study are discussed. Recommendations for better communication practice and further research are then made to complete this study of Australia's scientists' communication with the general public.

A review of the literature showed that beyond anecdotal evidence, quantitative and qualitative research that describes scientists' communication activities with the general public was generally lacking in Australia. This study therefore sought to address this lack of information. This thesis has presented scientists' views on the responsibility of scientists to communicate with the public and the benefits to scientists of this communication, the personal importance and the hindrances to their communication. What scientists believed would help them most to do so, has also been described and analysed. The significance of scientists' Sex, Age (Generation), Discipline and Employer on their communication activities is presented for the first time in an Australian context.

This study found a gap between what scientific and political leaders say they want, which is more effective communication between science and society, and what the employers of scientists actually do to support scientists' communication with the general public. There is also a gap between organisational practice and what scientists say they want, which is more communication training and opportunities and time to communicate and formal recognition of communication as part of the scientist's job. This was found to be particularly so for scientists working in the publicly funded Government departments and agencies.

It was found that scientists believe they have a responsibility to communicate with the general public and that there are many benefits for them from doing so. These benefits included positive feelings about themselves, their communication and their work, such as satisfaction, enjoyment and self-confidence; and their work and personal success such as direct public participation or co-operation in research and networking with potential employers and funders.

One of the most significant findings of this research was that many scientists value connections with people who are interested in and can use their knowledge and help with their research, because of how it makes scientists feel about themselves and their work. Given that other research has shown that many scientists, and in particular, women, applied scientists, younger scientists and those who choose to work in the public sector, are motivated to become a scientist by their desire to contribute to the public good, these feelings can not be ignored as they strike at the very heart of why many people choose to become, and remain, scientists.

The 20th century culture of science, that was defined by masculine norms that arguably encouraged and maintained a disconnect between scientists and a respectful society to maintain its authority, status and independence, is perhaps giving way to a younger and more gender-balanced culture that recognises the mutual benefits of communication between scientists and society, beyond the production of academic papers. This is a culture where perhaps scientists are seeing the failure of their communication because many communicate as impersonal 'androids or angels' described by John Ziman (1998, p. 1813).

Scientists in this study wrote about their feelings of satisfaction and value around their communication about their own work achievements; enjoyment from explaining and sharing what they do, love of sharing their enthusiasm and passion for their work, enjoyment of people being interested and enthused about their work, feelings of pride and self-esteem in making a contribution to society through either their communication or research, enjoyment helping others, enjoyment of a two-way exchange and 'Fun!'.

Most scientists communicated their knowledge at least once a year, though a variety of methods. This is despite the fact that generally, it was found that they were not recognised, or rewarded for communicating with the general public. It was not part of the job.

Their employers' work priorities, communication policies and approval processes and contracts were found to most hinder scientists that want to communicate with the general public. These often translated into a lack of time to communicate. It logically follows then, that many scientists were found to believe that communicating with the public was not a priority use of their time

when compared with non-negotiable activities such as securing funding and conducting and publishing research. Many stated that it was more important for their employers that they communicate with clients, scientific peers or collaborators and funders, than the general public. As one respondent succinctly stated, ‘Scientists must comply with employer priorities to survive’.

In science, ‘the conflict between long-range ambitions to inform the public and more pressing needs to concentrate on basic research’ (Goodell, 1977) for both the individual scientist and the scientific research organisation, has existed for at least four decades. This conflict is increasing, as government funding for publicly-funded research continues to decline while public expectations, that scientific knowledge is made publicly available about issues that concern them, are increasing.

Although the finding that most hindrances to scientists’ communication were found to occur within the workplace may seem obvious to some, it does clearly direct the focus for any improvement in attitudes and activities to scientists’ employers and funders, rather than the scientists themselves. By contrast, much of the political rhetoric from both scientific and political leaders in Australia about the need for better communication between scientists and the general public has been directed towards scientists (Batterham, 2000). In many ways, scientists in this study have stated that they are not in a position to choose the priorities for how they spend their time. It is their employer organisations and institutions and those that fund the research that determine if, how and when scientists communicate.

After this research was completed, statements by Australia’s Science Minister were directed toward institutions around scientists’ communication and ‘charters confirming the right of researchers in the four public research agencies in my portfolio to freedom of expression’, seemed to herald a positive change in communication practice between public sector researchers and the public (Carr, 2008a, 2008b, 2008c, 2008d, 2008e, 2008f, 2008g). Expectations have since been lowered amidst continuing media stories about censorship of scientists (ABC, 2009b; Beeby, 2009a). In this survey, scientists employed by the government at all levels, identified less secrecy and different employer public comment policies as helpful to their communication. Whether this is due to

actual censorship or unmet expectations of free speech in the public sector, or both, is the subject for another study. Even those scientists in universities, a crumbling bastion of free speech, are subject to commercial secrecy requirements.

Another finding of this research, concerning the government sector, was the relationship between scientists' communication activity, hindrances and needs. The more they communicated, the more hindrances they encountered, and the more they needed help. This may be because government scientists communicate more often and therefore encounter more hindrances and need more help; or perhaps that again, as public servants, they expect to communicate to the public that pays for them and their research, and find they can not.

Implications

This research provides a baseline of the views and activities around communication of Australia's scientists and complements the few national studies published elsewhere such as in the United Kingdom, within the last decade.

The findings of this exploratory and descriptive research provide a quantitative and qualitative basis to help and train scientists to be more effective communicators. The results inform scientists of what their Australian peers think and do about communication with the public. This provides a useful context for scientists to examine their own assumptions – arguably an important step to more effective communication with any audience.

These results imply that employers in general do little to facilitate direct communication between scientists and the general public. If, however, employers want to move beyond the public rhetoric of the importance of scientists' communication with society and invest in this communication for all the benefits that it can bring, they need to look at their own priorities for the scientists in their employ and identify mechanisms to provide the necessary recognition and support.

The finding that scientists communicated more frequently where communicating was part of a scientists' job or there was recognition for communication activities, implies that more of Australia's scientists would communicate if it

was a higher priority for their employers and formally part of their job. Scientists are generally not in a position to communicate with the public if it is not a priority for their employers.

This study highlighted the statistically significant demographic variation that exists between the views and activities of Australia's scientists with regard to what they think and do about communication with the general public. This has implications for science communication practice, training and research.

Those scientists who were hindered most and wanted more help to communicate were employed by publicly-funded government agencies and departments, and universities. This finding implies that there is an area of ambiguity between the rhetoric of political and government leaders encouraging scientists to communicate, and the workplace reality for many government-employed scientists.

Limitations of Study

The survey method was not designed to collect data from a sample that was representative of the scientist population of Australia as a whole. The descriptions, results and my conclusions are therefore based upon a sample that can not be considered totally representative or predictive. Instead it aimed to capture and reflect the views and activities of male and female scientists across a range of ages, science disciplines and employment sectors, and in this it succeeded.

Australian scientists were invited to participate in a national survey through professional science societies and associations, and employers of scientists, as well as through members of the Australian Science Communicators. This appears to have been a useful strategy as it succeeded in reaching a wide range of scientists, including those who had retired.

A disadvantage of the sampling strategy of self-selected scientists, foreseen from the outset, is that it can be assumed that the sample population had a certain over-representation of scientists sufficiently interested in contributing their views and experiences to a national survey about their science communication with the general public in response to an open invitation. The extent, if any, is unknown.

As this research is the first nationwide research focussed on a broad cross-section of scientists in Australia and their communication with the general public and is therefore necessarily exploratory, the advantages of being able to describe the range of responses from a potentially large number of scientists as the basis for further research were judged to override the possible lack of representativeness of the survey population. It appears, however, that the survey population did resemble the national population of scientists in Australia in terms of two (age and sex) of the four attributes of interest in this study. Other research suggests that perhaps this result in terms of the representativeness of sex could have been predicted because computer and Internet-usage apparently does not discriminate for sex among scientists. The survey sample was less representative of Australia's scientists in terms of their distribution across disciplines and employment sectors. For example, there was an over-representation of scientists in university and government sectors and an under-representation of scientists in industry.

A limitation of this survey that, again was foreseen, was that it deliberately did not include engineers, and therefore it is not directly comparable to those national surveys which did.

Recommendations for Practice

This research found that most scientists think it is important that they communicate with the general public, and that scientists have a professional responsibility to do so, but that these views were not reflected in the policies and practices of the organisations that employed them. This situation is believed to be similar to that in the United Kingdom, as summarised by Professor Martin Rees, President of the Royal Society: 'Many scientists are willing to engage in dialogue and debate, but they need encouragement and guidance, and they need to feel that their efforts are valued' (The Royal Society, 2006a).

Therefore, the following recommendations focus on the institutions and organisations that employ and fund scientists rather than the scientists themselves. Recommendations arising from this research overlap with some of those from United Kingdom studies which call for a national commitment amongst organisations that employed and funded scientists towards a cultural

change in attitude towards public communication and towards practical action (MORI, 2001b). Recommendations for cultural change within the workplace that have emerged from this current study are:

1. Those who wish to encourage scientists to communicate with the general public, including their professional associations, employers and funders and governments, should promote awareness of the many professional and personal benefits from communication identified by scientists in this study. This should include discussion about the values behind scientists' positive emotions about their communication with the general public.

2. Organisations and institutions that are committed to improving scientists' communication with the public should examine their work practices to identify any hindrances to communication, such as slow approval processes, and needs for improvement, such as formal recognition of communication with the public as part of the scientists' job descriptions and performance assessments for promotions.

3. Employers should be encouraged to formally recognise and reward a scientist's communication for all to see (especially scientists' managers and peers). Rewards include time-in-lieu for time spent communicating, and funding to participate and communicate (e.g. funds for travel and accommodation and, in the case of government organisations such as CSIRO, the provision of account codes against which to log communication activities).

4. Employers of female and all younger scientists (i.e. < 43 years-of-age) should identify opportunities for them to communicate with the public, and offer training to learn both how to communicate science directly to the public and via the media. All other scientists should be offered refresher courses.

5. Employers of older male scientists (i.e. > 43 years of age) should explicitly make communicating with the public a priority that is recognised through rewards such as bonuses or a requirement for promotion. This may facilitate their finding more time to communicate with the general public.

6. The younger scientists (i.e. < 27 years of age), and particularly those employed in universities, should be informed of their employer's expectations, or lack of them, with regard to communication with the public, to reduce the ambiguity that currently exists.

The following recommendations concern communication training at universities, and self promotion by science communicators.

7. Training in communication skills in universities for science undergraduates and postgraduates is strongly recommended to enable scientists of the future to learn and practice their communication skills. This recommendation is supported by a finding from the written submissions to the Australian report *Inspiring Australia* regarding the development of science communication capability:

8. Tertiary institutions should be encouraged to develop media awareness and communication skills as part of all research-based degrees as a key competency. (Department of Innovation Industry Science and Research, 2010, p. 75)

9. It is recommended that science communicators explicitly communicate the value of their knowledge and skills to the scientists, managers and organisations with which they work, especially in the strategic planning of communication activities. Although not explicitly stated by scientists in this study, it appears that most scientists' communication with the public is reactive, rather than the result of strategic planning, which would exacerbate further their lack of time to participate.

Recommendations for Science Communication Research

1. In science communication research, it is recommended that scientists are not treated as one homogeneous group, in terms of sampling and analysis of their views and activities; and the planning and implementation of their training and management. Scientist's sex, age, discipline and employers were shown in this study to be significant sources of variation in their views and activities around communication with the general public.

2. As engineers were excluded from the sampling strategy of this study, it is recommended that research be conducted to explore and describe

the views and activities of engineers around communication with the general public to complement and compare with this study of scientists in Australia.

3. There was an under-representation of scientists working in industry and elsewhere in the private sector in this study. It is recommended that further research focuses on scientists on the private sector, including non-government organisations. Given that most of Australia's scientists are employed in the private sector, research that identifies their communication hindrances and needs would contribute to a more complete picture.

4. Organisational practices that have been successful according to their own criteria should be identified. It would also be useful to know what organisations hope to achieve with their science communication with the general public (e.g. attraction of new funding and collaborators, enhancement of reputation) and what success looks like to them. This could be achieved through a national review of the effectiveness of science communication (science communicators and other communication resources be conducted) through interviews with senior science communication managers across the employer sectors (public and private). These examples of best practice in Australia (different models for different purposes and resource bases) would demonstrate to senior scientific management in all organisations the benefits of investing resources into scientists' communication with the general public.

5. It is also recommended that research is conducted to explore and describe the policies, practices and efficacy assessments regarding scientists' communication with the general public from the employer and funders' point of view (e.g. Commonwealth, State, Territory and Local Government), universities, research institutes, hospitals) and funders (e.g. ARC and NHMRC) of scientists in both the public and private sectors regarding scientists communication with the general public. Their views of the benefits and costs of scientists' communication with the general public would be very valuable and complement the findings from this research.

It is imperative that the employers and funders of Australia's scientists act, mindful of not adding further to scientists' heavy workload, to recognise that scientists' communication of their knowledge with the general public is as important, if not more so, that communication with their scientific peers. Scientists are the source of scientific knowledge and most believe that they have a responsibility to communicate with the general public, and to many it is personally important that they communicate their own knowledge. They are hindered, however, in many ways from doing so. If these hindrances remain; if communication with the public is not incorporated as an important criterion for their performance assessments and promotion cases, and scientists are not encouraged, funded and rewarded by their employers and their profession to communicate the best scientific information available, who will provide the public with the knowledge that they want and need?

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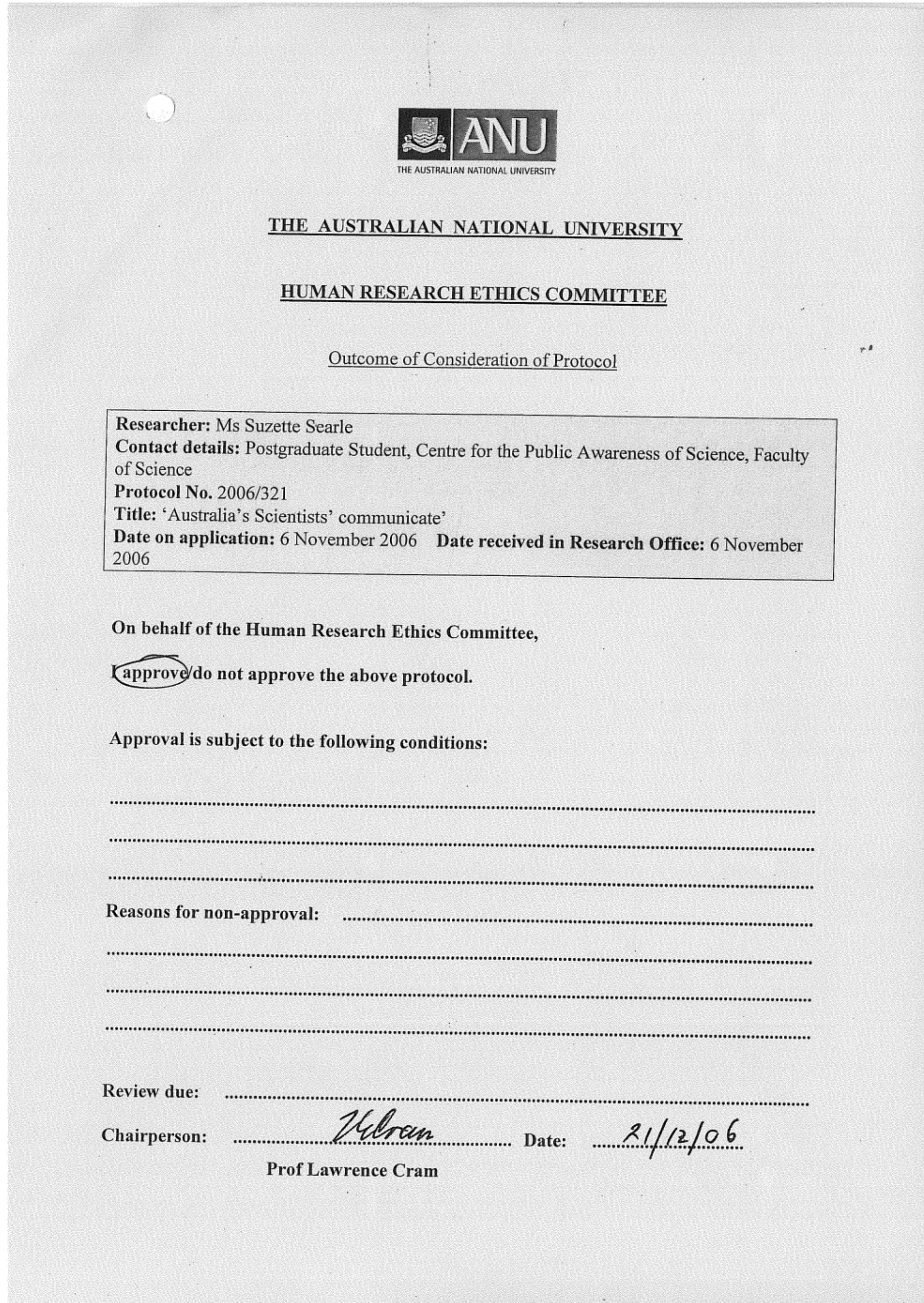
11. APPENDICES

Appendix 1 Human Research Ethics Committee approvals (4)



THE AUSTRALIAN NATIONAL UNIVERSITY

HUMAN RESEARCH ETHICS COMMITTEE

Outcome of Consideration of Protocol

Researcher: Ms Suzette Searle
Contact details: Postgraduate Student, Centre for the Public Awareness of Science, Faculty of Science
Protocol No. 2006/321
Title: 'Australia's Scientists' communicate'
Date on application: 6 November 2006 **Date received in Research Office:** 6 November 2006

On behalf of the Human Research Ethics Committee,

I approve/do not approve the above protocol.

Approval is subject to the following conditions:

....

....

....

Reasons for non-approval: ....

....

....

....

Review due: ....

Chairperson: ....**Date:** 21/12/06

Prof Lawrence Cram

THE AUSTRALIAN NATIONAL UNIVERSITY

RESEARCH OFFICE

Ms Yolanda Shave
Secretary, Human Research Ethics Committee

CANBERRA ACT 0200 AUSTRALIA
TELEPHONE:(02) 6125 7945
FACSIMILE: (02) 6125 4807
EMAIL: Yolanda.Shave@anu.edu.au

4 January 2007

Ms Suzette D Searle
Postgraduate Student,
Centre for the Public Awareness of Science
Faculty of Science
The Australian National University
ACT 0200

Dear Ms Searle,

Protocol 2006/321
'Australia's Scientists' communicate'

On behalf of the Human Research Ethics Committee I am pleased to advise that the above protocol has been approved as per the attached *Outcome of Consideration of Protocol.*

For your information:

1. Under the NHMRC/AVCC *National Statement on Ethical Conduct in Research Involving Humans* we are required to follow up research that we have approved. Once a year (or sooner for short projects) we shall request a brief report on any ethical issues which may have arisen during your research and whether it proceeded according to the plan outlined in the above protocol.
2. Please notify the Committee of any changes to your protocol in the course of your research, and when you complete or cease working on this project.
3. The validity of this current approval is five years' maximum from the date shown on the attached *Outcome of Consideration of Protocol* form. For longer projects you are required to seek renewed approval from the Committee.

Yours sincerely,

per J Radcliffe

Ms Yolanda Shave
Secretary, Human Research Ethics Committee

THE AUSTRALIAN NATIONAL UNIVERSITY

RESEARCH OFFICE

Ms Yolanda Shave
Secretary, Human Research Ethics Committee

CANBERRA ACT 0200 AUSTRALIA
TELEPHONE:(02) 6125 7945
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24 April 2007

Ms Suzette D Searle
Postgraduate Student,
Centre for the Public Awareness of Science
Faculty of Science
The Australian National University
ACT 0200

Dear Ms Searle,

Protocol 2006/321
'Australia's Scientists' communicate'
Variation: Amendments to Participation Consent statement on web based questionnaire

I am pleased to advise that the above variation to the above protocol, as described in your email to me of 24 April 2007, has been approved by the Chair of the Human Research Ethics Committee Prof Lawrence Cram on 24 April 2007. The approval of the variation will routinely be reported to the Committee at its next meeting.

Please do not hesitate to contact me if you have any queries.

Yours sincerely

J Radcliffe
per
Yolanda Shave
Secretary, Human Research Ethics Committee

THE AUSTRALIAN NATIONAL UNIVERSITY

RESEARCH OFFICE

Ms Yolanda Shave
Secretary, Human Research Ethics Committee

CANBERRA ACT 0200 AUSTRALIA
TELEPHONE:(02) 6125 7945
FACSIMILE: (02) 6125 4807
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14 May 2007

Ms Suzette D Searle
Postgraduate Student
Centre for the Public Awareness of Science
Faculty of Science
The Australian National University
ACT 0200

updated ARIES
20.3.08 [illegible]

Dear Ms Searle,

Protocol 2006/321
'Australia's Scientists' communicate'
Variation: Variation to Web-based Questionnaire

I am pleased to advise that the above variation to the above protocol, as described in your email to me of 1 May 2007, has been approved by the Chair of the Human Research Ethics Committee Prof Lawrence Cram on 2 May 2007. The approval of the variation will routinely be reported to the Committee at its next meeting.

Please do not hesitate to contact me if you have any queries.

Yours sincerely

JRadcliffe
per
Yolanda Shave
Secretary, Human Research Ethics Committee

Appendix 2. Participant organisations - government employers

Office of the Gene Technology Regulator (OGTR)

Cooperative Research Centres (42 CRCs)

Commonwealth Research Agencies

Australian Antarctic Division (AAD)

Australian Institute of Marine Science (AIMS)

Australian Nuclear Science and Technology Organisation (ANSTO)

Bureau of Meteorology Research Centre (BOM)

Commonwealth Scientific & Industrial Research Organisation (CSIRO)

Defence Science & Technology Organisation (DSTO)

Geoscience Australia (GA)

Greater Barrier Reef Marine Park Authority (GBRMPA)

Appendix 3. Copy of email sent to FASTS

From: Bradley Smith <FASTS@anu.edu.au>
Date: Mon, 07 May 2007 16:35:06 +1000
Subject: questionnaire: 'Scientists and science communication in Australia'

Memo to
FASTS Presidents
FASTS CEO
FASTS Board
FASTS Editors

Greetings

I would be grateful if your society could support a study into science and science communication being undertaken by Suzette Steel –a PhD candidate at ANU's National Centre for the Public Awareness of Science – by forwarding this e-mail to your membership.

This questionnaire is the first of its kind to give Australia's scientists, across the nation and different types of organisations and disciplines, a voice about their current views and experiences of communicating with the general public.

The questionnaire - 'Scientists and Science Communication in Australia' - is part of a research project aimed to help scientists and others who want to facilitate a greater understanding of Australia's scientists and their work.

The research findings will be published and the project is endorsed by FASTS and supported by the Australian Academy of Science

The questionnaire is open from Monday 7 May until Friday 8 June 2007 inclusive.

Please log onto this website to complete the questionnaire:

http://info.anu.edu.au/CPAS/012PP_Research_Projects/_scientists_poll.asp

Regards

Bradley

Bradley Smith
Executive Director
Federation of Australian Scientific and Technological Societies FASTS
LPO Box 8283 ANU ACTON ACT 2601
ph: 02 6257 2891 fax: 02 6257 2897
Mobile: 0408 511 261

Appendix 4. Email sent to Fellows of the Australian Academy of Science

Dear Fellows of the Academy of Science,

You are invited to participate in a study on 'Scientists and Science Communication in Australia' by completing an online questionnaire. The Study is being undertaken by Suzette Searle - a PhD candidate at the National Centre for the Public Awareness of Science, Australian National University.

This questionnaire is a first and has been designed to look at the Current views and experiences of Australia's scientists in communicating with the general public.

You may log onto this website to complete the questionnaire:
http://info.anu.edu.au/CPAS/012PP_Research_Projects/_scientists_poll.asp

Appendix 5. Email invitation sent to a Cooperative Research Centre (CRC)

From: Suzette Searle [mailto:suzette.searle@anu.edu.au]
Sent: Monday, 28 May 2007 11:00 AM
To: 'matthew.cuthbertson@autocrc.com'
Subject: Request for CRC scientists' participation in national survey 'Scientists and Science Communication in Australia'

CRC for Advanced Automotive Technology
Dr Matthew Cuthbertson
Chief Executive Officer
4 Central Boulevard PORT MELBOURNE VIC 3207

Dear Dr Cuthbertson

I am writing to request your support for the participation of your CRC scientists in a national survey, across employment sectors and science disciplines, called 'Scientists and Science Communication in Australia'.

The questionnaire is endorsed by the Federation of Australian Scientific and Technological Societies (FASTS) and supported by The Australian Academy of Science. Both organizations have invited their members to participate. The online questionnaire has been approved by The Australian National University's Human Research Ethics Committee and is taking people 7—25 minutes to complete, depending on what they choose to write.

I would be grateful if you would support this study into science and science communication by forwarding this e-mail to your CRC communication manager for distribution to the CRC's scientists. Your manager may wish to use the following words to accompany a link to the questionnaire:'Scientists and Science Communication in Australia'

You are invited to contribute your views about scientists and their science communication in Australia through an online questionnaire. It is the first of its kind to give Australia's scientists, across the nation and different types of organisations and scientific disciplines, a voice about their current views and experiences of communicating with the general public. The questionnaire - 'Scientists and Science Communication in Australia' - is part of a university research project aimed to help scientists and others who want to facilitate a greater understanding of Australia's scientists and their work.

Participants' responses are confidential: their identity and that of their employer is not sought, and anonymity is also guaranteed by the polling software used to collate responses.

The questionnaire is open until midnight on Sunday 8 July 2007 and can be reached via the following link: http://info.anu.edu.au/CPAS/012PP_Research_Projects/_scientists_poll.asp

This project is endorsed by the Federation of Australian Scientific and Technological Societies (the peak representative body for 60,000 Australian scientists and technologists). It is also supported by the Australian Academy of Science (Australia's peak science body). It is being conducted by a PhD candidate at The Australian National University.

I look forward to hearing from you as to whether this request meets with your approval, and please call me if you have any questions,

All the best,

Suzette Searle PhD Candidate The National Centre for the Public Awareness of Science,
The Australian National University, ACT 0200 Tel: 6125 7633
Email: suzette.searle@anu.edu.au

Appendix 6. Email letter of invitation to AusBiotech Ltd

From: Suzette Searle [mailto:suzette.searle@anu.edu.au]
Sent: Friday, 15 June 2007 12:05 PM
To: Anna Lavelle

Subject: Request for support from AusBiotech Ltd for research part-funded by CSIRO - 'Scientists and Science Communication in Australia'

Dr Anna Lavelle Chief Executive Officer AusBiotech Ltd

Tel: (03) 9828 1404

Dear Dr Lavelle

I am writing to ask if you would support research about Australia's scientists and their communication with the general public
by forwarding an invitation to AusBiotech's members for their scientists to participate in a national, online, anonymous survey.

This research is part-funded by one of your members, CSIRO, through a CSIRO Flagship postgraduate studentship.
I am conducting this research as part of a PhD at The Australian National University.

This project is endorsed by the **Federation of Australian Scientific and Technological Societies**. It is also supported by the **Australian Academy of Science**.

The questionnaire has been well received by the scientific community with scientists from 36 CRCs, major Commonwealth research agencies (ANSTO, CSIRO, DSTO, AIMS, Bureau of Meteorology Research Centre, Geoscience Australia, and the Australian Antarctic Division), members of Federation of Australian Scientific and Technological Societies and fellows of the Australian Academy of Science participating to date.

I note a number of these organizations are members of AusBiotech but any cross posting would simply serve as a first (and only) reminder.

To date 1,337 scientists have completed the questionnaire and I am hoping many more, especially from industry, will contribute their views and experience to this research before the questionnaire closes on 8 July.

I would be grateful if you would support this study into science and science communication by forwarding the invitation below to AusBiotech members (companies and individuals) who employ scientists in Australia.

A suggested invitation to scientists and link to the survey are below:

Scientists and Science Communication in Australia

(Apologies for any cross posting)

You are invited to contribute your views about scientists and their science communication in Australia through an online questionnaire.
It is the first of its kind to give Australia's scientists, across the nation and different types of organisations and scientific disciplines, a voice about their current views and experiences of communicating with the general public.

The questionnaire - 'Scientists and Science Communication in Australia' - is part of a university research project aimed to help scientists and others who want to facilitate a greater understanding of Australia's scientists and their work.

Participants' responses are confidential: their identity and that of their employer is not sought, and anonymity is also guaranteed by the polling software used to collate responses. The questionnaire is open until midnight on Sunday 8 July 2007 and can be reached via the following link:

http://info.anu.edu.au/CPAS/012PP_Research_Projects/_scientists_poll.asp

This project is endorsed by the **Federation of Australian Scientific and Technological Societies** (the peak representative body for 60,000 Australian scientists and technologists). It is also supported by the **Australian Academy of Science** (Australia's peak science body). It is being conducted by a PhD candidate at The Australian National University.

Please call me if you have any questions and I look forward to hearing from you as to whether this request meets with your approval.

All the best, etc.

Appendix 7. Email to the Australian Science Communicators (ASC) list

Subject: [ASC-list] Scientists and science communication in Australia -

online survey From: Meg.Rive@csiro.au

Date: Wed, June 27, 2007 8:32 am

To: asc-list@lists.asc.asn.au

Posted on behalf of Suzette Searle (suzette.searle@anu.edu.au

<mailto:suzette.searle@anu.edu.au>):

Scientists and Science Communication in Australia

Are you a scientist? If so, join more than 1380 other Australian scientists who have contributed their views to a national, online survey about communicating with the general public.

If you're a science communicator who works with scientists, please assist a fellow science communicator, by forwarding the invitation and link below to scientists that you know:

You are invited to contribute your views to research that gives Australia's scientists, across the nation and different types of organisations and scientific disciplines, a voice about their current views and experiences of communicating with the general public.

The questionnaire - 'Scientists and Science Communication in Australia' - is part of a university research project aimed to help scientists and others who want to facilitate a greater understanding of Australia's scientists and their work.

Participants' responses are confidential: their identity and that of their employer is not sought, and anonymity is also guaranteed by the polling software used to collate responses.

The questionnaire is open until midnight on Sunday 8 July 2007 and can be reached via the following link: http://info.anu.edu.au/CPAS/012PP_Research_Projects/_scientists_poll.asp

This project is endorsed by the Federation of Australian Scientific and Technological Societies (the peak representative body for 60,000

Australian scientists and technologists). It is also supported by the Australian Academy of Science (Australia's peak science body). It is being conducted by a PhD candidate at The Australian National University.

Appendix 8. Invitation via APESMA newsletter July 2010

APESMA is the Association of Professional Engineers, Scientists and Managers, Australia

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Scientists and science communication in Australia

Scientists are being asked to take part in a national survey about communicating their specialised knowledge with the general public, to facilitate a greater understanding of Australia's scientists and their work.

This survey is the first of its kind to give Australia's scientists, across the nation and different types of organisations and disciplines, a voice about their current views and experiences of communicating with the general public. More than 1,495 scientists have already completed the anonymous, 15-minute, on-line questionnaire.

The project is endorsed by the **Federation of Australian Scientific and Technological Societies** and the **Australian Academy of Science,** and **t**he research is being conducted by a PhD candidate from The Australian National University.

The questionnaire is open until midnight on Monday 9 July 2007 to scientists who:

live in Australia

have a university or other tertiary degree

are employed as a scientist, identify as a scientist, or are identified by others as a scientist

For more information or to take part in the survey, visit:

http://info.anu.edu.au/CPAS/012PP_Research_Projects/_scientists_poll.asp

Appendix 9. Description of a scientist (ABS, 1998)

According to the ABS, 234:

NATURAL AND PHYSICAL SCIENCE PROFESSIONALS perform analytical, conceptual and practical tasks in relation to environmental factors and agricultural production, the chemical and physical properties of the universe, the extraction and processing of mineral ores, life forms including the physiology and biochemistry of humans, plants and animals, and disease prevention.

Indicative Skill Level:

In Australia and New Zealand:

Most occupations in this minor group have a level of skill commensurate with a bachelor degree or higher qualification. In some instances relevant experience and/or on-the-job training may be required in addition to the formal qualification (ANZSCO Skill Level 1).

Appendix 10. Screen capture of questions about scientists' communication activities

.Section 7. YOUR COMMUNICATION WITH THE GENERAL PUBLIC (Questions marked * are mandatory)

All the following questions are about your communication with the 'general public' - a term which has many meanings.

For this questionnaire 'general public' means people outside your field

who are unconnected with groups or activities associated with your work or field.

This means, for example, we are not asking about your communication with your colleagues, collaborators, clients, industry or government funders, students you teach, or policy makers (politicians or government officials), regulators or lobby groups.
Have you communicated your specialised knowledge with the general public in Australia over the past 12 months through:

The survey continued with questions 19 to 36:

		No	Once	2-10 times	>10 times
Q19. *	an interview for a national or local newspaper	○	○	○	○
Q20. *	an interview, monologue or panel discussion on radio	○	○	○	○

Appendix 11. Employer insights for the generations (McCrindle Research, 2006)

Baby Boomers - Employer insights

Boomers have lived through incredible change and have adapted to (and in many cases created) the change. They are therefore a very adaptive and flexible generation and this can be seen in everything from their embracing of technology (even if they couldn't all programme their VCR's) to their collaborative management style. Therefore it is important that age stereotypes don't replace real research. This generation are likely to remain in leadership positions for longer than any previous generation and their experience combined with their adaptivity will keep them relevant.

Generation X

Originally labelled as the Baby Busters, Post Boomers, or the Slackers Generations only the label Generation X (or Xer) has stuck. It was in 1991 right at the time that this new generation were emerging that Canadian author Douglas Coupland wrote a book which he entitled "Generation X: Tales for an accelerated culture". Ironically the book was about a generation that defy labels – "just call us X" he said, yet the label has stuck, and spored the labels for Generation Y and Z also!

Employer Insights:

Generation X is the perfect bridge generation. They understand and usually adopt the work ethic and focus of the Boomers (remember the Xers began their economic life when jobs were harder to get and keep in the early 1990's during which there was a recession and much downsizing of the workforce – very different to the near-full employment today). Yet they are closer in age to the Gen Y's and so can connect somewhat with their culture, views, and even values. (McCrindle Research, 2006, p. 9)

Generation Y - employer insights

While derided as fickle, self-focussed, and transient the reality is that they just reflect their times. Economic cycles come and go, jobs aren't guaranteed, and profits are seemingly pre-eminent - so it is not an inherent selfishness but a response to the corporate realities. When managers step from behind the corporate image and build staff rapport and relate to individuals then loyalty and commitment from Gen Y can indeed be garnered. (McCrindle Research, 2006, pp. 9-10)

Generation Z - employer insights

Generation Z are almost exclusively the children of Generation X. And so the Generation Z's are powerful players in today's work culture as the maternity & paternity leave, childcare options, and the rostering flexibility offered to their parents are critical retention factors to the Generation Xers. Expect the politics of child care, parental leave, and paid maternity leave to continue to dominate employment debates(McCrindle Research, 2006, p. 10).

Appendix 12. Generational differences in the funds management industry (Salt, 2007)

Baby Boomers: this generation was mostly born during the 15 years to June 30, 1961. The impact of WWII was profound in that it stifled birth rates in participating nations over the six years to 1945. The birth rate ratcheted almost immediately following the demobilization of troops: in Australia troops were first demobilized in September 1945; the birth rate jumped nine months later in June 1946. The parents of baby boomers were young adults during the war; they also "touched" the Great Depression of the early 1930s. These experiences shaped the households of young baby boomers. Unlike their frugal parents the boomers are proven consumerists; they have also enjoyed generally prosperous economic times throughout the second-half of the 20th century in participating nations. Boomers now hold senior management positions in the workforce and over the last decade many have been accumulating and storing wealth in preparation for their retirement. It is this generation that has largely underpinned the rise of the FM industry over the last 15 years.

Generation X: this generation was born over the 15 years to June 30, 1976. Generation X was named by Canadian author Douglas Coupland with the release of his book of the same name in 1992. Xers struggled throughout their youth to establish an identity that was separate from the preceding boomer generation. The focus had always been on boomers and on their cultural causes. Xers have been labelled cynical largely because they matured to adulthood in the wake of the 1987 stock market crash. They entered the job market amid an era of economic rationalism in the early 1990s. Xers struggled to enter the housing market in many nations where property prices were leveraged up by the preceding generation of household-forming boomers. Xers are now transitioning into senior management positions in the office.

Generation Y: this generation was born over the 15 years to June 30, 1991. Generation Y, or Gen Y, are the children of the baby boomers. Some see the Ys as the children of rich and indulgent baby boomer parents. The boomers were the first generation to deliver two incomes to the household and have been inclined to indulge their children as a consequence. In many nations, such as the U.K., China and Australia, Ys have only ever experienced a world of rising economic prosperity. Generation Y are less likely to make commitments to marriage, to mortgage, to children or to career until late in their 20s. This generation is more likely to live at home or, in the case of the U.S., to continue to draw upon parental income support after leaving home. Some have labelled this phenomenon as Gen Y having access to the "Bank of Mom & Dad". This generation is highly educated, generally entrepreneurial (in comparison with previous generations) and global in their thinking. All of this makes Generation Y focussed on the here and now and, from an employers perspective, it also makes this generation especially difficult to retain in the office (Salt, 2007).

Appendix 13. Natural and Physical Science Professionals at the Unit Group (8) level

Occupations in this minor group (234) for Natural and al science professionals are classified into the following ANZCO Unit groups:

2341 Agricultural and Forestry Scientists

2342 Chemists, and Food and Wine Scientists

2343 Environmental Scientists

2344 Geologists and Geophysicists

2345 Life Scientists

2346 Medical Laboratory Scientists

2347 Veterinarians

2349 Other Natural and Physical Science Professionals (ABS, 2006c)

Appendix 14. RFCD Classification highlighting ABS divisions used in questionnaire'

6. The divisions are:

210000 - Science - General
220000 - Social Sciences, Humanities and Arts - General
230000 - Mathematical Sciences
240000 - Physical Sciences
250000 - Chemical Sciences
260000 - Earth Sciences
270000 - Biological Sciences
280000 - Information, Computing and Communication Sciences
290000 - Engineering and Technology
300000 - Agricultural, Veterinary and Environmental Sciences
310000 - Architecture, Urban Environment and Building
320000 - Medical and Health Sciences
330000 - Education
340000 - Economics
350000 - Commerce, Management, Tourism and Services
360000 - Policy and Political Science
370000 - Studies in Human Society
380000 - Behavioural and Cognitive Sciences
390000 - Law, Justice and Law Enforcement
400000 - Journalism, Librarianship and Curatorial Studies
410000 - The Arts
420000 - Language and Culture
430000 - History and Archaeology
440000 - Philosophy and Religion (ABS, 1998)

Appendix 15. Current discipline or research field

Q14.* From the list below, which category most closely describes your current discipline or research field from the following Australian Bureau of Statistics list of categories?

Please select one:

Agricultural, Veterinary and Environmental Sciences
Architecture, Urban Environment and Building
Behavioural and Cognitive Sciences
Biological Sciences
Chemical Sciences
Earth Sciences
Engineering and Technology
Information, Computing and Communication Sciences
Mathematical Sciences
Medical and Health Sciences
Physical Sciences
Science (General)
Social Sciences, Humanities and Arts (General)
Other research field. Please specify...

Appendix 16. Fields of Research

The Field of Research (FOR), the second element of the classification, categorises R&D activity by academic discipline. Under this classification the following SET fields apply:

• Science – general;

• Mathematical Sciences;

• Physical Sciences;

• Chemical Sciences;

• Earth Sciences;

• Biological Sciences;

• Information, Computing and Communication Sciences;

• Engineering and Technology; and

• Agricultural, Veterinary and Environmental Sciences (ABS, 1998)

Appendix 17. Question order in the questionnaire ‘ Scientists and science communication in Australia’

Question
Section 1. DO YOU MEET AT LEAST THREE OF THE FIVE CRITERIA NEEDED TO FILL OUT THIS QUESTIONNAIRE? (Questions marked * are mandatory) Those shaded yellow are demographic questions
Q1.* Do you live in Australia?
Q2.* Do you have a university or other tertiary degree?
Q3.* Are you employed as a scientist?
Q4.* AND/OR do you identify yourself as a scientist?
Q5.* AND/OR are you identified by others as a scientist?
Section 2. ABOUT YOU
Q6.* Are you: Female Male
Q7.* Where (State/Territory) do you live?
Q8.* In what year were you born?
Section 3. YOUR OCCUPATION, EMPLOYMENT AND ROLE
Q9.* What is your current employment situation?
Q10.* What is your current occupation?

Q11.* What best describes your current role from the following list?
Section 4. YOUR QUALIFICATIONS (Questions marked * are mandatory)
Q12.* What is your highest completed educational qualification?
Q13.* In what year did you complete your highest qualification?
Section 5. YOUR CURRENT DISCIPLINE AND FIELD(S) OF INTEREST
Q14.* From the list below, which category most closely describes your current discipline or research field from the following Australian Bureau of Statistics list of categories?
Q15. What is (are) your field(s) within these disciplines/research fields?
Q16. Are you a member of any professional society, institute or association?
Section 6. YOUR CURRENT EMPLOYER
Q17.* Which best describes the sector to which you, or your employer institution or organisation belong?
Q18.* Which best describes the type of institution or

organisation for which you work or, if you no longer work, used to work for most of the time?
Section 7. YOUR COMMUNICATION WITH THE GENERAL PUBLIC (Questions marked * are mandatory)   **All the following questions are about your communication with the 'general public' - a term which has many meanings.**   For this questionnaire 'general public' means people outside your field   **who are unconnected with groups or activities associated with your work or field.**   This means, for example, we are not asking about your communication with your colleagues, collaborators, clients, industry or government funders, students you teach, or policy makers (politicians or government officials), regulators or lobby groups.   Have you communicated your specialised knowledge with the general public in Australia over the past 12 months through:
Q19.* an interview for a national or local newspaper
Q20.* an interview, monologue or panel discussion on radio
Q21.* an interview on television
Q22.* an interview for a popular science magazine   e.g. 'Australasian Science', 'Cosmos', 'New Scientist'
Q23. speaking on talk-back radio
Q24.* speaking at a meeting, workshop, symposium or similar

specifically intended to inform the general public (i.e. other than scientific conferences for scientific professionals)
Q25.* participating in a meeting or event specifically intended for two-way communication between you and the general public e.g. community/public forum, deliberative forum, citizens' jury, web forum
Q26.* speaking at a field day for the general public
Q27.* speaking at an institutional open day for the general public
Q28.* speaking with students and/or teachers at schools/colleges or elsewhere
Q29.* speaking at science centres/museums with the general public
Q30.* responding to questions from the general public via email, letter or telephone
Q31. informal discussions with members of the general public (in situations not listed above)
Q32.* working with schoolteachers (including writing educational materials)
Q33.* providing information (text, images, audio, video) for the Internet (including your own personal webpage)
Q34.* writing for a popular science magazine (interdisciplinary or monodisciplinary)
Q35.* writing for publication in the national or local press (including 'Letters to the Editor')

Q36.* writing a book for the general public
Q37. Other - Please specify
Q38. Which of the following did you communicate with the general public?
Q39.* How important is it to you personally that you communicate your specialised knowledge with the general public?
Q40. Please comment on why you said that (list or use dot points):
Q41.* In your opinion, do you benefit professionally from communicating your work and/or specialised knowledge with the general public?
Q42. If yes, please give examples of how it benefits you (list or dot points):
Q43.* In your opinion, do you benefit personally from communicating your work and/or specialised knowledge with the general public?
Q44. If yes, please give examples of how it benefits you (list or dot points):
Q45.* Is communicating with the general public part of your job description/duty statement or project requirement?
Q46.* Is communicating with the general public expected by your employer?
Q47.* Does your institution or organisation financially reward your communication with the general public?

Q48.* OR does your institution or organisation otherwise recognise or acknowledge your communication with the general public?
Q49. If yes to either question, how?
Q50.* How skilled do you feel you are to communicate your specialised knowledge with the general public?
Q51. Please comment on why you said that:
Q52.* Does anything hinder you from communicating in the way you would like with the general public?
Q53. If yes, please describe (list or dot points):
Q54.* If you want or have to communicate with the general public, what, if anything, would help you most to communicate in the way you would like?
Section 8. YOUR VIEWS ABOUT SCIENTISTS' COMMUNICATION WITH THE GENERAL PUBLIC (Questions marked * are mandatory)
How strongly do you agree or disagree with the following statement:
Q55.* There is a need for more effective one-way communication of knowledge and views from the scientific community to the general public?

Q56. Please comment on your answer:
How strongly do you agree or disagree with the following statement:
Q57.* There is a need for more effective two-way communication of knowledge and views between the scientific community and the general public?
Q58. Please comment on your answer:
Q59.* How strongly do you agree or disagree with the statement: Scientists, within both the public and private sectors, have a responsibility to ensure the timely communication to the public of research results that are in the public interest.
Q60. Please comment on why you said that:
Q61. Is there anything you would like to add?

Appendix 18. Questionnaire titled 'Scientists and Science Communication in Australia – screen capture

This questionnaire is the first of its kind to give Australia's scientists, across the nation and different types of organisations and disciplines, a voice about their current views and experiences of communicating with the general public.

This questionnaire is part of a research project aimed to help scientists and others who want to facilitate a greater understanding of Australia's scientists and their work.

Australia's political and scientific leaders have called for better communication between the scientific community and the general public — to help society make choices about new technologies, limited resources and environmental degradation. This research will assist in finding ways to help scientists in this regard.

This project is endorsed by the **Federation of Australian Scientific and Technological Societies** (the peak representative body for 60,000 Australian scientists and technologists). It is also supported by the Australian Academy of Science (Australia's peak science body).

This survey is being conducted by Suzette Searle, a PhD candidate at the Centre for the Public Awareness of Science (CPAS) at The Australian National University.

Please complete the questionnaire if you:

live in Australia

have a university or other tertiary degree

are employed as a scientist, identify yourself as a scientist,
or are identified by others as a scientist.

It will take about 20 minutes to complete.

Thank you for your interest in this research project!

If you have any queries, concerns or comments about this research please contact the researcher,
Suzette Searle
Tel. 02 6125 7633
Email: suzette.searle@anu.edu.au

or the Research Supervisor, Dr Sue Stocklmayer,
Tel. 02 6125 8157
Email: sue.stocklmayer@anu.edu.au

If you have any ethical concerns about the way in which
this research has been conducted, please contact:

Human Research Ethics Committee
The Secretariat, Research Office
The Australian National University
Tel. 02 6125 7945
Email: human.ethics.officer@anu.edu.au

This poll may take about 20 minutes to complete. Please note it must be completed in the one sitting as your answers will not be saved until you submit at the end of the questionnaire.

Privacy Statement

PARTICIPANT CONSENT

Your participation in this research project is voluntary, and you may withdraw at any stage or avoid answering questions you do not wish to answer. However once you have submitted your answers to this questionnaire we are unable to withdraw your data.

Your personal identity is not sought and your responses will not be used to identify you or your employer.

Your answers to this questionnaire are initially collated by a web-based software (APOLLO) that will ensure the anonymity of your identity i.e. we can view individual's responses but we are not able to identify who made them.

We may use verbatim quotes from questionnaire answers to illustrate particular views but these will not be attributed to any individual. We may attribute them from the perspective of a particular sector or academic discipline. Information given will enable us to describe questionnaire respondents in general terms and enable comparisons between people in different groupings.

This research project has been considered and approved by The Australian National University Human Research Ethics Committee.

If you agree to participate in this research, please click on 'Begin'.

Begin »

Appendix 19. Questions (grouped) in 'Scientists and science communication in Australia'

Screening questions (5 questions)

Do you live in Australia?

Do you have a university or other tertiary degree?

Are you employed as a scientist?

AND/OR do you identify yourself as a scientist?

AND/OR are you identified by others as a scientist?

About you (13 questions)

Sex, Location and Year of birth (3)

Occupation, Employment and Role (3)

Qualifications – highest and year of completion (2)

Current discipline and field(s) of interest and membership of professional society, institute or association (3)

Current employer (2)

Your communication with the general public (36 questions)

Communication incl. frequency with the general public (GP) (19 questions)

What was communicated (1)

Personal importance of communicating with the GP (2)

Professional benefits from communicating with the GP (2)
Personal benefits from communicating with the GP (2)

Is communicating with the GP part of job description (1)

Is communicating with the GP expected by employer (1)

Is communicating with the GP financially rewarded by employer (1)

Or otherwise recognised or acknowledged? (2)

How skilled do you feel you are to communicate with the GP (2)

Does anything hinder you from communicating in the way you would like? (2)

If you want or have to communicate with the GP, what would help most? (1)

Your views about scientists' communication with the general public (6 questions)

How strongly to you agree or disagree with statements about the need for more effective one-way communication, two-way communication and that 'Scientists, within both the public and private sectors, have a responsibility to ensure the timely communication to the public of research results that are in the public interest'? (6)

Is there anything you would like to add? (1)

Appendix 20. Scores for communication frequency

Communication frequency options for questions about communication activities (Q19–Q36)	Score for response
No	0
Once	1 (low)
2-10 times	2 (medium)
>10 times	3 (high)

Appendix 21. Communication expected by employer x Sex – cross-tabulation

Crosstab

			Q6. Sex		
			1 Male	2 Female	Total
Q. 46 Expected by employer	1 No	Count	262	212	474
		Expected Count	285.7	188.3	474.0
		% within Q. 46 Expected by employer	55.3%	44.7%	100.0%
		% within Q6. Sex	29.6%	36.3%	32.2%
		% of Total	17.8%	14.4%	32.2%
	2 Yes	Count	241	128	369
		Expected Count	222.4	146.6	369.0
		% within Q. 46 Expected by employer	65.3%	34.7%	100.0%
		% within Q6. Sex	27.2%	21.9%	25.1%
		% of Total	16.4%	8.7%	25.1%
	3 Don't know	Count	24	25	49
		Expected Count	29.5	19.5	49.0
		% within Q. 46 Expected by employer	49.0%	51.0%	100.0%
		% within Q6. Sex	2.7%	4.3%	3.3%
		% of Total	1.6%	1.7%	3.3%
	4 Sometimes - depends on issue/project	Count	359	219	578
		Expected Count	348.4	229.6	578.0
		% within Q. 46 Expected by employer	62.1%	37.9%	100.0%
		% within Q6. Sex	40.5%	37.5%	39.3%
		% of Total	24.4%	14.9%	39.3%
Total		Count	886	584	1470
		Expected Count	886.0	584.0	1470.0
		% within Q. 46 Expected by employer	60.3%	39.7%	100.0%
		% within Q6. Sex	100.0%	100.0%	100.0%
		% of Total	60.3%	39.7%	100.0%

Appendix 22. Communication expected by employer x Age (Generation) – cross-tabulation

Q. 46 Expected by employer * Q8. Age (Generation) Crosstabulation

			Q8. Age (Generation)				Total
			1 Builders	2 Boomers (born 1946-64)	3 Gen. X	4 Gen. Y	
Q. 46 Expected by employer	1 No	Count	37	140	228	69	474
		Expected Count	36.8	191.5	193.1	52.6	474.0
		% within Q. 46 Expected by employer	7.8%	29.5%	48.1%	14.6%	100.0%
		% within Q8. Age (Generation)	32.5%	23.6%	38.1%	42.3%	32.2%
		% of Total	2.5%	9.5%	15.5%	4.7%	32.2%
	2 Yes	Count	38	177	129	25	369
		Expected Count	28.6	149.1	150.4	40.9	369.0
		% within Q. 46 Expected by employer	10.3%	48.0%	35.0%	6.8%	100.0%
		% within Q8. Age (Generation)	33.3%	29.8%	21.5%	15.3%	25.1%
		% of Total	2.6%	12.0%	8.8%	1.7%	25.1%
	3 Don't know	Count	0	14	24	11	49
		Expected Count	3.8	19.8	20.0	5.4	49.0
		% within Q. 46 Expected by employer	.0%	28.6%	49.0%	22.4%	100.0%
		% within Q8. Age (Generation)	.0%	2.4%	4.0%	6.7%	3.3%
		% of Total	.0%	1.0%	1.6%	.7%	3.3%
	4 Sometimes - depends on issue/project	Count	39	263	218	58	578
		Expected Count	44.8	233.6	235.5	64.1	578.0
		% within Q. 46 Expected by employer	6.7%	45.5%	37.7%	10.0%	100.0%
		% within Q8. Age (Generation)	34.2%	44.3%	36.4%	35.6%	39.3%
		% of Total	2.7%	17.9%	14.8%	3.9%	39.3%
Total		Count	114	594	599	163	1470
		Expected Count	114.0	594.0	599.0	163.0	1470.0
		% within Q. 46 Expected by employer	7.8%	40.4%	40.7%	11.1%	100.0%
		% within Q8. Age (Generation)	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	7.8%	40.4%	40.7%	11.1%	100.0%

Appendix 23. Communication expected by employer x Discipline (≥ 50 people) – cross-tabulation

Crosstab

			Q14. Discipline coded for > 50 people								
			1 Agricultural, veterinary & environmental sciences	2 Biological sciences	3 Chemical sciences	4 Earth sciences	5 Engineering & technology	6 Mathematical sciences	7 Medical & health sciences	8 Physical sciences	Total
Q. 46 Expected by employer	1 No	Count	65	109	46	31	34	25	80	63	453
		Expected Count	98.5	101.2	29.9	50.6	30.2	21.0	69.6	51.9	453.0
		% within Q. 46 Expected by employer	14.3%	24.1%	10.2%	6.8%	7.5%	5.5%	17.7%	13.9%	100.0%
		% within Q14. Discipline coded for > 50 people	21.7%	35.4%	50.5%	20.1%	37.0%	39.1%	37.7%	39.9%	32.8%
		% of Total	4.7%	7.9%	3.3%	2.2%	2.5%	1.8%	5.8%	4.6%	32.8%
	2 Yes	Count	107	69	12	52	11	9	49	30	339
		Expected Count	73.7	75.7	22.4	37.9	22.6	15.7	52.1	38.8	339.0
		% within Q. 46 Expected by employer	31.6%	20.4%	3.5%	15.3%	3.2%	2.7%	14.5%	8.8%	100.0%
		% within Q14. Discipline coded for > 50 people	35.7%	22.4%	13.2%	33.8%	12.0%	14.1%	23.1%	19.0%	24.6%
		% of Total	7.8%	5.0%	.9%	3.8%	.8%	.7%	3.6%	2.2%	24.6%
	3 Don't know	Count	3	15	4	2	3	2	7	10	46
		Expected Count	10.0	10.3	3.0	5.1	3.1	2.1	7.1	5.3	46.0
		% within Q. 46 Expected by employer	6.5%	32.6%	8.7%	4.3%	6.5%	4.3%	15.2%	21.7%	100.0%
		% within Q14. Discipline coded for > 50 people	1.0%	4.9%	4.4%	1.3%	3.3%	3.1%	3.3%	6.3%	3.3%
		% of Total	.2%	1.1%	.3%	.1%	.2%	.1%	.5%	.7%	3.3%
	4 Sometimes - depends on issue/project	Count	125	115	29	69	44	28	76	55	541
		Expected Count	117.7	120.8	35.7	60.4	36.1	25.1	83.2	62.0	541.0
		% within Q. 46 Expected by employer	23.1%	21.3%	5.4%	12.8%	8.1%	5.2%	14.0%	10.2%	100.0%
		% within Q14. Discipline coded for > 50 people	41.7%	37.3%	31.9%	44.8%	47.8%	43.8%	35.8%	34.8%	39.2%
		% of Total	9.1%	8.3%	2.1%	5.0%	3.2%	2.0%	5.5%	4.0%	39.2%
Total		Count	300	308	91	154	92	64	212	158	1379
		Expected Count	300.0	308.0	91.0	154.0	92.0	64.0	212.0	158.0	1379.0
		% within Q. 46 Expected by employer	21.8%	22.3%	6.6%	11.2%	6.7%	4.6%	15.4%	11.5%	100.0%
		% within Q14. Discipline coded for > 50 people	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	21.8%	22.3%	6.6%	11.2%	6.7%	4.6%	15.4%	11.5%	100.0%

Appendix 24. Communication expected by employer x Employer (≥ 50 people) – cross-tabulation

Crosstab

			Q18.Type of employer institution/organisation with more than 50 scientists							
			1 University	2 Commonwealth government agency/department	3 State/ Territory/local government department or agency	4 Industry	5 Hospital	6 Medical research institute	7 Private consultancy business	Total
Q. 46 Expected by employer	1 No	Count	160	150	51	47	28	18	15	469
		Expected Count	152.3	152.7	81.7	26.6	23.0	17.8	14.9	469.0
		% within Q. 46 Expected by employer	34.1%	32.0%	10.9%	10.0%	6.0%	3.8%	3.2%	100.0%
		% within Q18.Type of employer institution/organisation with more than 50 scientists	34.0%	31.8%	20.2%	57.3%	39.4%	32.7%	32.6%	32.4%
		% of Total	11.1%	10.4%	3.5%	3.2%	1.9%	1.2%	1.0%	32.4%
	2 Yes	Count	106	108	86	17	18	11	16	362
		Expected Count	117.6	117.8	63.0	20.5	17.8	13.8	11.5	362.0
		% within Q. 46 Expected by employer	29.3%	29.8%	23.8%	4.7%	5.0%	3.0%	4.4%	100.0%
		% within Q18.Type of employer institution/organisation with more than 50 scientists	22.6%	22.9%	34.1%	20.7%	25.4%	20.0%	34.8%	25.0%
		% of Total	7.3%	7.5%	5.9%	1.2%	1.2%	.8%	1.1%	25.0%
	3 Don't know	Count	29	13	3	0	2	2	0	49
		Expected Count	15.9	15.9	8.5	2.8	2.4	1.9	1.6	49.0
		% within Q. 46 Expected by employer	59.2%	26.5%	6.1%	.0%	4.1%	4.1%	.0%	100.0%
		% within Q18.Type of employer institution/organisation with more than 50 scientists	6.2%	2.8%	1.2%	.0%	2.8%	3.6%	.0%	3.4%
		% of Total	2.0%	.9%	.2%	.0%	.1%	.1%	.0%	3.4%
	4 Sometimes - depends on issue/project	Count	175	200	112	18	23	24	15	567
		Expected Count	184.2	184.6	98.7	32.1	27.8	21.6	18.0	567.0
		% within Q. 46 Expected by employer	30.9%	35.3%	19.8%	3.2%	4.1%	4.2%	2.6%	100.0%
		% within Q18.Type of employer institution/organisation with more than 50 scientists	37.2%	42.5%	44.4%	22.0%	32.4%	43.6%	32.6%	39.2%
		% of Total	12.1%	13.8%	7.7%	1.2%	1.6%	1.7%	1.0%	39.2%
Total		Count	470	471	252	82	71	55	46	1447
		Expected Count	470.0	471.0	252.0	82.0	71.0	55.0	46.0	1447.0
		% within Q. 46 Expected by employer	32.5%	32.6%	17.4%	5.7%	4.9%	3.8%	3.2%	100.0%
		% within Q18.Type of employer institution/organisation with more than 50 scientists	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	32.5%	32.6%	17.4%	5.7%	4.9%	3.8%	3.2%	100.0%

Appendix 25. Financial reward for communication x Age (Generation) – cross-tabulation

Q. 47 Financially rewarded * Q8. Age (Generation) Crosstabulation

			Q8. Age (Generation)				Total
			1 Builders	2 Boomers (born 1946-64)	3 Gen. X	4 Gen. Y	
Q. 47 Financially rewarded	1 No	Count	117	546	523	120	1306
		Expected Count	112.1	526.9	526.9	140.1	1306.0
		% within Q. 47 Financially rewarded	9.0%	41.8%	40.0%	9.2%	100.0%
		% within Q8. Age (Generation)	94.4%	93.7%	89.7%	77.4%	90.4%
		% of Total	8.1%	37.8%	36.2%	8.3%	90.4%
	2 Yes	Count	4	15	17	6	42
		Expected Count	3.6	16.9	16.9	4.5	42.0
		% within Q. 47 Financially rewarded	9.5%	35.7%	40.5%	14.3%	100.0%
		% within Q8. Age (Generation)	3.2%	2.6%	2.9%	3.9%	2.9%
		% of Total	.3%	1.0%	1.2%	.4%	2.9%
	3 Don't know	Count	3	22	43	29	97
		Expected Count	8.3	39.1	39.1	10.4	97.0
		% within Q. 47 Financially rewarded	3.1%	22.7%	44.3%	29.9%	100.0%
		% within Q8. Age (Generation)	2.4%	3.8%	7.4%	18.7%	6.7%
		% of Total	.2%	1.5%	3.0%	2.0%	6.7%
Total		Count	124	583	583	155	1445
		Expected Count	124.0	583.0	583.0	155.0	1445.0
		% within Q. 47 Financially rewarded	8.6%	40.3%	40.3%	10.7%	100.0%
		% within Q8. Age (Generation)	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	8.6%	40.3%	40.3%	10.7%	100.0%

Appendix 26. Reward/recognition/acknowledgement analysed as a multiple response for Sex, Age, Discipline & Employer

Independent variable	df	N (Responses)	χ2	p	Chi-square statistic significant at the 0.05 level
Sex	6	905	11.277	0.08	No
Age (Generation)	18	905	59.385	0	Yes
Discipline (≥ 50 scientists)	Assumptions of test not met. More than 20% of cells in table have expected cell counts less than 5				
Employer (≥ 50 scientists)	Assumptions of test not met. More than 20% of cells in table have expected cell counts less than 5				

Appendix 27. Communication taken into account for career advancement x Age (Generation) – frequency

Crosstab

			Q49CB2. Taken into account for career advancement		
			0 No	1 Yes	Total
Q8. Age (Generation)	1 Builders	Count	131	15	146
		Expected Count	119.5	26.5	146.0
		% within Q8. Age (Generation)	89.7%	10.3%	100.0%
		% within Q49CB2. Taken into account for career advancement	10.5%	5.4%	9.6%
		% of Total	8.6%	1.0%	9.6%
	2 Boomers (born 1946-64)	Count	479	123	602
		Expected Count	492.8	109.2	602.0
		% within Q8. Age (Generation)	79.6%	20.4%	100.0%
		% within Q49CB2. Taken into account for career advancement	38.5%	44.6%	39.6%
		% of Total	31.5%	8.1%	39.6%
	3 Gen. X	Count	488	118	606
		Expected Count	496.0	110.0	606.0
		% within Q8. Age (Generation)	80.5%	19.5%	100.0%
		% within Q49CB2. Taken into account for career advancement	39.2%	42.8%	39.8%
		% of Total	32.1%	7.8%	39.8%
	4 Gen. Y	Count	147	20	167
		Expected Count	136.7	30.3	167.0
		% within Q8. Age (Generation)	88.0%	12.0%	100.0%
		% within Q49CB2. Taken into account for career advancement	11.8%	7.2%	11.0%
		% of Total	9.7%	1.3%	11.0%
Total		Count	1245	276	1521
		Expected Count	1245.0	276.0	1521.0
		% within Q8. Age (Generation)	81.9%	18.1%	100.0%
		% within Q49CB2. Taken into account for career advancement	100.0%	100.0%	100.0%
		% of Total	81.9%	18.1%	100.0%

Appendix 28. Verbal recognition/praise/gratitude x Age (Generation) – frequency

Crosstab

			Q49CB5. Verbal recognition/praise/gratitude		
			0 No	1 Yes	Total
Q8. Age (Generation)	1 Builders	Count	105	41	146
		Expected Count	113.8	32.2	146.0
		% within Q8. Age (Generation)	71.9%	28.1%	100.0%
		% within Q49CB5. Verbal recognition/praise/gratitude	8.9%	12.2%	9.6%
		% of Total	6.9%	2.7%	9.6%
	2 Boomers (born 1946-64)	Count	471	131	602
		Expected Count	469.4	132.6	602.0
		% within Q8. Age (Generation)	78.2%	21.8%	100.0%
		% within Q49CB5. Verbal recognition/praise/gratitude	39.7%	39.1%	39.6%
		% of Total	31.0%	8.6%	39.6%
	3 Gen. X	Count	481	125	606
		Expected Count	472.5	133.5	606.0
		% within Q8. Age (Generation)	79.4%	20.6%	100.0%
		% within Q49CB5. Verbal recognition/praise/gratitude	40.6%	37.3%	39.8%
		% of Total	31.6%	8.2%	39.8%
	4 Gen. Y	Count	129	38	167
		Expected Count	130.2	36.8	167.0
		% within Q8. Age (Generation)	77.2%	22.8%	100.0%
		% within Q49CB5. Verbal recognition/praise/gratitude	10.9%	11.3%	11.0%
		% of Total	8.5%	2.5%	11.0%
Total		Count	1186	335	1521
		Expected Count	1186.0	335.0	1521.0
		% within Q8. Age (Generation)	78.0%	22.0%	100.0%
		% within Q49CB5. Verbal recognition/praise/gratitude	100.0%	100.0%	100.0%
		% of Total	78.0%	22.0%	100.0%

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Appendix 29. Scientists have a greater responsibility to research and publish

There needs to be a clear distinction between the roles of scientists (who discover, gather and evaluate data and conduct experiments) and the decision makers who examine these findings in order to develop policy. (Strongly agree)

Unpublished research only informs the researcher. The body of knowledge available to all must continually grow if we are to solve the issues that are facing us as a planet. Science builds on itself but this cannot happen when results are sequestered away. (Strongly agree).

They have responsibility but only after meeting more important ones including publishing their research in scientific journals, getting industry funds and reporting to funding bodies. (Neutral)

Scientists have to do their jobs, which is to research. Yes, the public needs to be informed of research results, but I am not certain it is up to scientists to spend their time doing this. It is a different skill and its extremely time consuming if done well, as it needs to be. (Neutral)

I don't believe we have a direct responsibility to communicate our results. It is our responsibility to produce the results and the responsibility of others who wish to benefit from the findings (either financially or politically) to do the communicating. (Neutral)

I do not think it is a 'responsibility' to communicate, but I do think when the public requests communication it should be forthcoming. (Neutral)

There is a responsibility to communicate important results.... Not sure whether the responsibility to communicate it to the public lies with the scientists themselves. (Neutral)

Not sure that is the scientist’s job per se. The institution should have media personnel who talk the talk and walk the walk to translate the science into general interest language. (Neutral)

It is up to the scientist if they want to contribute to the public interest or not and it may be a matter of opinion as to what will benefit the public interest. (Disagree)

… scientists THEMSELVES may not necessarily have the responsibility to communicate with the public - in fact this may not be the best communication model! - I do think that scientists have a responsibility to publish (Disagree)

Appendix 30. Not all scientists are good communicators

I agree, provided that 'scientists' is deemed to be a generic term. Not all scientists are skilled or motivated to become engaged in communication with the public… (Agree)

While I think scientists should communicate with the public, I also see that scientists are good at doing science and not all are effective communicators… (Agree)

The theme that I have developed is that we train and use people in different areas of science, one being science communication. Scientists in research, that is the people generating new knowledge have a quite specific set of expertise….(Neutral)

Good communicators should communicate. Bad communicators (like most of us) make matters worse. (Disagree)

Not all scientists are good communicators…. (Strongly disagree)

…Not all scientists (perhaps few scientists) have the personal capacity to be effective communicators. Better to have good communication departments that a well supported by the scientist. (Strongly disagree).

Appendix 31. The need for professional science communicators

Scientists doing the research don't necessarily have the time to communicate their findings to the lay person; scientific teams need to be integrated with effective communicators that can act as the nexus between the researcher and the public…(Agree)

There is a problem here. Scientists should be willing to communicate but it should not be a 'responsibility'. I find it much more effective if I can work with a science communicator. .. (Agree)

Not sure that is the scientist's job per se. The institution should have media personnel who talk the talk and walk the walk to translate the science into general interest language. (Neutral)

It is great for some scientists to communicate with the public, however, it is a time-consuming task, and sometimes scientists are not the best communicators. I believe that some should be given the freedom to simply do science. But I do believe that it is important to get the messages out there - perhaps via science communicators associated with the institution/scientist group. (Neutral)

The theme that I have developed is that we train and use people in different areas of science, one being science communication. Scientists in research, that is the people generating new knowledge, have a quite specific set of expertise. They MUST remain on top of new knowledge in the science arena, and new knowledge is increasing at an explosive rate. To maintain managerial and communication expertise is asking quite a lot of all of them. A more logical approach is to develop communication experts who cover science (much like we have science journalists ranging from those in specialist magazines like New Scientist, through to the journalists in daily newspapers. The links between scientists and communicators, then, become critically important. (Neutral)

Science communication is the responsibility of science communicators. In the absence of science communicators, it is the scientist's responsibility. (Disagree)

The organisations that scientists work for have that responsibility. Not all scientists (perhaps few scientists) have the personal capacity to be effective communicators. Better to have good communication departments that are well supported by the scientist (Strongly disagree)

Dissemination of research to the public needs to be handled by communication professionals. Getting scientists to do this is not good use of their time. (Strongly disagree)

Dissemination of research to the public needs to be handled by communication professionals. Getting scientists to do this is not good use of their time. (Strongly disagree)

It is not the scientists' responsibility. It is the agencies, their management and governments of all levels to communicate the scientists findings effectively. I am very, very certain that the role of science communicators is one which is increasingly being valued and in dire need of promotion as a new and lucrative career in tertiary institutions. The scientists in this country do not get paid enough to do ground breaking research whilst also being experts in public image, media liaison and public communication for their agencies. There is a need for specialist communicators in all science agencies around Australia. Great scientists and excellent communicators are sometimes two very different personalities. I don't think they should be expected to go hand in hand. (Very strongly disagree)

Appendix 32. Responsibility rests with employers and funders

Scientists' may have a responsibility but it is their managers need to make it feasible. (Strongly agree)

Scientists within the public sector are constrained to voice those opinions that are sanctioned by management, unless it involves their own private research. (Strongly agree)

There may be exceptions (e.g. national security) but there is an obligation on the organisation to communicate its outcomes. Probably the most appropriate form of media is the web. (Strongly agree)

But need employers support/encouragement to so, and appropriate avenues. (Agree)

Motivation disposition is irrelevant - the issue is how our employers encourage and reward us for such communication (Agree)

This should be done on an agency basis so that it is well coordinated, timely and we don't desensitise the public with excessive information. Our biggest obligation is to our clients who provide direct financial support… (Agree)

Yes, they have a responsibility. But their employer has the responsibility to make available the opportunities and support for this. So the onus is first on the employer (Agree)

They have a responsibility to a degree, but they require support if they're to communicate effectively, to the right people and in the right way, and be given the right opportunities' (Agree)

Scientists have a responsibility to ensure the timely communication of research results only to their funders. It is up to the funders of the research to decide whether communication of results to the general public is a priority. (Neutral)

It all depends on the project and the ramifications of the outcomes for the public. If it is part of the funding agreement for that project then yes, if not, then no it is not necessarily the responsibility of the scientists. In the public sector sense it is sometimes more the responsibility of the managers to ensure timely communication. (Neutral)

While I agree there is a need, to overcome general public scientific ignorance, I do not believe there is a responsibility. That lies with the agencies for which we work… (Disagree)

The organisations that scientists work for have that responsibility... (Strongly disagree)

Appendix 33. Responsibility rests with the scientific community, governments and the media

because they do . It's important. But they don't have sole responsibility. Scientists are already pretty poorly treated by government policy and recognition in this country, and often have all they can do and more to look after themselves. (Strongly agree)

Communicating research results is essential to improving public knowledge and understanding, but it's not the responsibility of scientists alone. There is also a lot of responsibility on Government and media outlets…(Agree)

It is not the prerogative of scientists to unilaterally decide what information to disseminate. Governments should decide what is in the public interest otherwise anarchy will reign. (Disagree)

It is not the scientists responsibility it is the agencies, their management and governments of all levels to communicate the scientists findings effectively… (Strongly disagree)

Appendix 34. Scientists' responsibility in the public versus the private sector

Government research organisations owe it to the public to communicate their findings. (Very strongly agree)

[The] public may contribute money to support science through their taxes; knowledge should be shared so that all can benefit from it if they choose to. (Very strongly agree)

Scientists in the public sector are publicly funded and thus have an obligation to disclose how the public money is spent. Scientists in the private sector probably have more of a moral rather than absolute obligation… (Strongly agree)

Scientists within the public sector are constrained to voice those opinions that are sanctioned by management, unless it involves their own private research. (Strongly agree)

What's the point of doing research if you then don't do anything with it? Not to mention the bit where the research was probably, directly or indirectly, funded by the public. (Strongly agree)

Publicly funded scientists should have a much greater responsibility for timely public communication than privately funded scientists. (Strongly agree)

The scientific community has a responsibility to the general public that largely supports it through payment of taxes, etc, though it is complicated when there are conflicts (e.g. security, political, unethical behaviour). (Strongly agree)

If taxpayers funded the research, then they deserve to know how their money was spent. Research funding can be direct (ARC, NHMRC, Austrade etc) or indirect in tax relief. (Strongly agree)

Agree, with considerable qualification in an era of growing emphasis of privately funded research. If the public hasn't paid for it, there is an argument (albeit debatable) that the public has no right to it. (Agree)

I do not think commercial organisations have a responsibility to report their results, even if it would benefit the public. The public do not pay for the research. Having said that, I think that an ethical commercial organisation would report such findings, unless there was a significant financial disincentive. (Agree)

Corporate scientists have a responsibility primarily to their corporation and its share holders. If there is a science issue where there is a moral responsibility to make it more widely known than it is, then I would agree more strongly. (Agree)

Because the public pays for most research, and in a democracy people need to be informed about factors that may affect their lives. (Agree)

…We have a moral responsibility to communicate in the public interest; taxpayer dollars fund research grants - more often than not. Communication should be part of a democratic system. (Agree)

For publicly funded research this is obvious; the community pays for the improved knowledge and understanding of the world. For private research this is murkier. (Agree)

This is not black and white, as some findings are more important than others in terms of public interest and need to know. In general scientists with public support need to communicate. (Agree)

'Will anyone be interested?' Not all scientific results are newsworthy to the general public and that is why only 'sexy' or 'common interest' results make the popular media. That being said, if the tax-payer is funding research at a Government or University lab they should be able find reports about this work easily. The Department of Energy (DOE) has just this system setup currently via the web. (Neutral)

If the research is Govt.-funded (CSIRO or ARC) then yes, otherwise, no. (Neutral)

For publicly funded science there is a responsibility, but not for privately funded. (Neutral)

If research is private, that information is owned by someone, it's not to be always made public. Public funded research should be made available. (Neutral)

I agree strongly with this for public sector scientists, but in industry there are a range of other considerations, competitive position, IP etc (Neutral)

Due to the impact of competitors research results from the private sector cannot always be shared. (Disagree)

Appendix 35. Scientists' views of communicating to a particular public

These comments concern scientists' views of a public that does not understand, does not care or is not interested

We have focussed communication toward our target audiences, not the general public. (Agree)

Yes but these things need to be communicated carefully, the public may not be able to interpret the results, parties with vested interests may wish to hide/skew/misrepresent results, may raise false hopes about 'cures' for things. (Agree)

We should report our research in a manner that the public can follow, but whether the public really cares is another story. (Agree)

'Will anyone be interested?' Not all scientific results are news worthy to the general public and that is why only 'sexy' or 'common interest' results make the popular media...(Neutral)

This is not the primary role of science and the public is not the primary audience for such material (Disagree)

Appendix 36. Criticisms of the question's statement

A number of scientists criticised the statement they were asked about on the basis of its intent or 'vagueness' and on this basis disagreed with or were neutral about the statement:

This question is biased by the vague term 'public interest'. I agree that there may be results which will be of interest to the public that it is appropriate (not a duty or responsibility) to communicate. (Disagree)

It seems a very mixed up question to me, written to elicit a positive response. For private sector scientists however, there may well be other issues at play. (Neutral)

The question is vague and ambiguous. What is in the 'public interest' depends very much on whose agenda is being followed. Similarly, there is very little straightforward reporting of research results - most of what is discussed is the implications of the research. (Neutral)

Some scientists commented that they agreed but had reservations and therefore qualified their agreement with phrases such as, 'I agree provided…'; 'I agree but reservedly'; 'I agree with this statement generally, although…; 'I agree up to a point' and 'I agree assuming that…'. Others thought this was a motherhood statement; or that such a statement i possibly ideal but not always possible:

Sounds obvious to me. Science outcomes are for the whole community (Very strongly agree)

Not always possible though (Agree)

There were those who agreed to some extent but also believed this was a motherhood statement:

Sounds obvious to me. Science outcomes are for the whole community. (Very strongly agree)

Of course I agree but it's a motherhood statement. The real question is 'who does the communicating?' It should NOT be left as the exclusive role of scientists to do the communicating - other disciplines also have a responsibility to communicate. (Strongly agree).

Have you stopped beating your wife. (Agree)

Results that in the 'public interest' Duh. (Agree)

Self evident, unless it clashes with concerns (security, financial etc). (Agree)

It's a bit of a motherhood statement isn't it? In an ideal world it would go without saying. But there may be other responsibilities, institutional codes, conflicts with colleagues' attitudes etc. that make such action less than straightforward. (Agree)

Appendix 37. What is 'timely'?

Scientists commented on particular aspects of the statement, such as the meaning of 'timely' in the following examples where respondents' agreement ranged from 'Very Strongly agree' to 'Very strongly disagree'. Scientists with very different levels of agreement with the statement, often made similar comments as can be seen from the following comments on the use of the word 'timely'.

With the important qualification that they should not pre-empt publication in peer-reviewed journals or regard media publication as its equivalent. We are getting too much hypothetical and conjectural media science in the media instead of honest reports… (Very strongly agree)

Unfortunately, I think that a lot of research findings are not quickly or effectively expressed to the Australian public because of the timelines associated with bringing a product to market or to change public health/environmental policy. (Strongly agree)

Yes - but via the usual processes of peer review and scrutiny - not via media releases. Where public health, safety etc might be compromised by any such process - eg emergence of a contagious disease, then public research results should be communicated.. . (Agree)

There is also the issue of waiting for a modicum of certainty - note the aluminium/deodorant/Alzheimer's scare. (Agree)

The communication must be after good quality peer review so that mistakes, such as cold fusion, do not occur. Press release scientific announcements is NOT the way to go. (Agree)

The statement is true, but things take a long time in research before they are well understood. I think the timing of public communication is very important. If it is done prematurely, it can do more damage than good i.e. GM crops. (Agree)

Depends what you mean by timely and the moral dimension of how important the research is. If the public understood the uncertainty inherent in science maybe it would be communicated sooner. There are also intellectual property issues. These could be weighed up against moral issues if we are talking about peoples lives being at risk. (Neutral)

Depends on the definition of 'timely'. I don't think researchers need to immediately present results, except perhaps if they relate to an issue of public safety. (Neutral)

If researchers and their sponsors want to release results to the public it should be done in a timely manner. If research is being paid for by the public then results should be released promptly. (Neutral)

Whether the timeliness of communication has a positive or negative effect on the general public depends upon the level of understanding had in regards to the subject. For researchers in the same field, timeliness is important. In regards to notification of the public of the first successful test of a desirable new drug on cell tissue in a petri dish, a limited understanding of the drug testing process and limitation of the results may lead to a negative perception of science if initial potential is not immediately realised. (Neutral)

In principle one can only agree but there are many issues that might cloud the situation, especially where protection of intellectual property is involved. (Neutral)

Some research should not be communicated to the public until it is independently confirmed (e.g. 'Vitamin K injections in newborns increased childhood cancer rates' reported to media and since confirmed to be untrue. Reports caused panic among parents and an increased incidence of vitamin K deficient bleeding in babies.) Other research should be RESPONSIBLY reported - i.e. should quote the scientist's conclusions and not some unsubstantiated hyped up lay person's version of the significance of the results. (How many times have we seen 'Cure for cancer/arthritis/(insert favourite disease here)' in the media?). (Very strongly disagree)

Comments about the meaning of 'timely' ranged across concerns about when it was appropriate during a R&D process, or scientific publication point of view; legal from an intellectual property or other commercial perspective; desirable from a institution or party political point of view or necessary from a public safety point of view. For some the word 'timely' meant after peer-review and for others it meant after a scientific application has have been proven:

The communication must be after good quality peer review so that mistakes, such as cold fusion, do not occur. Press release scientific announcements is NOT the way to go. (Agree)

The statement is true, but things take a long time in research before they are well understood. I think the timing of public communication is very important. If it is done prematurely, it can do more damage than good i.e. GM crops.(Agree)

It can be difficult to know when the science is mature enough that it can be presented to the public in a way that won't simply confuse the issue and make the public distrust science. (Agree)

Others commented that the timing of communication depended on who paid for the research or when scientists or their employers wanted to attract funding, or when scientists had time for this low priority activity:

It depends on what 'timely' means. Often 'breakthroughs' seem to be announced as a way of trying to improve generate public pressure to affect research funding applications rather than through a genuine desire to communicate well-established findings. (Agree)

Depends on the situation. 'Timely' has different meanings for different people. We are often asked to offer 'key messages' before the research project is complete. However, I do feel that key messages should be made available soon after completion. (Agree)

If researchers and their sponsors want to release results to the public it should be done in a timely manner. If research is being paid for by the public then results should be released promptly. (Neutral)

On occasions results are communicated too early thereby raising false hopes/ expectations - apparently to raise the profile of the research and/or secure more funding. (Agree)

Some commented on the need for more time to be 'timely':

Sure - given the time and support and public forum. (Strongly agree)

So long as we are given time for timely communication, results need to be out in the public influencing our lives. (Strongly agree)

…What is 'timely', as we have tight schedules and in my position this communication is a low priority, so timely may not be possible. (Agree)

On occasions results are communicated too early thereby raising false hopes/ expectations - apparently to raise the profile of the research and/or secure more funding. (Agree)

Sometimes it is hard judging public interest - some are interested, others are not interested in things that I believe may strongly affect them. I try to get information out, however sometimes time constraints affect how quickly & effectively ... (Agree)

One scientist described bureaucratic impediments to timely communication as formidable:

I agree, but mostly the systemic bureaucratic impediments to timely communication are formidable. (Agree)

Appendix 38. What is the 'public interest'

What I think is in the public interest may not be what you think is in the public interest and neither of us may be right anyway. (Strongly agree)

Sometimes it is hard judging public interest - some are interested, others are not interested in things that I believe may strongly affect them. I try to get information out, however sometimes time constraints affect how quickly & effectively ... (Agree)

In essence, I agree with the sentiment, however, it hinges on what is 'in the public interest'. This may be difficult to determine and so should be treated carefully. (Neutral)

While I don't disagree about the responsibility of scientist is to communicate to the public the results of research, I would not limit it to results that are labelled 'public interest'. Just what is 'the public's interest'? As a guide as to what should be communicated the public interest is often fickle and unreliable and is often does not always represent what actually is the best for the 'public'. Actually it can be quite unpalatable. Climate Change is a good and topical example. Scientists have been 'communicating' the concerns of global warning for now over a decade (maybe even 2), yet it is only now that the public (and their representatives) have decided that it is important enough to start acting on. If scientists had not voiced their data and its implications even when unpopular and unbelieved then global warming may have never reached the stage of 'public interest'. Actually the accurate communication of all scientific results should form part of what is used to decide what is in the public interest, not the other way around. (Neutral)

Others commented on politics and ‘public interest’:

If the subject is in the public interest then scientists, especially government scientists who are in part funded by the public, should communicate their findings unfettered by any political influence’ (Very strongly agree)

The critical phrase is 'in the public interest'. For instance climate change is an example where scientists tried for years to better inform the public, but where in many cases prevented due to government politics. (Strongly agree)

This is a very noble sentiment but who defines what is in the public's interest, hopefully not politicians or bureaucrats. Sometimes the public are unwilling or uneasy in dealing with controversial results. (Strongly agree)

The history of science is just too replete with examples of the ways by which neither scientists nor others can appreciate the 'public interest' of scientific work at the time it is conducted/concluded/reported. Public interest is a very political notion, one that, while displaying and depending upon a reasonable awareness of history, is also subject to whim and fashion. Ultimately, the importance of scientific findings can only be judged from an historical perspective (and even then, of course, it is subject to much change), and can almost never be judged at the time, therefore, such notions of responsibility are largely irrelevant and certainly naive. (Neutral)

Scientists in my area are not encouraged to communicate research results with the public for political reasons, and sometimes commercial confidentiality reasons, even though the results are in the public interest. (Disagree)

A few scientists pointed out that public interest ‘spin’ is used to attract funding:

Research results usually need to be published in the conventional, peer-reviewed journals FIRST .... and how does one define 'public interest'? Everyone can put a 'public interest' spin on their research when they apply for a grant. Also, the people who are MORE likely to be successful in obtaining communication to the public may NOT necessarily have the 'public interest' at heart. No, I don't think the responsibility lies entirely with the scientist - until AFTER conventional publication etc. (Neutral)

'Public interest' is a very loose term. There may be security implications or you may make the situation worse by releasing findings prematurely. In many cases, scientists release information 'in the public interest' with the sole aim of getting more funding. If you get a political lobby going behind you, you'll get more money. (Neutral)

'In the public interest' or in the scientist's interest? For instance a story linked to a grant renewal or giving puff to some published research that may bring benefits in 10-15 year's time. (Neutral)

Communication of research results with the public is usually best left to someone with less direct involvement than the original researchers. I don't think there are many situations in which the originators are the best communicators although it sometimes happens. Too often such communicators are seen by their peers as trumpeting their stuff to attract more funding. That is particularly true in certain areas like human nutrition. (Neutral)

Others commented on who does, or should, decide what is in the ‘public interest’:

Please define what you mean by 'results that are in the public interest.' Who decides what is in the public interest. Right now the organic food, environmental and anti-GM groups tell the public what is in their interest. NGO's tell the general public what is in their interest. However, there is no accountability of these groups for feeding misinformation about

science to the public. However, there may be huge consequences to the scientists for releasing confidential information that is 'in the public interest'. (Neutral)

Who decides what's in the public interest? The scientist is not necessarily responsible but their organisation is. (Neutral)

In most cases the decision will be made by the organizations involved rather than the scientist per se. (Neutral)

Surely all science is in 'the public interest', and thus all scientists have a duty to communicate their work? Or are you talking more about 'that the public may find interesting' - and then who makes that decision? (Neutral)

Appendix 39. Professional & personal benefits ─ broad descriptions

Examples of professional and personal benefits to scientists from communicating with the general public (Q42 & 44)

Work success

*Expected/recognised/rewarded by employer/funder/taken into account for promotion
*Improves grant-writing ability/success
*Increases public involvement in science (e.g. volunteers for clinical trials)
Improves impact/uptake of science by end-users
Improves scientists personal reputation with public, other scientists, funders & potential employers
Networking/raises awareness amongst potential business/research contacts/employers/looks good on CV
Building relationships on personal level/social interaction

Scientist's understanding of their own science/work

Improves/affirms/validates the relevance/importance/purpose and quality of their science
Improves scientists understanding of their own science/clarifies scientists own understanding
Receive useful information from two-way communication e.g. local knowledge
Broadens perspectives/brings relevance/reality check/puts work in context/makes you think about your work from a diff. perspective/new approach
Stimulating conversation

Scientist's understanding of the public

Improves scientists understanding of the public and their concerns/feelings/keeping in touch with the community/feedback on research/generates new ideas/directions

Skills/confidence (e.g. communication, grant-writing)

Improves scientists communication with the public (how and what) & other scientists
Improves my confidence in my field/helps me develop as a scientist/person

Public input into existing & future work or research

e.g. public feedback, two-way communication, new knowledge, new research questions, input or direction (excludes direct participation in research)

Good of the organisation/profession/science/society

Contributes to an informed/enlightened society
Maintains/increases the public & other funding for science/science organisations/recognition of the value of previous funding

Recruits new scientists

Public understanding/support
Improves public awareness/knowledge/understanding/recognition/acceptance of scientists/science organisations/science
Increases support (not explicitly financial) for scientists/scientific project or organisation

Positive feelings about themselves, their communication and their work
Keeps you motivated; reminds you why you are doing it
Feels good/warm fuzzy feeling/satisfaction/enjoy it/makes me feel useful/appreciated/improves self esteem/self worth/self/personal satisfaction/
Pride/ego boost/share my passion/enthusiasm

The following categories are self-explanatory
Positive feelings (with no further explanation of why)
Duty or responsibility or obligation (as scientist, public servant, employee or beneficiary of scientific research)
Recruitment of science students or scientists
Defence against hostile, critical, ignorant, irrational, obstructive, suspicious or distrustful public

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Appendix 40. Positive feelings ─ examples (23) of positive feelings[222]

Scientists' positive feelings about themselves, their communication and their work

A certain satisfaction. Additionally, it is gratifying to see the 'look of sudden understanding' on peoples faces when being told some of the fundamental principles underlying their everyday lives.[223]

Satisfaction gained through sharing knowledge that is valuable, countered slightly by frustration of meeting hard-cast opinions that are based on demonstrably false assumptions [224]

A feeling that the work is worth doing and appreciated[225]

A warm fuzzy glow develops. I also like the feeling that I may have been able to help someone personally (either by 'developing their mind' or by explaining a problem to them in a way that can be understood).[226]

And it's fun to pick up on some of the enthusiasm that may have been diluted along the way![227]

Because I enjoy showing the public what I do and how hopefully one day it'll be able to help their lives It also helps me see what I'm doing from their perspective and it motivates me.[228]

By giving the general public enjoyment and for them to find interest in my work is very satisfying and makes the challenges of research become more bearable[229]

Communicating work provides a 'reason to be' and assists with improving self-value.[230]

Educating and entertaining people is innately satisfying and encouraging[231]

Everyone is usually genuinely interested and makes me feel useful and interesting[232]

Explaining things is why I do science. I get considerable personal satisfaction from finding ways of explaining the science I do to the general public. I enjoy the challenge of deciding in what way to simplify complex concepts; choosing the information to retain, and the information to discard in a way that misleads only in particular (chosen) ways.[233]

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[222] Spelling/capitalisation errors in quotes have been edited. Unedited transcripts are available on request.

[223] Male, 35, Chemical sciences, Commonwealth Govt.

[224] Male, 44, Co Agricultural, veterinary & environmental sciences, Consultant

[225] Female, 39, Biological sciences, University

[226] Female, 46, Medical & health sciences, University

[227] Female, 29, Biological sciences, University

[228] Female, 28, Medical & health sciences, Medical research institute

[229] Female, 28, Mathematical sciences, University

[230] Female, 41, Agricultural, veterinary & environmental sciences, University

[231] Male, 43, Biological sciences, State/Territory/Local Govt

[232] Female, 36, Biological sciences, Commonwealth Govt.

[233] Male, 43, Earth sciences, State/Territory/Local Govt.

Feel that by communicating the outcomes of R&D and fielding questions from the general public makes me feel wanted and respected as a scientist and contributing member of society.[234]

Generally, it makes me realise that what I do is important and interesting to others and helps me not get lost in academic life[235]

Gives a sense of acceptance, a reason for striving to achieve breakthrough science for the community; Assists with self esteem issues Makes your job seem more worthwhile and less mundane.[236]

I work in an interesting and important area and it's nice to be appreciated - I enjoy the interaction as a contrast to my normal research work, which by definition is detailed and of interest to very few other specialists.[237]

It builds confidence and a self-assurance that I'm doing good in the world.[238]

It helps reinforce the value of what I do it reminds me that my work is funded by people with 'real jobs' and that it is a privilege to be in my position[239]

It's fun, and invariably I find the public is very appreciative of scientists who take the time to speak in public forums[240].

Job satisfaction the ability to share knowledge and ideas that can influence, in a positive way, the ways in which we interact with each other & the environment a society that has more information is better equipped to make more meaningful decisions that positively effect the way things run in the future[241]

Personal satisfaction (from helping to answer queries, correct misconceptions, promote my profession etc).[242]

Presenting to such groups, on the relatively rare occasions that I do, provides an affirming reminder that I have high level skills in a field, that have grown from the investment of an extraordinary level of effort to develop the required expertise and qualifications. It is also rewarding to see the interest of others when I endeavour to explain in non-technical terms issues of which they only get cursory, and often misleading, information from the ordinary press.[243]

The general public can give you the drive you need to keep going and to keep believing that it can be done. [Their] eagerness to help out in whatever way they can increases your self-esteem and helps you go on.[244]

There is the enjoyment of broadening people's knowledge but also one also can learn so much oneself through public contact.[245]

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234 Male, 49, Chemical sciences, Private consultancy business

235 Female, 27, Biological sciences, University

236 Male, 31, Chemical sciences Commonwealth Govt.

237 Male, 54, Engineering & technology, Commonwealth Govt.

238 Male, 30, Information, computing and communication sciences, Commonwealth Govt.

239 Female, 44, Physical sciences, Commonwealth Govt.

240 Male, 33, Earth sciences, Commonwealth Govt.

241 Female, 28, Biological sciences, State Govt.

242 Female, 53, Agricultural, veterinary & environmental sciences, Commonwealth Govt.

243 Male, 55, Agricultural, veterinary and environmental Sciences, University

244 Female, 27, Biological sciences, University

245 Male, 61, Agricultural, veterinary and environmental sciences, State Gov.

Appendix 41. Personal importance x Employment situation - cross-tabulation

Q 39. How personally important * Q9 Employment recoded Crosstabulation

			Q9 Employment recoded					
			1 Permanent/indefinite/tenured	2 Term contract	3 Student (postgraduate)	4 Self-employed	5 Retired	Total
Q 39. How personally important	1 Extremely unimportant	Count	14	0	1	0	0	15
		Expected Count	8.2	4.3	1.3	.4	.7	15.0
		% within Q 39. How personally important	93.3%	.0%	6.7%	.0%	.0%	100.0%
		% within Q9 Employment recoded	1.7%	.0%	.7%	.0%	.0%	1.0%
		% of Total	.9%	.0%	.1%	.0%	.0%	1.0%
	2 Very unimportant	Count	2	4	0	0	0	6
		Expected Count	3.3	1.7	.5	.2	.3	6.0
		% within Q 39. How personally important	33.3%	66.7%	.0%	.0%	.0%	100.0%
		% within Q9 Employment recoded	.2%	.9%	.0%	.0%	.0%	.4%
		% of Total	.1%	.3%	.0%	.0%	.0%	.4%
	3 Unimportant	Count	46	28	6	2	6	88
		Expected Count	48.1	25.4	7.9	2.6	3.9	88.0
		% within Q 39. How personally important	52.3%	31.8%	6.8%	2.3%	6.8%	100.0%
		% within Q9 Employment recoded	5.6%	6.5%	4.5%	4.5%	9.0%	5.9%
		% of Total	3.1%	1.9%	.4%	.1%	.4%	5.9%
	4 Neutral	Count	138	78	27	6	9	258
		Expected Count	141.1	74.6	23.1	7.6	11.6	258.0
		% within Q 39. How personally important	53.5%	30.2%	10.5%	2.3%	3.5%	100.0%
		% within Q9 Employment recoded	16.9%	18.1%	20.1%	13.6%	13.4%	17.3%
		% of Total	9.2%	5.2%	1.8%	.4%	.6%	17.3%
	5 Important	Count	266	138	46	6	21	477
		Expected Count	260.8	137.9	42.8	14.0	21.4	477.0
		% within Q 39. How personally important	55.8%	28.9%	9.6%	1.3%	4.4%	100.0%
		% within Q9 Employment recoded	32.6%	31.9%	34.3%	13.6%	31.3%	31.9%
		% of Total	17.8%	9.2%	3.1%	.4%	1.4%	31.9%
	6 Very important	Count	195	96	29	8	17	345
		Expected Count	188.7	99.8	30.9	10.2	15.5	345.0
		% within Q 39. How personally important	56.5%	27.8%	8.4%	2.3%	4.9%	100.0%
		% within Q9 Employment recoded	23.9%	22.2%	21.6%	18.2%	25.4%	23.1%
		% of Total	13.1%	6.4%	1.9%	.5%	1.1%	23.1%
	7 Extremely important	Count	156	88	25	22	14	305
		Expected Count	166.8	88.2	27.4	9.0	13.7	305.0
		% within Q 39. How personally important	51.1%	28.9%	8.2%	7.2%	4.6%	100.0%
		% within Q9 Employment recoded	19.1%	20.4%	18.7%	50.0%	20.9%	20.4%
		% of Total	10.4%	5.9%	1.7%	1.5%	.9%	20.4%
Total		Count	817	432	134	44	67	1494
		Expected Count	817.0	432.0	134.0	44.0	67.0	1494.0
		% within Q 39. How personally important	54.7%	28.9%	9.0%	2.9%	4.5%	100.0%
		% within Q9 Employment recoded	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	54.7%	28.9%	9.0%	2.9%	4.5%	100.0%

Appendix 42. Personal importance x Sex, Age, Discipline and Employer

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	187.629(a)	33	5.686	3.827	.000	.086
Intercept	7069.790	1	7069.790	4759.153	.000	.779
Q6SEXANALYSYS	.000	1	.000	.000	.993	.000
Q8GENERATIONANALYSIS	20.739	3	6.913	4.654	.003	.010
Q14DISCIPINESMORETHAN50	67.445	7	9.635	6.486	.000	.033
Q18EMPLOYERTYPEMORETHAN50	40.429	6	6.738	4.536	.000	.020
Q6SEXANALYSYS * Q8GENERATIONANALYSIS	13.230	3	4.410	2.969	.031	.007
Q6SEXANALYSYS * Q14DISCIPINESMORETHAN50	3.254	7	.465	.313	.948	.002
Q6SEXANALYSYS * Q18EMPLOYERTYPEMORETHAN50	3.578	6	.596	.401	.878	.002
Error	2002.473	1348	1.486			
Total	40803.000	1382				
Corrected Total	2190.102	1381				

R Squared = .086 (Adjusted R Squared = .063).This is a two-way between-groups analysis.

Appendix 43. Communication activity (total) score – frequency and per cent

Communication (total score)				
Score	Frequency	Percent	Valid Percent	Cumulative Percent
0	207	13.6	13.6	13.6
1	52	3.4	3.4	17.0
2	116	7.6	7.6	24.7
3	103	6.8	6.8	31.4
4	113	7.4	7.4	38.9
5	94	6.2	6.2	45.1
6	99	6.5	6.5	51.6
7	86	5.7	5.7	57.2
8	66	4.3	4.3	61.6
9	52	3.4	3.4	65.0
10	68	4.5	4.5	69.5
11	52	3.4	3.4	72.9
12	38	2.5	2.5	75.4
13	51	3.4	3.4	78.8
14	29	1.9	1.9	80.7
15	25	1.6	1.6	82.3
16	31	2.0	2.0	84.3
17	31	2.0	2.0	86.4
18	30	2.0	2.0	88.4
19	20	1.3	1.3	89.7
20	19	1.2	1.3	90.9
21	19	1.2	1.3	92.2
22	25	1.6	1.6	93.8
23	15	1.0	1.0	94.8
24	3	0.2	0.2	95.0
25	11	0.7	0.7	95.7
26	8	0.5	0.5	96.3
27	8	0.5	0.5	96.8
28	3	0.2	0.2	97.0
29	8	0.5	0.5	97.5
30	5	0.3	0.3	97.8
31	1	0.1	0.1	97.9
32	5	0.3	0.3	98.2
33	7	0.5	0.5	98.7
34	1	0.1	0.1	98.8
35	2	0.1	0.1	98.9
36	5	0.3	0.3	99.2
37	3	0.2	0.2	99.4
38	1	0.1	0.1	99.5
39	3	0.2	0.2	99.7
40	1	0.1	0.1	99.7
41	2	0.1	0.1	99.9
42	1	0.1	0.1	99.9
43	1	0.1	0.1	100.0
Total	1520	99.9	100.0	
Missing	1	0.1		
Total	1521	100.0		

Appendix 44. Communication activity and communication as part of job

Q. 45 part of job * Communication score (categories) Crosstabulation

			Communication score (categories)				
			0 None	1 Low	2 Medium	3 High	Total
Q. 45 part of job	1 No	Count	174	762	65	5	1006
		Expected Count	132.7	755.3	109.8	8.1	1006.0
		% within Q. 45 part of job	17.3%	75.7%	6.5%	.5%	100.0%
		% within Communication score (categories)	88.3%	68.0%	39.9%	41.7%	67.4%
		% of Total	11.7%	51.0%	4.4%	.3%	67.4%
	2 Yes	Count	13	296	89	6	404
		Expected Count	53.3	303.3	44.1	3.2	404.0
		% within Q. 45 part of job	3.2%	73.3%	22.0%	1.5%	100.0%
		% within Communication score (categories)	6.6%	26.4%	54.6%	50.0%	27.1%
		% of Total	.9%	19.8%	6.0%	.4%	27.1%
	3 Don't know	Count	10	63	9	1	83
		Expected Count	11.0	62.3	9.1	.7	83.0
		% within Q. 45 part of job	12.0%	75.9%	10.8%	1.2%	100.0%
		% within Communication score (categories)	5.1%	5.6%	5.5%	8.3%	5.6%
		% of Total	.7%	4.2%	.6%	.1%	5.6%
Total		Count	197	1121	163	12	1493
		Expected Count	197.0	1121.0	163.0	12.0	1493.0
		% within Q. 45 part of job	13.2%	75.1%	10.9%	.8%	100.0%
		% within Communication score (categories)	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	13.2%	75.1%	10.9%	.8%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	111.298[a]	6	.000
Likelihood Ratio	115.940	6	.000
Linear-by-Linear Association	62.101	1	.000
N of Valid Cases	1493		

a. 2 cells (16.7%) have expected count less than 5. The minimum expected count is .67.

Appendix 45. Relationships between recognition/acknowledgement and communication activity

Crosstab

			Communication score (categories)				Total
			0 None	1 Low	2 Medium	3 High	
Q. 48 Recognise/acknowledge	1 No	Count	91	580	46	4	721
		Expected Count	89.0	546.5	80.0	5.5	721.0
		% within Q. 48 Recognise/acknowledge	12.6%	80.4%	6.4%	.6%	100.0%
		% within Communication score (categories)	51.1%	53.1%	28.8%	36.4%	50.0%
		% of Total	6.3%	40.2%	3.2%	.3%	50.0%
	2 Yes	Count	38	391	107	7	543
		Expected Count	67.0	411.6	60.2	4.1	543.0
		% within Q. 48 Recognise/acknowledge	7.0%	72.0%	19.7%	1.3%	100.0%
		% within Communication score (categories)	21.3%	35.8%	66.9%	63.6%	37.7%
		% of Total	2.6%	27.1%	7.4%	.5%	37.7%
	3 Don't know	Count	49	122	7	0	178
		Expected Count	22.0	134.9	19.8	1.4	178.0
		% within Q. 48 Recognise/acknowledge	27.5%	68.5%	3.9%	.0%	100.0%
		% within Communication score (categories)	27.5%	11.2%	4.4%	.0%	12.3%
		% of Total	3.4%	8.5%	.5%	.0%	12.3%
Total		Count	178	1093	160	11	1442
		Expected Count	178.0	1093.0	160.0	11.0	1442.0
		% within Q. 48 Recognise/acknowledge	12.3%	75.8%	11.1%	.8%	100.0%
		% within Communication score (categories)	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	12.3%	75.8%	11.1%	.8%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	112.878[a]	6	.000
Likelihood Ratio	106.123	6	.000
Linear-by-Linear Association	.066	1	.797
N of Valid Cases	1442		

a. 2 cells (16.7%) have expected count less than 5. The minimum expected count is 1.36.

Appendix 46. Hindrances – emergent themes from scientists' examples by Sex – frequency

If anything hinders you from communicating in the way you would like with the general public, please describe	Male	Female
Commercial, legal & confidential considerations e.g. contracts, Codes of Conduct, industry regulations	20	20
Media - Perceptions & experience	25	8
Personal characteristics or circumstances (lack of confidence, lack of knowledge, motivation, fear)	36	57
Lack of communication skills & training (science, media, general)	16	14
Lack of experience or practice	9	9
Politics, political sensitivities, implications or impacts (employer, government, industry, funders, client & unstated) or policies	34	6
National security or highly classified	6	1
Public - Perceptions & experience of public(s) views, reactions & interests (e.g. lack of interest)	35	30
Science culture, language, practice, content (difficult to simplify or communicate)	18	10
Workplace culture, requirements, sensitivities, characteristics, approvals, policies, responsibilities (including projects)		
Culture and circumstances(Other) e.g. lack of direction or policies from management	10	6
Cost, limited benefit or negative aspects of communicating	8	2
Lack of funds or payment or resources for communication activities	17	10
Lack of help, encouragement, interest, reward, appreciation or recognition of effort involved	18	9
Lack of opportunity e.g. limited by employer, opportunities rare, not often asked, not my job to seek them or not often have something to communicate	25	20
Lack of opportunity - have to be sought and difficulties finding own opportunities or don't have access or contact or support to contact with media, specialised or general public or forum or not sure how to go about it	15	16
Not part of my job or someone else's responsibility in organisation	11	8
Policies, legislation, contracts or regulations, restrictions, sensitivities, positions or reluctance	50	26
Approval processes or protocols - need, time and effort and knowing when to do it and what to do	27	11
Issue - Sensitivities or lack of clarity related to particular subjects (not specifically security or politics)	14	5
Time or opportunity cost to organise it, prepare for it, and present it		
Time - (no further explanation)	54	27
Time - Heavy workload - other work commitments/demands on time	33	17
Time - Not a priority or competes with time after work time or does not contribute to advancement	17	8
Time - The process of communicating takes time (finding opportunities, work to do, opportunity cost or time to be trained and practice)	11	6
Other - not sure how to categorise including being hampered by science communicators	4	3
Descriptions - Total (842)	513	329

Appendix 47. Hindrances by Sex ─ significance of differences

Hindrances	Male Observed	Male Expected	Female Observed	Female Expected	Sub-total Observed	% Observed	Chi-square	P
Workplace or employer resources, culture, requirements, approvals, policies or practices	208	191	106	123	314	37.4	4	0.0455
Time - lack of time to organise it, prepare for it, and present it	125	115	65	75	190	22.6	2.1	0.1473
Personal characteristics or circumstances e.g lack of confidence	35	56	58	37	93	11.1	20.7	<.0001
Lack of opportunity or experience	41	49	39	31	80	9.5	3	0.0833
Public - Perceptionsand experience of the public's views or interests of science & scientists	33	36	26	23	59	7.1	0.6	0.4386
Communication - related to ability to communicate.e.g lack of skills & training	24	27	20	17	44	5.2	0.7	0.4028
Media - Scientists' perceptions of & experience with the media	24	19	8	13	32	3.8	2.7	0.1003
Science - training, culture, language, practice, content (difficult to simplify/communicate)	18	16	9	11	27	3.2	0.4	0.5271
Total	508		331		839	99.9		
% of males and females who selected Yes to Q52	60.70%		39.30%					
			331					
Categories in common with 'what would help you most'								
New categories from 'what hinders you?' e.g not given as options for question re. 'what would help you most?'								
Other - not sure how to categorise	4		3		7			

Appendix 48. Hindrances by Age (Generation)

									Sub-total		
What hinders?	Gen. Y	E(GenY)	Gen. X	E(GenX)	Boom.	E(Boom.)	Build.	E(Build.)	observed	Chi Square	P
2 : MEDIA - Perceptions and experience	0	3.1	12	12.4	16	14.3	4	2.1	32	4.9	0.179
3 : PERSONAL characteristics or circumstances	14	9.0	38	36.2	32	41.7	9	6.2	93	6.3	0.098
4 : PUBLIC - Perceptions and experience of the public'	13	5.7	26	23.0	19	26.4	1	4.0	59	14.0	0.003
5 : SCIENCE - Scientific training, culture, language, pr	6	2.6	12	10.5	9	12.1	0	1.8	27	7.2	0.066
6 : WORKPLACE or employer resources, culture, requ	23	30.5	126	122.1	149	140.7	16	21.0	314	3.6	0.308
7 : Lack of COMMUNICATION skills & training	8	4.3	16	17.1	18	19.7	2	2.9	44	3.8	0.284
8 : Lack of EXPERIENCE	3	1.7	11	7.0	4	8.1	0	1.2	18	6.4	0.090
9 : Lack of OPPORTUNITY	6	6.0	33	24.1	17	27.8	6	4.2	62	8.3	0.040
10 : Lack of TIME to organise it, prepare for it, and pres	8	18.4	62	73.9	106	85.1	14	12.7	190	13.1	0.004
	81	81.4	336	326.4	370	375.9	52	56.2	839	0.7	0.873
	82		336		375						
Generational ratio: those who they were hindered in an	9.7		38.9		44.8		6.7				

Appendix 49. Hindrances – scientists' examples

Personal Characteristics

Wanting to do a good job

My own anxiety. My desire to make the subject appealing and attractive. Lack of preparation time to produce high quality presentations. I note that presenting to the public takes even more thought and effort than an ordinary research presentation.

I'm a new comer to Aus (from RSA). A lack of understanding for the Aus culture (use of abbreviations, certain expressions) is sometimes problematic. Also, the cultural practices, methods of farming, grower attitudes, etc are quite different here & I'm sometimes uncertain that my approach is appropriate for the Aus situation. Thus, a lack of familiarity with the Aus way of doing things can erode my confidence when speaking to growers / the public (Female born 1963 Qld Agricultural veterinary and environmental sciences State/Territory government science or research agency)

Lack of self-confidence/skill

Self confidence, not in my area of expertise, but in the general communications with the public. Being an introverted personality, I lack the public confidence to be more 'extroverted' on this.

Sometimes unsure of what terminology to use, how to tie into the wider body of knowledge in lay language (Plus nervousness, occasionally!)

I know my subject material better than most - but my presentation skills will never get me a gig on TV

Personality, lack of confidence with public speaking/ self-promotion.

Lack of confidence in public speaking- no matter how often I do it

Lack of a certain outgoing personality

Lack of confidence in presenting to broad audience, generally introverted

Not knowing how to access the public, and how to generate public interest

Scientific Culture

Recognition of difficulty of communicating with non-scientists

The largest difficulty is the gap in knowledge between scientists and the general public. It is hard to remember that the general public is often poorly informed on many issues and so there is the danger of talking over their heads, but one does not want to over simplify things and risk talking down to them. (Male born 1977 NSW Biological sciences University)

With training and experience in a former career as a teacher, I feel my communication skills are well up to the task. However, in specialised and complex fields of science one has specific skills in certain areas and not in others. The public, on the other hand, often perceive that if one knows about science, one knows everything about science. This has the potential of putting one in a position of being expected to know about, talk about, and debate about, things in which one has little knowledge. To then be seen to fail is a daunting prospect. It seems to me that the skills to handle this circumstance is one of the valuable things that one can learn from specific training (such as the ABC's science communication program) (Male born 1952 NSW Agricultural veterinary and environmental science)

Struggle making topic matter relevant and available to all levels

Sometimes unsure of what terminology to use, how to tie into the wider body of knowledge in lay language (Plus nervousness, occasionally!)

Sometimes the research is too difficult to understand without a science degree or further education.

Science is dumbed down to pre-school levels before it is presented in a public forum (ie TV program Catalyst). Specific information is important in science and serves to provoke interest, generalised comments are of little utility. It is expected and even taught that science must be dumbed down before it is presented to the public, the expectation to do this undermines ambition to communicate to the public. Any technical presentation is seen as a failure on the presenters part because it does not cater for the morons of society.(Postgrad male student Vic born in 1982)

Sometimes I don't evaluate the public's background knowledge in the area appropriately, and therefore start explanations from the wrong depth.

Sometimes hard to simplify the topic enough to be understood

Often the client is nervous about public interactions due to the complexities of the science involved and will tend to avoid communication unless absolutely necessary. It does not help the situation when there are publically recognised academics who have a poor grasp of the science making alarmist comments. There is a shortfall of any meaningful training in toxicology in Australia and, therefore, few scientists with an in depth understanding. (Male born 1962 toxicologist WA)

There is a tradition in science for colleagues to very publicly undermine each other regarding their theories, views and research. This can be destructive for one's career. There can be professional envy and I have also encountered sexism. One can also be concerned regarding lawsuits as we become more and more litigious. (Qld Female Chemist self employed born 1966)

Go to conference - and listen to the shit that is talked about. Now how do we translate this into publicly digestible form. Where is the forum? Could say more, but must do some work. (Neutral)

Employer/Workplace

The very real constraint that I must be extremely careful not to upset my political masters, my professional clients (esp. fellow agencies who part fund my work) and the agency I work for. It is very difficult not to be able to directly comment on public policy when your research results clearly show that current policy is inadequate. (Male, Qld born in 1957, Biological sciences Commonwealth Govt.)

Employer does not allow communication with media unless topic and subject are cleared by management. Organisation communicators are hand picked by management and those do not necessarily understand the issues that they are commenting on. Not allowed to discuss opinion or on politically sensitive issues - as determined by management. (Male Qld born 1953 Agricultural, veterinary and environmental sciences Commonwealth govt)

My managers and I do not see it as high priority. My job is primarily to do research which benefits client groups (growers, farm advisers, research funding bodies), and to communicate the results to these clients. (Male NSW born in 1951 Agricultural, veterinary and environmental science State/Territory)

Government employee's represent the government of the day which means that anything that is perceived to have any political ramification cannot be commented on. (Male Qld born 1959 Agricultural, veterinary and environmental sciences State/Territory government science or research agency)

My organisation does not believe in free and open communication with the public any more. (It used to). Formal permissions must be obtained in many cases. (Male Born 1949 Earth Sciences ACT Commonwealth Govt.)

Time. My employer does not provide me with any time to speak to the general public. I am only encouraged to speak to clients. Also as a representative of my department I am not allowed to offer opinions to the general public, especially ones that would make my minister or department look bad. (Female born 1972 Qld, Agricultural Agricultural, veterinary and environmental science, State/Territory government science or research agency)

Occasional political interference by my Departmental executives and State politicians. I have in the past been threatened with dismissal if I spoke out on a particular sensitive subject, but I have so far ignored such threats by speaking out as a private citizen not affiliated with government. My Public Sector Union would have backed me were dismissal to have still occurred. (Male born 1952 SA Earth Sciences, State/Territory government department or agency (non-scientific or non-research) including regulatory bodies.

Agency censorship in broad sense of discouraging all but senior executive from speaking in major fora and allowing more junior staff only to speak informally and under guidance from senior management. (Female Born 1967 ACT Biological sciences Commonwealth government Department)

You get the impression that employees are encouraged to communicate as long as the employer is sure it is good for business. There are understandably perhaps, approvals to be gained. But surprisingly, unless you have worked at higher levels in organisations, more approvals need to be gained within publicly funded agencies and government departments and government ministers than private sector agencies

Organizational hierarchy prevents me from discussing some sensitive matters e.g. climate change.

Institutional culture/practice

Older, more experienced) scientists are approached preferentially (although they know little about the work taking place in the lab on a daily basis).[246]

Employer does not allow communication with media unless topic and subject are cleared by management. Organisation communicators are hand picked by management and those do not necessarily understand the issues that they are commenting on.

I am not authorised to make public comment. My employer discourages scientists from making public comment except through carefully controlled channels, especially in areas relevant to government policy. (Female, ACT born 1973 Commonwealth Govt)

Lack of opportunity

Lack of opportunity - despite working for the 'Public Service', the public seem to come last in any efforts made by our organisation to communicate the science it does…

Lack of opportunities / forums which require minimal effort on the part of a busy person to present at. Lack of official time available for science communication.

Politically sensitive issues

The very real constraint that I must be extremely careful not to upset my political masters, my professional clients (esp. fellow agencies who part fund my work) and the agency I work for. It is very difficult not to be able to directly comment on public policy when your research results clearly show that current policy is inadequate[247].

Working for public sector - you always do what you are told; management seemed to be more interested in show casing themselves that doing the right things. I work for an organisation that tends to police and regulate rather than finding practical solutions to engage people to work for sustainable solutions[248]

…Also as a representative of my department I am not allowed to offer opinions to the general public, especially ones that would make my minister or department look bad[249].

Not allowed to discuss opinion or on politically sensitive issues - as determined by management[250].

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[246] Male, 28, Biological sciences, University
[247] Male, 50, Biological sciences, Commonwealth Govt. on term contract
[248] Female, 49, Information, computing & communication Sciences State/Territory/Local Govt.
[249] Female, 35, Agricultural, veterinary & environmental science, State/Territory/Local Govt.

As a government employee, I have to obtain approval from my CEO and our Corporate Communications division. Usually they are too busy with 'political' issues to do with departmental administration to respond quickly to something that is only of scientific interest, so there is a sometimes a conflict between the deadlines of science journalists and our departmental media people in terms of priorities (the department is always happy about the positive publicity a good fossil story brings). Another problem is that the department media people have a high turn-over, so it takes a while to get them trained up again to the point where they recognise that I know what I am doing and that I only need formal approval from them. [251]

Working for the government seems to require at least the appearance of being focussed solely on the current mandate and I have been told it is considered 'poor judgment' (from a career perspective I imagine) to been seen to communicate knowledge or research on topics outside the current mandate (e.g. planetary science) as a government research scientist. Therefore my considerable research and publications (done in my own time) in fields outside by specific job description are not attributed in any way to the organisation I work for, and I do feel less inclined to accept speaking offers as I am concerned it will be disapproved of by management, despite some library and communications staff expressing frustration at this attitude, believing it to hinder the public appeal of government research scientists and their interest to the general public, particularly children.[252] *lack of opportunity - despite working for the 'Public Service', the public seem to come last in any efforts made by our organisation to communicate the science it does, the effort is focussed on: #peers in the Mining industry, and their bosses - to increase exploration, to keep the government of the day happy #Ministers - selling ourselves to keep the money coming to our organisation #peers in academia - the only ones interested in whatever science our staff manage to find time to do #school students - the workforce of the future (and they only get to hear from specialist Education Officers, mostly ex-teachers) the rest of the staff get no practice at dealing with students.[253](

Older (more experienced) scientists are approached preferentially (although they know little about the work taking place in the lab on a daily basis)

My State Government agency requires all communication with the public be screened through media officers. The hassle involved in getting permission to speak is often not worth the effort.

Medicines Australia code of conduct

Not applicable now that I have 'retired', but certainly when I was in full time (senior) employment the answer would have been 'yes'. My Board was always worried that the consequences of one error or controversial statement would outweigh hundreds of good experiences.[254]

My organisation does not believe in free and open communication with the public any more. (It used to). Formal permissions must be obtained in many cases[255].

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[250] Agricultural, veterinary & environmental sciences, Commonwealth Govt.

[251] Female, 61, Earth sciences, State/Territory/Local Govt.

[252] Female, 32, Earth sciences, Commonwealth Govt.

[253] Female, 50, Earth Sciences, Commonwealth Govt.

[254] Male, retired, Medical & health sciences, Medical research Institute

[255] Male, 58, Earth sciences, Commonwealth Govt.

working for public sector - you always do what you are told; management seemed to be more interested in show casing themselves that doing the right things. I work for an organisation that tends to police and regulate rather than finding practical solutions to engage people to work for sustainable solutions (Female WA born in 1958 Information, Computing and Communication Sciences State/Territory government department or agency (non-scientific or non-research) including regulatory bodies

Misinformation from the media and science management's use of inflationary spin to excite the general public leading eventually to disillusionment and distrust of scientists and their motives (over-promised & under-delivered). This makes being authentic and effective very difficult. (Female NSW born 1953 Life Scientist State Govt.

You get the impression that employees are encouraged to communicate as long as the employer is sure it is good for business. There are understandably perhaps, approvals to be gained. But surprisingly, unless you have worked at higher levels in organisations, more approvals need to be gained within publicly funded agencies and government departments and government ministers than private sector agencies

Organisational gagging or censorship

I work for government who have decided that only senior managers should talk to the press, also aware I can get into trouble if I say the wrong thing (this has happened, got ticked off...for saying something that was true in a newspaper article)[256]

The public not a priority

Lack of recognition of its impact and importance, which does not help us professionally.

My managers and I do not see it as high priority. My job is primarily to do research which benefits client groups (growers, farm advisers, research funding bodies), and to communicate the results to these clients.

Discouraged by employers

Mistrust by certain managers. Punishment. Career limiting

The moronic attitude to employment contracts and intellectual property that pretty much excludes anyone who knows anything about a topic from making public comment on it. We are really only permitted to communicate spin. We are not

[256] Female, 53, Agricultural, veterinary & environmental sciences, State/Territory/Local Govt.

permitted to discuss or debate or even present fact unless approved as politically or commercially beneficial. [257](Male Qld born 1966 Agricultural, veterinary and environmental sciences. State govt)

Comment on science communicators

Being the scientist communicating directly is hampered often by the drive from science communicators (who often know very little about science) to further their own careers. They would do better to act as connectors so that the scientist can speak.

Most scientists I think are just extremely busy with the pressures of research and obtaining funding to have time to organize communication with the general public, which is why PR people are needed.[258]

Specific Work or Project

Workload

There are only 24 hrs in each day, and my university (and the government) demands that I always strive to teach better, do more research and more admin work, in the face of the declining level of staff, declining quality of resources, increasing number of questionnaires to answer (out of which nothing ever improves) etc etc[259]

So busy doing our job (research) plus the increasing amount of admin work we are required to do (as our admin people are continually reduced) and communication with industry/funding people makes communication to the public a low priority.[260]

Too many other calls on my time. Modern academia is very unforgiving in its teaching and admin load, leaving research for 'spare time' and communication after that!

Too busy, public hospitals are notoriously short-staffed.

Not enough time to do as much as I would like in this area, due to a heavy workload in other areas.

Lack of time as admin tasks required by university and government seem to be ever increasing

Time - recognition communication takes time prepare for and do

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[257] Male, 41, Agricultural, veterinary &environmental sciences, State/Territory/Local Govt.

[258] Female, 30, Medical & health sciences, Business

[259] Male, 64, Mathematical sciences, University

[260] Female, 34, Agricultural veterinary & environmental sciences, State/Territory/Local Govt.

Time...It takes a lot of time... and that is what i am short of.

Sufficient time to prepare (no additional time allowed from work)

Time... and opportunity. If someone comes to me with a ready made request it will usually get done. If I have to make the opportunity its never going to happen.

Time, time, time. There have been several instances I would like to have responded to articles, or letters to the editor, in the local newspaper, but my work duties absorb too much time to be able to develop a careful, reasoned, response.

Time! But any time on public communication is less elsewhere so this more time in this area merely increases pressures elsewhere ...

Other work commitments limit the time that can be spent

Opportunity cost of communicating

Simply that we are not rewarded/acknowledged for doing so in any of the performance measures. Thus, while the university wants us to do it, we suffer an opportunity loss via not doing other things that are more directly measured. [261]
Requires time and resources spent away from gainful employment so not encouraged

Lack of time for this type of activity in a highly competitive research environment. This work is not rewarded and therefore it is seen as 'extra' and a community service to do this - but may interfere with my research productivity

There are only 24 hours in a day! Most of Australian science is not up to international standards, and it's probably more important for me to be helping raise the standard in my Institute, than to sell old mediocre stuff to the public. I do believe that communication with the public is important, but one must have a story to tell first![262]

Communication with the public is not a priority

Our job success is measured by research output. As communication with the public is a low priority, little time and effort is put into trying to improve this skill.

Time constraints. My work needs to get done. There is no time to 'waste' on these non-research things. For that matter, I probably shouldn't fill in this survey.

Time constraints. It's hard enough publishing in scientific journals and teaching.

[261] Male, 39, Biological sciences, University
[262] Male, 52, Physical sciences, Commonwealth Govt.

There is never enough time in the day to do a job that involves management, doing empirical science, and science communication

[Lack of] Time available given the priority of other duties and responsibilities[263]

Time - it is difficult to just publish work and complete research projects let alone make time to improve public communication or actually do some communication. If it is was part of my job I think I would improve and obviously do it more.[264]

Time - huge pressure to apply for funding and produce results and publications, public communication seems less essential than the research and scientific communication.[265]

Lack of interest by the general public in an area they commonly see as unimportant to them, as most are not consumers (or very low consumers) of pulse products. 2. Caution as to loss of IP (has happened to me before). Funding bodies and employer do not really value communication to the general public, more so to our industry people. 3. So busy doing our job (research) plus the increasing amount of admin work we are required to do (as our admin people are continually reduced) and communication with industry/funding people makes communication to the public a low priority.[266]

Sensitivity of research/issue

Poor or negative public perception of agriculture in use of water or pesticides

Occasionally as I my research is done on animals which can be seen negatively in some instances

Not necessarily a hindrance but at times you have to skirt around politically sensitive issues so that it more awkward to communicate what is actually going on

Sometimes feel that (as scientists) we need to be guarded about what we say given the possibility for liability or 'someone to take things the wrong way'. (Especially since my research field is health-related).

Employment agency does not promote active independent transfer of information to the general public. Forestry debate is so polarised that it is impossible to contribute without distortion of the information

Need to be sensitive to impact issues of fire weather research in relation to other government agencies

Limited time and unwillingness to be part of hostile arguments

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[263] Male, 57, Medical & health sciences, University

[264] Female, 25, postgraduate student, Biological sciences, University,

[265] Female, 29, term contract, Biological sciences, University

[266] Female, 34, Agricultural, veterinary & environmental sciences, State/Territory/Local Govt.

Lack of opportunity

Lack of opportunities / forums which require minimal effort on the part of a busy person to present at. Lack of official time available for science communication.

Time. My employer does not provide me with any time to speak to the general public. I am only encouraged to speak to clients[267]..

Our job success is measured by research output. As communication with the public is a low priority, little time and effort is put into trying to improve this skill.

Time - it is difficult to just publish work and complete research projects let alone make time to improve public communication or actual do some communication. If it is was part of my job I think I would improve and obviously do it more.

Time - huge pressure to apply for funding and produce results and publications, public communication seems less essential than the research and scientific communication.

Critical peers

Although most scientists commented more on hindrances linked with their managers and employers, a few commented on their peers. For example:

My view is that being seen as a communicator with the public is a positive disadvantage to people in their career. It is usually described (behind peoples' backs) as being a 'media tart', and delays promotion. This is particularly true for women scientists[268].

Yes? It depends on how and to whom, but in general communication can raise the profile of a scientist if it is 'good' for the individual and the organization. The public do seem to really enjoy the opportunity to hear about science. However I am cautious in this regard having heard a significant number of stories in recent years about scientists who have said unpopular or unwelcome truths in public spaces and been punished both professionally and personally for their candour - not by the public, but by their professional colleagues or employing organizations or by government.

There is a tradition in science for colleagues to very publicly undermine each other regarding their theories, views and research. This can be destructive for one's career. There can be professional envy and I have also encountered sexism. One can also be concerned regarding lawsuits as we become more and more litigious[269].

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[267] Female, 35, Agricultural, veterinary & environmental sciences, State/Territory Government science or research agency

[268] When asked to describe the benefits, this retired medical laboratory scientists, aged +67 years, commented on the disadvantage of being seen as a communicator with the public.

[269] Female, Chemist, self employed

…It does not help the situation when there are publicly recognised academics who have a poor grasp of the science making alarmist comments. There is a shortfall of any meaningful training in toxicology in Australia and, therefore, few scientists with an in depth understanding. (Toxicologist)

External to Workplace

Scientists' perception of the public

The general public seems to have little interest in pure science. I see no point in spending the time to explain technical concepts to people who simply don't care.

Technical terms People aren't familiar with science People aren't that smart (sort of) People who think they know better People don't care or see the significance People look down on life scientists because they don't see benefit in our work. General public only see value in applied science or science that earns the big bucks. (Male born 1983 Qld Postgraduate student Biological sciences University)

Lack of interest by the general public in an area they commonly see as unimportant to them, as most are not consumers (or very low consumers) of pulse products[270].

A common prejudice that science is boring, irrelevant or evil[271]

Public perception and media images of the sciences/academia tend to be very one-dimensional and stereotypical. The image of the scientist as confined to the ivory tower, having no knowledge, skill or interest in `the real world', typically bumbling and useless outside of their specialty, is something that has to be overcome every time we communicate with the public. It is a barrier to people listening or taking the subject seriously.[272]

The public's lack of knowledge

The low overall standard of background science knowledge.

Poor scientific education of the general public makes it extremely difficult to communicate complex issues in a short time frame, or any time frame!

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[270] Female, aged 34, Agricultural veterinary & environmental sciences, State Govt.

[271] Male, aged 52, Engineering &technology, Industry

[272] Male, aged 36, Mathematical sciences, University Gen.X

The general lack of understanding of the general public about many aspects of science that we, as scientists, often take for granted.

The fact that few people have the basics to understand. It's very difficult to explain things when the basis are not known...

the complexity of my research and the amount of special terms that need explaining and the fact a large number of people are mathephobic.

Some people have a fear of mathematics.

Public's lack of ability to understand logical or mathematics based argument

The appalling base of science education in Australia. Many very basic ideas are very difficult to get across accurately and are very time consuming but must be done for the transfer of information on any but the most basic of levels.

Sometimes feel reluctant to express an opinion because of general 'anti-science' feelings in some parts of the community.

lack of science literacy in the community

Scientists' disappointment in/distrust of the media

I have often been involved in controversial issues where there has been press interest. Frequently the agenda being run by the press is not a scientific one and in these circumstances experience has shown that it is impossible to get a scientific perspective out to the public. The press are more interested in sensational headlines and cherry pick what you have said to provoke an argument. [273]

Have had a bad experience with the gutter press from the TV tabloids. Will never speak with a journalist unless their credentials have been checked. If it is TV, would demand editorial control, so they don't edit an interview, and use your responses out of context, as answers to different questions. [274]

The assumption (promoted by advertisers) by the media that the public are more fascinated by celebrities than they are by science stories. Given a choice (e.g. online news sources), more people would read such stories, but instead newspapers and television are crammed with the finance and sport news which attracts advertisers, not public attention.[275]

Journalists fail to follow up press releases. Interest is demonstrated by reprinting of excerpts of the press release in some papers. Possibly there is a lack of resources/time for journalists

Don't trust the media not to get hold of something I say and misrepresent me

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[273] Male, 64, Earth sciences, Commonwealth Govt.
[274] Male, 43, Physical sciences, University
[275] Male, 41, Physical sciences, Commonwealth Govt.

Disinterest by the media

Lack of public/media interest in basic science research. Media is more interested in science with shock value or a cool tag

Well, I think there has to be some given and take -- by which I mean the media need to have more interest in getting comment from a wider range of sources than they do, or are interested in doing. In my own case I wrote a paper on how quadratic functions could be used to analyse whether the Government was optimizing taxpayer savings..... a very topical and controversial issue. The broader intention was to show how school level mathematics could be used to analyze policy issues, and influence the public perception of mathematics. I wrote a short article on this for the Sydney Morning Herald -- not published. I also brought it to the attention of national commentators -- no acknowledgment, let alone any actual interest. I really don't think there is that much wider interest or support for scientists and academics putting their ideas out in the media. This is not the first time I have had that feeling based on my own experience. The issue is also discussed in Shelley Gare's recent book 'The Triumph of the Airheads', pp.230-231.[276]

Also most journalists reporting on science do not have a science background and do not appreciate or understand what they could be reporting on. With the exception of Cosmos magazine the standard of reporting on science in Australia is dismal with an emphasis on 'breakthroughs' rather than informing the public of the long years of research it takes to achieve a so called 'breakthrough'. Most science reported is completely wrong due to the journalist not doing background research or understanding the topic or the important facts are cut out to reduce the story to the sensational 'breakthrough'. I have had the science reporter from the Courier Mail in Brisbane tell me he was only interested in doing stories about 'flashy' science as all the rest was terribly boring. A great attitude for the science reporter to have and demonstrating a complete mis-understanding of the nature of science research.

Public perceptions or expectations of scientists

Only in a fairly minor way - but I find that the public REALLY wants me to be motivated by emotional reasons (i.e. a higher calling to cure people with cancer) when in fact my chief motivation is absolute fascination with how things work. Sometimes I try and get this view point across, by suggesting that if we spent all our time worrying about the people who currently have cancer, we would never be able to focus on the discoveries that will generate the huge improvements and novel approaches, however generally people look a bit concerned with this and I find myself having to say - but of course the driving motivation is to help people with cancer TODAY (smiles all round once this statement is made!).[277]

[276] Male, 62, Mathematical sciences, University
[277] Female, 40, Medical & health sciences, Hospital

Public sensitivity of the research

A large proportion of my research required animal testing of antimalarial drugs. When presenting to the public I have to delete any reference to my use of animals as the public do not understand the importance of animal research or the stringent ethics that we must abide to. Their opinions are swayed by media attention and opinions to animal research. For open days in the university that I work, I have to take down any of my research posters that reference the use of animals so that I do not offend anyone from the public. It would be wonderful if animals did not have to be used for research, however what most of the public do not understand or think about is that if we didn't test on animals what other model would be use, humans? Thus I feel that public opinion of this model of testing prevents me from presenting the true nature of my research, which is often most disappointing as we are helping society as a whole. [278]

Occasionally as I my research is done on animals which can be seen negatively in some instances

Employment agency does not promote active independent transfer of information to the general public. Forestry debate is so polarised that it is impossible to contribute without distortion of the information.

Government politics and policies

I'm on a 1 year renewable appointment....which means that I am always cautious of speaking on topics which are related to my specialist area which might be seen by the powers that be as criticising government policies. My workload is also extremely heavy...just today I have been approached to go to a school, but may not be able to do it because I'm drowning.[279]

The general public appears to be indifferent to science and technology. …I also do not believe politicians have any appreciation either and I suspect this might be because too many of them come form a legal or non-industrial background…I feel very strongly about the very serious decline in the political attention [such attention as occasionally appears I feel is a sop to opinion] to Science and Technology as indicated by their unwillingness properly to provide adequate support. The general public fails to understand where matters are heading.[280]

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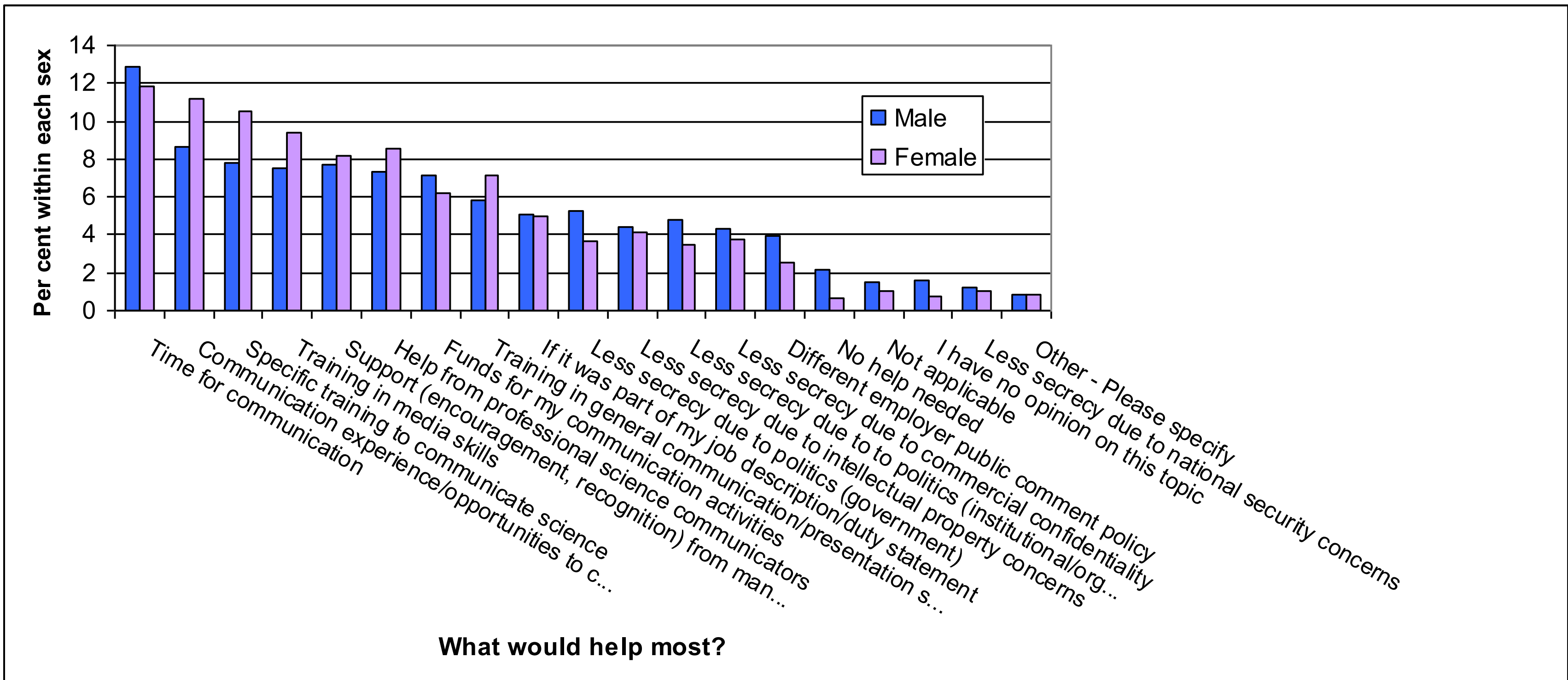
[278] Female, 25, Medical & health sciences, University
[279] Female, 33, Physical sciences, University
[280] Male, 67+

Appendix 50. What would help scientists most x Sex – frequency



Appendix 51. 'Help most' x Sex ─ Summary of Chi-square analyses

Based on respondents (or cases) - not responses						
	Chi-square			0.05 or		
	test for independence			smaller		
Help most' options	with Yates					
for which there were significant differences	Continuity Correction	df	n	p value	phi	Effect size
between Sexes	χ^2				coefficient value	
Specific training to communicate science	35.668	1	1,521	0	0.155	Small-medium
Communication experience/opportunities to communicate	33.404	1	1,521	0	0.15	Small-medium
Training in media skills	20.794	1	1,521	0	0.118	Small
Help from professional science communicators	13.433	1	1,521	0	0.095	Small
Training in general communication/presentation skills	13.368	1	1,521	0	0.095	Small
No help needed	9.921	1	1,521	0.002	-0.084	V. small
Support (encouragement, recognition) from management	5.989	1	1,521	0.014	0.064	V. small
Different employer public comment policy	3.802	1	1,521	0.051	-0.052	V. small

Appendix 52. 'Help most' x Age (Generation) – Summary of Chi-square analyses

Help most' options for which there were significant differences between Age (Generation)	Chi-square test for independence (Pearson Chi-Square) χ2	df	N	0.05 or smaller p value	Cramer's V coefficient value	Effect size
Specific training to communicate science	85.361	3	1,521	0.000	0.237	Small-medium
Communication experience/opportunities to communicate	84.801	3	1,521	0.000	0.236	Small-medium
No help needed	41.76	3	1,521	0.000	0.167	Small-medium
Time for communication	38.146	3	1,521	0.000	0.158	Small-medium
Training in media skills	36.313	3	1,521	0.000	0.155	Small-medium
Training in general communication/presentation skills	35.181	3	1,521	0.000	0.152	Small-medium
Less secrecy due to intellectual property concerns	22.529	3	1,521	0.000	0.122	Small
Help from professional science communicators	21.058	3	1,521	0.000	0.118	Small
If it was part of my job description/duty statement	20.504	3	1,521	0.000	0.116	Small
Less secrecy due to politics (government)	17.692	3	1,521	0.001	0.108	Small
Support (encouragement, recognition) from management	16.923	3	1,521	0.001	0.105	Small
Different employer public comment policy	15.512	3	1,521	0.001	0.101	Small
Funds for my communication activities	10.226	3	1,521	0.017	0.082	V. small

Appendix 53. ‘Help most’ x Discipline with ≥ 50 scientists ─ Summary of Chi-square tests for independence (Pearson Chi-square) analyses

Help most' options	Chi-square test (Pearson)			0.05 or smaller	Cramer's V coefficient	Effect size
for which there were significant differences between disciplines	$\chi 2$	df	N	p value	value	Cohen (1988)
Less secrecy due to politics (government)	69.565	7	1426	0	0.221	Small-medium
Less secrecy due to commercial confidentiality	55.125	7	1426	0	0.197	Small-medium
Less secrecy due to intellectual property concerns	47.673	7	1426	0	0.183	Small-medium
Less secrecy due to politics (institutional/organisational)	44.893	7	1426	0	0.177	Small-medium
Less secrecy due to national security concerns	24.061	7	1426	0.001	0.13	Small
Funds for my communication activities	22.613	7	1426	0.002	0.126	Small
Different employer public comment policy	16.175	7	1426	0.024	0.107	Small
Support (encouragement, recognition) from management	15.078	7	1426	0.035	0.103	Small
Training in media skills	14.199	7	1426	0.048	0.1	Small

Appendix 54. 'Help most' x Employer type with ≥ 50 scientists ─ Summary of Chi-square analyses

Help most' options for which there were significant differences between types of employers	(Pearson Chi-Square) χ2	df	N	0.05 or Smaller p value	Cramer's V coefficient value	Effect size Cohen (1988)
Less secrecy due to politics (government)	135.525	6	1496	0.000	0.301	Small-medium
Different employer public comment policy	98.701	6	1496	0.000	0.257	Small-medium
Less secrecy due to national security concerns	62.016	6	1496	0.000	0.204	Small-medium
Less secrecy due to politics (institutional/organisational)	59.563	6	1496	0.000	0.20	Small-medium
Less secrecy due to commercial confidentiality	57.183	6	1496	0.000	0.196	Small-medium
Funds for my communication activities	39.725	6	1496	0.000	0.163	Small-medium
Support (encouragement, recognition) from management	31.243	6	1496	0.000	0.145	Small
Less secrecy due to intellectual property concerns	25.914	6	1496	0.000	0.132	Small
Time for communication	21.544	6	1496	0.001	0.120	Small
Communication experience/opportunities to communicate	18.372	6	1496	0.005	0.111	Small
If it was part of my job description/duty statement	15.268	6	1496	0.018	0.101	Small
Help from professional science communicators	12.705	6	1496	0.048	0.092	Small

Options for which there were significant differences with small to medium effect size are shaded yellow.

Appendix 55. Less secrecy due to national security x Employer – frequency

Q18.Type of employer institution/organisation with ≥ 50 scientists	Less secrecy due to national security concerns Frequency		
	No	Yes	Group Total
University	487	5	492
Commonwealth government agency/department	438	47	485
State/Territory/local government department or agency	250	4	254
Industry	83	2	85
Hospital	74	0	74
Medical research institute	55	0	55
Private consultancy business	49	2	51
Group Total	1,436	60	1,496