A Background in Science

What science means for Australian society

Kerri-Lee Harris
Centre for the Study of Higher Education
The University of Melbourne

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Acknowledgements

This project was an initiative of the Australian Council of Deans of Science (ACDS), the latest in a series of studies commissioned by the ACDS to investigate various aspects of science teaching and learning outcomes. The Council's continuing support for such work demonstrates their ongoing commitment to the development of science education in Australia.

The Centre for the Study of Higher Education (CSHE) at the University of Melbourne was commissioned to undertake the study as an independent research project.

I would like to acknowledge my CSHE colleagues for their support during the project. In particular, I thank Lucy Maxwell for her valuable assistance in getting the study underway, Michelle van Kampen for lending her creative design expertise to the promotion of the survey, and Chi Baik for her insightful and constructive feedback during the preparation of the report.

I am grateful to the ACDS Executive for their valuable suggestions during the design of the study, and to ACDS Executive Director John Rice for his enthusiastic support throughout the project.

Importantly, I would like to sincerely thank the hundreds of people who participated in the survey. In a way, the survey posed quite challenging questions. It asked people to think about and describe something that they may normally take for granted – the nature of their own 'disciplinarity'. Their willingness to do so is greatly appreciated. I hope that the findings will be of interest to them and that the report will provide practical insights into the science community of which they are part.

Kerri-Lee Harris

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Foreword

What is the point of studying science if you aren't going to be a scientist?

This study called on people to come forward and tell us what they got out of studying science. Over 800 people responded. While only two in five might be termed 'working scientists', the vast majority spoke of the essential contribution that their science background made to their work and to their lives. They saw themselves as scientific people whose scientific knowledge and scientific mind-set mattered; for how they do their job, for how they help their friends and family, and for the ability it gave them to understand and contribute to discussion on global issues.

This is a vexed question that has occupied the Australian Council of Deans of Science for some time. Their study *What did you do with your science degree?*, commissioned in 2002, focussed like many others around the world on science degrees; what people did with them, or what employers wanted out of them. This current study, by contrast, focusses on the people. These articulate, well-educated professionals have significant insights as to what a science education delivers - to them personally, to their employers, to their professions and to society in general. Hearing them sheds new light on what society and individuals gain by studying science.

What they say highlights the importance of critical thinking skills, the ability to analyse, and commitment to processes based on evidence. While these may appear, and indeed are, more in the nature of generic intellectual skills, the study participants themselves see them in a form embodying characteristics peculiar to science. In particular, they advocate strongly that a science education should include such basics as mathematics, physics and chemistry, seeing these subjects as essentially connected to the development of generic skills characteristic of a scientific mind-set. Elaborating this connection and its implications for university science education remains a key and compelling challenge for Science Faculties.

The study did not ask the participants to specify how science should be taught. For now we can but see their impressions distilled through the craft and insight of the author of the study, Kerri-Lee Harris. However, the study does empower university science to set a broader goal for science education, beyond discipline specialties and technicalities. For one of the most compelling things about this study is the strength and unanimity of its subjects on the view that there is such a thing as a scientific mind-set; and that its acquisition through learning science is one of the most valuable things, for them, for the economy and for their society.

John Rice

Executive Director
Australian Council of Deans of Science

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Executive summary

Science and science education make vital contributions to Australian society. There are the obvious national benefits that stem from scientific research and innovation, including economic benefits. Importantly, there are also widespread personal and social benefits that arise from ensuring the scientific literacy of the population. As the findings from this study demonstrate, having a background in science is highly valued by individuals and of benefit to their communities.

A Background in Science examined the reach of science in Australian society. The Australian Council of Deans of Science (ACDS) commissioned the Centre for the Study of Higher Education (CSHE) to conduct this independent study. The study's findings highlight the breadth of influence of science in society.

Prior to this research little was known about the ways in which people draw upon their science backgrounds. An earlier CSHE study for the ACDS – *What Did You Do With Your Science Degree?* – examined employment outcomes and confirmed that many science graduates pursue careers outside scientific research (McInnis *et al*., 2000). There was also widespread acceptance among science educators that the study of science developed transferable skills and attributes. There was little evidence, however, confirming the precise nature of such science attributes, and beyond individual examples and anecdotes, the range of situations in which people draw upon their science knowledge and skills was poorly understood.

A Background in Science looked beyond career pathways and sought to understand the influence of a science education and background on people's lives more broadly. What influence does science training have upon the ways in which people think and approach problems? What aspects of science education do graduates most value?

The study collected input from people who identified as having a background in science, irrespective of occupation or field of study. Study participants described the various ways in which their science backgrounds influenced their lives, and offered views on the priorities for university science education.

The study was based on a large scale, qualitative survey involving more than 800 university graduates. Most had graduated more than ten years ago, with one in five completing their Bachelor's degrees before 1982. They were living in Australian cities, in inner, outer and remote regions of the country, or overseas.

As a whole, the survey participants represent the diversity of people in Australian society who identify with their science background. Scientists work in many different roles, and in a wide variety of organisations. Whatever their occupation, respondents identified influences from their backgrounds in science upon the ways they lived and worked.

The respondents were diverse in many ways – in age, occupation, and fields of study, for example. Yet they were united in the ways that they described what it means to have a science background. As a result, this report includes a depiction of the characteristics of a scientist, from the perspective of those who should know – people with backgrounds in science.

Most respondents offered extensive and considered written comments, providing a unique insight into the lives and values of scientists. The following summary describes the most prominent themes to emerge from those comments.

The findings are of relevance to university staff involved in the design of curricula, and to employers looking to recruit people with particular ways of thinking, approaching problems, and making decisions. In addition, the results provide important contextual information for Australian governments when considering science education policies and priorities.

Scientists in Australian society

- People in a wide variety of workplaces identify as scientists. One in four respondents worked in science or medical research organisations, and 12 per cent in science and engineering industries. Yet people with science backgrounds also worked in business, government, law, health, education, food and agriculture, mining and construction, and education.
- Scientists have diverse roles in society. Some respondents had clearly science-related occupations: geologists; scientific researchers; engineers; statisticians, for example. Just as many responses, however, were received from people in other roles and professions, including lawyers, journalists, policy analysts, nurses, teachers, financial advisors, farmers, musicians, and ministers of religion.
- Management in business, government and the public service all involve people with backgrounds in science. Thirteen per cent of respondents described themselves as managers, including people with senior executive roles in government and chief executive roles in business.
- Respondents ranged widely in age and level of qualification. One in four were over fifty years of age, while 17 per cent were under thirty. All were university graduates, and one in three held a PhD. Men slightly outnumbered women (53% to 47%), and were on average older (45 years cf 38 years) – reflecting the changing pattern of university enrolments in Australia over time.
- Graduates with science PhDs work in a variety of roles. While half the respondents with PhDs worked as researchers or academics, other respondents with science PhDs included public servants, consultants, policy advisors and managers.
- A background in science is typically developed through more than university studies. Most respondents (75%) described other contributions, including work experiences, personal interests and learning, and the influences and experiences of their early lives.

Developing the scientific mindset

- A science background is strongly associated with a particular way of thinking. Based on respondents' descriptions of science in their lives, scientists tend to be:
    - Analytical – they think through issues in a systematic and critical way, looking for the underlying logic
    - Objective – they try to avoid emotive responses to issues, favouring instead an evidence-based approach
    - Evaluative – they assess information, examining the validity of the data and reliability of the source
    - Questioning – they take an investigative approach to issues and a questioning approach to assertions by others

  Seventy-three per cent of respondents highlighted at least one of these traits in their written comments describing the influence of science in their lives.

- Scientists also tend to be:
  - Lifelong learners – inherently curious, and equipped with the skills and knowledge to investigative and learn
  - Problem solvers – confident in facing new challenges, with the skills to identify problems and develop solutions
- Development of scientific ways of thinking should be given high priority in university education, according to many respondents (n=282, 38%). These were among the most personally valued outcomes from a background in science.
- Scientists also value their own knowledge base, and consider knowledge a fundamental component of a science education. Thirty per cent of respondents specified particular subject areas as fundamental to a university science, calling for various combinations of mathematics (16%), chemistry (10%) and/or physics (10%). One in six emphasised the importance of breadth of science knowledge, while the same number described understanding of the 'process of science' as fundamental knowledge.
- The skills respondents most strongly associated with their science background related to analysis of problems, evaluation of evidence, and the ability to research new information (97%, 97% and 96% agreement, respectively). There was much more disagreement or ambivalence concerning the development of collaboration or leadership skills through a background in science.
- Scientists tend to be lifelong learners. For half the respondents, work experience both drew upon and contributed to their backgrounds in science. Irrespective of occupation, however, one in three people described a continuing interest in science learning for its own sake.

The influence of a science background upon individuals

- Scientists' knowledge and skills influence many aspects of their lives. Almost all respondents (97%) recognised an influence from their science background at work. Most also described a connection with their personal lives, including their social interactions and the approaches they take to understanding contemporary issues in society.
- It was common for both science knowledge and science-associated skills to be utilised at work (91% respondents), covering all kinds of work environments. In written comments describing the work environment, researchers were more likely to specify the role of knowledge, while people outside research were the most likely to discuss the application of skills.
- For most respondents (88%), their science background influenced their approach to contemporary issues in society. The application of science in understanding environmental issues and critiquing media reporting was given particular emphasis.
- An individual's science background has a flow on effect to society more broadly through the advice and assistance they provide others. Most respondents (83%) drew upon their science background – knowledge or skills – in giving advice to family and friends, whether in discussion of issues such as health and the environment, or more generally.
- Nearly nine out of every ten respondents recognised a connection between their science background and their personal interests and pursuits.

The benefits that flow from science education

Science education plays an important role in Australia, for individuals, for their social networks and communities, and for the society as a whole.

People with backgrounds in science value the development of a scientific way of thinking and approaching problems. They also connect their science knowledge and skills with enhanced capacities to appreciate the natural and physical world, and to understand issues in their lives and in society. And they share their knowledge with family and friends, contributing a 'different way of thinking' to many situations and discussions.

For society, the education of future science researchers and professionals is essential. Just as important, however, is the level of scientific literacy in the broader population. A background in science helps to equip people with the knowledge and skills to engage confidently with contemporary issues in society.

Chapter 1: The study's purpose, methods, and dataset

The importance of science education is widely recognised. Whether considered in terms of economics or society generally, whether locally or globally, science and science education are considered fundamental contributors to human development and the 'public good'.

For large numbers of university graduates, the study of science constitutes a major component of their tertiary education. In 2009, for example, six per cent (n=16,167) of all new university graduates had primarily studied in the natural and physical sciences, and this figure does not account for the many graduates from science-related degrees such as agriculture and environmental studies (n=3,546), engineering (n=14,063), and health (n=35,344), most of whom would have also studied science subjects as part of their degrees (Dobson, 2012). And while a significant proportion of science graduates go on to careers in scientific research, many more pursue other endeavours, including work in organisations outside science (McInnis, Hartley, & Anderson, 2000).

And science learning need not be confined to academia. Whether through work, personal study or general interests, for many graduates science learning continues well beyond the completion of their university studies.

Yet while we recognise the importance of science in society, and many people are involved in science study at some time in their lives, the fundamental influences of a science background are not well understood.

What characterises a background in science, and who in society identifies with such a background? How does a science background influence individuals in their work, and in their lives more broadly?

It is these questions that the study set out to examine.

On science in society

The principal focus of the study is science in society. The research seeks to understand who in Australian communities identify as having a background in science and why. It asks how their backgrounds influence them, including in terms of their interactions with others and their approaches to societal issues. It identifies the aspects of a science background most valued, and seeks recommendations on the priorities for science education into the future.

On graduate attributes

While not specifically a study *of* university graduate attributes, the findings will contribute to understanding in this area. The study provides insight into 'science attributes' more broadly, and from the perspective of people who identify as having developed them. There are many ways in which people learn and gain experience in science, and this study adopts a broad definition of 'science background'.

The focus on individuals, rather than programs of study, and encompassing people in all walks of life, make this study quite unique. The approach contrasts with recent studies in the UK, for example, that examined skills associated with particular degree programs in science, and evaluated the relevance of these skills to the workplace (Hanson & Overton, 2010a, 2010b, 2010c).

On career pathways

Similarly, while not a study *of* careers pathways, the findings do provide insights into the diversity of careers followed by people with backgrounds in science. A previous study undertaken for the Australian Council of Deans of Science (ACDS) (McInnis, Hartley, & Anderson, 2000) *What did you do with your science degree?,* had career outcomes as its principal focus. The present study took quite a different approach and provides data that is both distinct and complementary. *A Background in Science* actively sought input from people working in diverse occupations and roles, and asked them to describe the influence of their science background, rather than questions of income or satisfaction with employment outcomes. The study design avoided a course evaluation approach, and instead encouraged people to consider their science background holistically, incorporating contributions outside university study.

Study methods

The study design needed to meet two competing objectives. First, the study needed to encourage people to reflect upon the nature and effects of their own 'disciplinarity'. This kind of self-analysis is probably not something people do on a regular basis, at least not to the extent that they can then describe that thinking to someone else. Such research requires a qualitative approach, with people providing information in their own words. Second, the study needed to involve large numbers of people. Only a survey approach could uncover the breadth and diversity in science backgrounds and roles across the community.

The resulting study design was for a large scale, qualitative survey.

The questionnaire

The survey was by online questionnaire. It consisted of a combination of Likert-scale questions, check boxes, and open comments.

The overall design and logic for the questionnaire is explained in Appendix 1 and a copy of the questionnaire is included as Appendix 6.

Survey promotion

One of the practical challenges for this study was to find a way to reach people across Australian society, including people who had graduated from university some time ago.

It is common for surveys of university graduates to use the alumni records of universities. One limitation of this approach is the extent to which such records remain current. For this reason, a variety of strategies were used to promote the study to as wide an audience as possible. This included advertisement in a popular science magazine and on social and professional networking websites.

Details of the promotion methods are provided in Appendix 2.

In all cases participation was voluntary and anonymous, with no incentives or inducements offered.

The online survey was open from late November 2011 to the end of January 2012, and most promotion took place in December 2011.

Analysis

A grounded theory approach was used in the analysis of the written comments. That is, themes were first identified and then refined on the basis of the comments themselves, and then all comments were recoded against these themes.

A range of cross-tabulation testing was applied to the data. In particular, statistical tests were used to check for differences in the pattern of responses on the basis of age, gender, occupation, or highest level of qualification. Chi-squared testing was used, both goodness-of-fit tests and tests of independence. The probability results for these tests are indicated in the report as GF or TI, respectively.

The online survey data was downloaded as a spreadsheet, and then imported into a database application for viewing, coding and searching. All coding was performed manually, with the comments interpreted in context rather than as particular target words or phrases. Statistics and charts were prepared using spreadsheet software.

Case studies

Upon completion of the online questionnaire, respondents were asked to indicate their willingness to provide further input through a follow-up interview. Given the rich data provided through the questionnaire, however, it was decided that a better approach was to compile a set of case studies on the basis of individuals' written comments. Eleven cases were selected, on the basis that they illustrated one or more of the themes identified in the study, and that they represented a diversity of occupation, age, gender, and current residential location. Individuals were invited to edit and approve the text, which would then be included in the report *verbatim*. Individuals are not identified in the cases.

The dataset

A total of 805 completed responses formed the dataset for analysis. A further 99 incomplete responses (i.e. lacking any background information, Part D) were omitted. The universities' contact of alumni was responsible for more than half the responses (61%), and this group was significantly younger than the sample overall (GF $P<0.0001$ in comparison of <40yrs with 40+yrs). Other respondents learned of the study through professional or personal contacts (13%) or advertisement (26%).

As discussed earlier, the study needed people to be willing to consider and describe their own disciplinarity in ways they might not be practised in. The survey response is testament to the strength of feeling in the community on the influence of a science background. Of the 805 who completed the check-box sections of the survey, nearly all also provided written comments (n=780), and half (n=404) responded to all of the open questions.

Select features of the dataset

- Likely to be broadly representative of science graduates in society – profiles resemble the trends in university enrolments over time, including in terms of gender, and PhD completions
- Wide range of ages, including 26 per cent over 50 years of age
- People with years – in many cases, decades – of post-graduation experience
- All levels of science study background, from Bachelor degrees through to PhDs
- Predominantly natural and physical sciences, yet including representation from graduates in engineering, health, and education
- Large amount of data, including thousands of coded comments from hundreds of individual respondents

Occupation and background

The objective to reach people in a diverse array of occupations and with diverse histories was achieved. The occupations and backgrounds of people who identify with a science background are presented in Chapter 2.

It is not possible to be sure the sample mirrors the distribution of science in society. It may be that some occupations are over-represented while for others the converse may be true. For this reason, the relative numbers of people in different occupations or with particular science histories are not presented as representative of the Australian population. Rather, the data highlights the mosaic character of the population who identify with a background in science, and the many ways in which that background influences individuals' lives and the lives of those around them.

For various analyses, it was useful to identify people in scientific research roles. On the basis of their stated occupation and also comments relating to work history (in responses to Q5 & Q7), 221 respondents were recognised as having worked as researchers, at the time of the survey or previously.

Age and gender

The median age of respondents was 39 years (Fig. 1.1). Older age groups were also well represented, including 86 people 60 years of age or older. The age distributions by gender, however, were markedly different (Fig. 1.2). While overall males outnumbered females at 53 and 47 per cent respectively (n=422 males; n=372 females), females dominated the younger age groups, and the opposite was true above 40 years of age (Fig. 1.2). Due to this distribution pattern, all analyses were conducted using a combination of age plus gender, divided around the median age of 39 years.

In part, the age-gender profiles might reflect the changing gender mix in Australian universities over time. Prior to 1987, females were in the minority on campus (Booth & Kee, 2010) and this remained true in science, deemed a 'non-traditional' field of study for women, throughout the 1990s (Dobson & Calderon, 1999).

Enrolments pattern alone, however, do not explain the high proportion of female respondents (69%) in the 25-29 years of age group (Fig. 1.2). This over-representation is likely to be at least partly due to a stronger inclination to complete such surveys among women, a phenomenon recognised in other similar studies (e.g. McInnis *et al.*, 2000). A decision was taken not to apply any corrective weighting to the data. Any under-representation of the younger male 'voice' was arguably offset by the male dominance of the older age groups.

Residential location

Most respondents (88%) were living in Australia at the time of the survey (Appendix 3). While responses were received from all states and territories, the majority came from the eastern states, in particular Victoria (n=240) and New South Wales (n=172). Across Australia, respondents lived in cities (69%), regional (29%) and remote (2%) communities (Appendix 3).

Ninety-three respondents were resident in other countries at the time of the survey. Some may have been international students returned home. Others, however, were likely to be Australian citizens working overseas. For example, one in three (n=29) had completed both undergraduate and postgraduate university studies in Australian universities. Most of this group were living in Europe or North America (n=21), and more than half were working as researchers (n=17).

University qualifications

All respondents were university graduates, holding Bachelor's degrees or higher qualifications. One in three held a PhD (n=248), while a further 22 per cent (n=180) held Master's degree qualifications as their highest university degree.

The survey was targeted to university graduates of 2007 or earlier – that is, at least five years after completion of a Bachelor's degree. This was based on the assumption that post-graduation experiences provide both the context for the application of knowledge and skills, and likely opportunities for their further development.

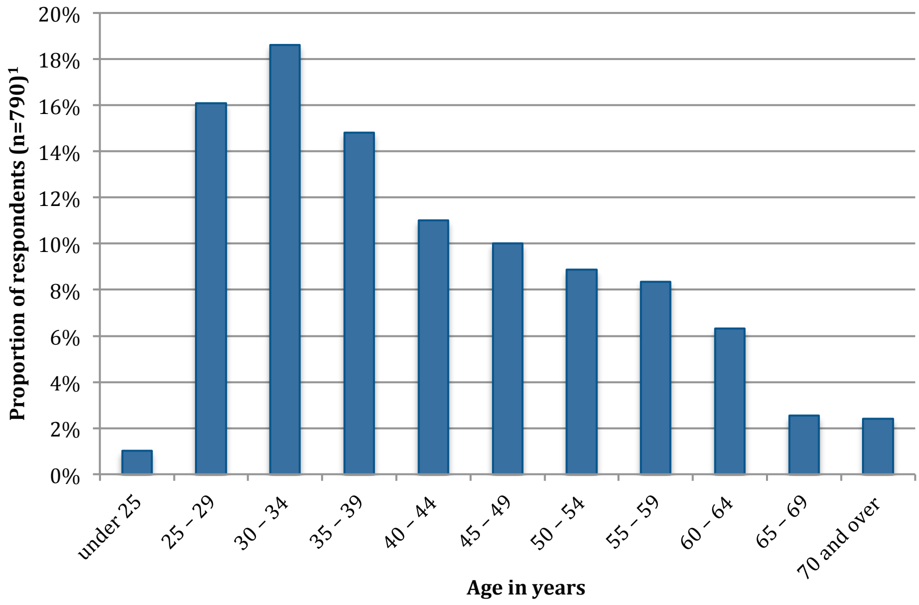

Figure 1.1 Age distribution of survey respondents
[1]15 respondents did not provide age details

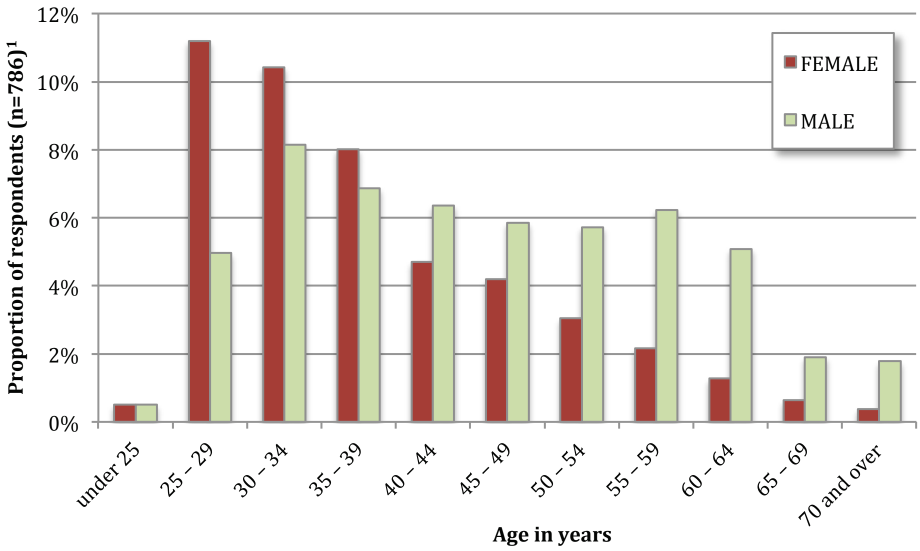

Figure 1.2 Age distributions of survey respondents, by gender
[1]19 respondents did not provide both age and gender details

With very few exceptions (n=19), respondents completed their undergraduate degrees prior to 2008 (Fig. 1.3). Fifty per cent graduated prior to 1997. The pattern of PhD completion dates is shown in Figure 1.4. The surge in numbers between 1991 and 2002 reflects the large increase in PhD completions in Australia during that period (Dobson & Calderon, 1999).

All respondents had studied in Australian universities, and 16 per cent had also studied in other countries.

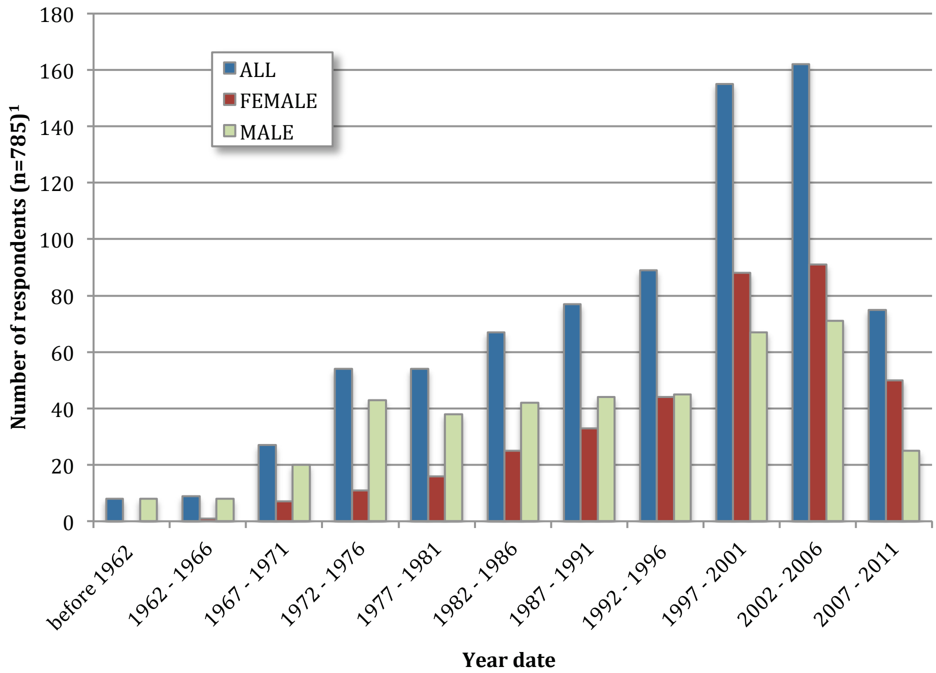

Figure 1.3 Respondents' date of completion of a Bachelor's degree

[1]20 respondents did not provide date of completion

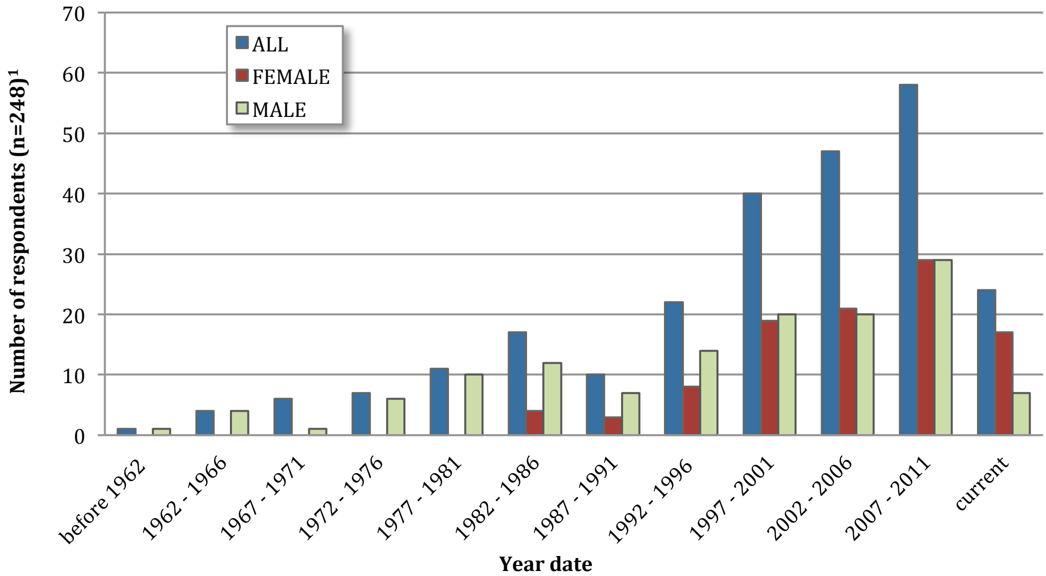

Figure 1.4 Respondents' date of completion of PhD

[1]16 respondents did not provide gender details

Fields of study

The study purposefully avoided a focus on science qualifications. There was no provision in the questionnaire to name the degree, nor to specify major areas of study. This was in keeping with the overall focus of the study upon people self-identifying as having a science background, irrespective of their particular degree. Indeed, one of the purposes for the study was to discover the profile of people identifying in this way.

The study background of respondents is, however, an important dimension of the overall demographic of the dataset.

Respondents were asked to indicate the highest year level they had studied in a range of subject areas, including the 'enabling sciences' (ACDS, 2003) of chemistry, physics and mathematics (Table 1.1). The following sections present a summary of respondents' study backgrounds in the natural and physical sciences, and in select areas of applied science.

The patterns of study described below, including the extent of study in the enabling sciences, may seem unusual to someone familiar with recent university enrolment statistics. In Australian universities in 2009:

> *"40.6 per cent of teaching in the 'science' disciplines was in the Biological Sciences, followed proportionately by the Mathematical Sciences (27.7 per cent), Other Natural and Physical Science (10.8 per cent), Chemical Sciences (9.9 per cent), with 5.0 per cent and 6.0 per cent respectively for Physical Sciences and Earth Sciences."*
> (p59, Dobson, 2012)

In large part, the study profile of the respondents reflects the patterns of study of their time. More than 60 per cent of the survey respondents completed their Bachelor's degrees prior to 2000, and one third prior to 1990 – when university populations were smaller overall, and female students more likely to be in the minority. The 1990s is recognised as a period of significant change in university science in Australia. Between 1989 and 1997, the growth in science enrolments (58%) outpaced the general booming university numbers (49%), with the greatest increases in the Life Sciences (80%) and Computing (101%) (ACDS, 1999; Dobson & Calderon, 1999).

Importantly, this data is based on subject learning rather than unit classifications. That is, a person may recall learning statistics at third year level, even if that learning took place as part of a unit formally classified in another subject area – a biology unit, for example, or even a unit outside science altogether. The data reported here reflects graduates' perspective on their learning, rather than university enrolment statistics.

Mathematics and/or statistics

Among the survey respondents, it was common to have studied mathematics or statistics as part of a Bachelor's degree, and for 60 per cent of respondents this included study beyond first year (Table 1.1). There was no significant difference by gender or age (Appendix 4)

It is likely that for some of this group the study was predominantly in statistics. The survey did not ask people to distinguish between mathematics and statistics in level of study. However, when asked about areas of specialised knowledge, ten per cent of the group who had studied mathematics or statistics beyond first year university also disagreed that they had specialist knowledge in mathematics. Chapter 3 provides further explanation of respondents' confidence in their knowledge by subject area.

Chemistry

While most survey respondents had studied university-level chemistry (78%), for many (n=261, 32%) this study did not continue beyond first year (Table 1.1). Among the under 40 years age group, females were more likely to have studied chemistry at university (TI males/females: under 40 yrs, P<0.01)(Appendix 4)

Table 1.1 Highest level of study for a range of broad science subject areas

Highest level of study	Biological sciences (inc biomedical)		Physics		Chemistry		Mathematics or Statistics		Environ'. science (inc Earth science)		Engineering or computing sciences		Health sciences		Veterinary Science		Behavioural science (inc Psychology)	
	Number of respondents, and proportion of total (n=805)[1]																	
Never	**48**	6%	**29**	4%	**6**	1%	**2**	<1%	**204**	25%	**206**	26%	**314**	39%	**626**	78%	**378**	47%
School Yrs 7-10 (any)	**115**	14%	**69**	9%	**30**	4%	**1**	<1%	**80**	10%	**67**	8%	**78**	10%	**17**	2%	**25**	3%
School Yrs 11-12 (any)	**97**	12%	**152**	19%	**98**	12%	**53**	7%	**54**	7%	**78**	10%	**84**	10%	**19**	2%	**38**	5%
SUBTOTAL (not studied at university)	**260**	**32%**	**250**	**31%**	**134**	**17%**	**56**	**7%**	**338**	**42%**	**351**	**44%**	**476**	**59%**	**662**	**82%**	**441**	**55%**
Bachelor 1st year	**100**	12%	**233**	29%	**261**	32%	**215**	27%	**99**	12%	**153**	19%	**39**	5%	**16**	2%	**127**	16%
Bachelor 2nd or 3rd yr	**202**	25%	**155**	19%	**252**	31%	**323**	40%	**131**	16%	**113**	14%	**96**	12%	**9**	1%	**75**	9%
Bachelor honours level	**82**	10%	**36**	4%	**53**	7%	**93**	12%	**65**	8%	**60**	7%	**35**	4%	**3**	<1%	**12**	1%
Masters or Grad. Dip.	**44**	5%	**24**	3%	**9**	1%	**47**	6%	**61**	8%	**44**	5%	**41**	5%	**4**	<1%	**46**	6%
PhD	**84**	10%	**61**	8%	**56**	7%	**26**	3%	**40**	5%	**10**	1%	**24**	3%	**3**	<1%	**21**	3%
SUBTOTAL (studied at university)	**512**	**64%**	**509**	**63%**	**631**	**78%**	**704**	**87%**	**396**	**49%**	**380**	**47%**	**235**	**29%**	**35**	**4%**	**281**	**35%**
TOTAL	*772*	*96%*	*759*	*94%*	*765*	*95%*	*760*	*94%*	*734*	*91%*	*731*	*91%*	*711*	*88%*	*697*	*87%*	*722*	*90%*

[1] Not all respondents provided information on age, gender, and highest level of study in each subject area.

Physics

Physics was commonly part of the science background of respondents (63%, Table 1.1), and although nearly one in three (29%) had studied to first year only, 11 per cent had studied at the post-graduate level.

Physics study was a particularly common component of the science background among male respondents, particularly in the over 40 years of age group (TI males/females: under 40 yrs, $P<0.0001$; 40 yrs & over, $P<0.00001$) (Appendix 4).

Biological sciences (including biomedical)

While one in three respondents had not studied biology at university (32%, Table 1.1), the majority who had, continued study beyond first year level. There was a clear gender-based preference for this subject, with females far more likely than their male counterparts to have studied in this area, irrespective of age group (TI males/females: under 40 yrs, $P<0.00001$; 40 yrs & over, $P<0.00001$) (Appendix 4).

Environmental sciences (including earth science)

Nearly half the survey respondents (49%) had studied in some area of environmental or earth science at university (Table 1.1), including many who had studied at honours (8%) or postgraduate (13%) level. There was no significant difference by gender or age (Appendix 4).

Applied sciences

Respondents were also asked to indicate their highest level of study in each of the following four broad areas of applied science: engineering or computing sciences; health sciences; veterinary science; behavioural science (including psychology).

A background in engineering or computing science was the most common applied science, with just over half the respondents having studied in this area at university (Table A4.1), typically at Bachelor's degree level. One in three respondents had studied health science, and a minority had studied behavioural science. Only five per cent had studied veterinary science.

The influence of gender on career choice is widely recognised. Engineering, for example, continues to be male dominated (Kaspura, 2011) while the opposite is true of many health professions (Booth & Kee, 2010), such as nursing and physiotherapy (McMeeken *et al.,* 2008). Despite continuing efforts to address the gender imbalance in university application and enrolment, the pattern continues. It is unsurprising, therefore, that the study profile of the survey respondents follows similar patterns.

Of the 380 respondents who studied university-level engineering or computing science (Table 1.1), 260 (68%) were men (Appendix 4). This gender effect is highly statistically significant, among the younger age group as well as the older group (TI males/females: under 40 yrs, $P<0.00001$; 40 yrs & over, $P<0.0001$).

The gender differences were less pronounced for health or behavioural science (Appendix 4). In both cases, the difference was seen in older age groups only. Men over 40 years of age were less likely to have studied health science (TI males/females: 40 yrs & over, $P<0.001$) or behavioural science (TI males/females: 40 yrs & over, $P<0.01$).

Most people who had studied in the applied sciences also reported quite extensive study in the enabling sciences of physics, chemistry, and mathematics or statistics. Studies in engineering or computing science were typically accompanied by studies in physics and mathematics or statistics (Appendix 4). In contrast, studies in health science were commonly combined with university level studies in chemistry and mathematics or statistics, but rarely with physics beyond first year, if at all.

Summary demographics

Table 1.2 presents a summary of the respondent demographics, including a comparison of the groups with and without a history in scientific or medical research. People in the 'researcher' group were, on average, older and more likely to hold a PhD. There was little difference, however, in representation of each of the four age-gender categories.

Table 1.2 Summary demographics of respondents

	Number of survey respondents (% of total) ALL	Researchers[1]	No research history
TOTAL	**805** (100%)	**221** (100%)	**584** (100%)
Age-gender category[2]			
Female <40 years of age	**237** (29%)	**54** (24%)	**183** (31%)
Female 40+ years of age	**128** (16%)	**38** (17%)	**91** (16%)
Male < 40 years of age	**161** (20%)	**49** (22%)	**112** (19%)
Male 40+ years of age	**259** (32%)	**74** (33%)	**185** (32%)
Other characteristics			
Have completed a PhD	**248** (31%)	**140** (63%)	**108** (18%)
		years	
Average age	**42.1**	**43.7**	**41.5**
Years since Bachelor's degree completion	**18.9**	**21.3**	**18.1**
Years since PhD completion	**13.2**	**15.4**	**10.3**

[1] Respondents who described working as scientific or medical researchers, at the time of the survey or previously.
[2] 19 respondents did not provide both age and gender details

The report structure

The following five chapters present the findings of the study in detail. The introduction to each chapter includes a summary of the key points.

In some sections, extensive use is made of quotes taken from the survey responses. The quotes complement summaries presented in the tables, providing the context and specific illustration of information that is otherwise abstracted through thematic analyses. The quotes return the voice to the data. It is possible, however, to read the findings without reading all quotes in detail.

Chapter 7 presents a set of individual case studies. Again, these provide illustration of the themes identified in the study. Unlike the isolated quotes used in the preceding chapters, however, the case studies include more detailed background information on individuals, and typically present more extended discussion, and on multiple issues.

Chapter 2: Scientists in Australian society

Many people in Australian society have science backgrounds. 'Scientists' are not isolated within laboratories and academia, and nor is their background in science relevant only to their lives at work.

We know from previous studies, for example, that Bachelor of Science graduates go on to diverse careers, including careers outside science, research, and technology (McInnis *et al*., 2000). We also know that many university students study science subjects as a component of degrees outside science or even applied science. In 2009, 54 per cent of university science teaching was for students enrolled in other 'field of education' categorised courses, such as health, engineering, management and commerce (Dobson, 2012).

What has been unclear until now has been the extent to which graduates continue to identify with their science background, and in what work environments and social settings. In addition, graduate statistics are unable to account for non-university contributions to a science background, such as work, further study, and other life experiences.

Select findings

- ❖ People in diverse workplaces identify as 'scientists' – from small businesses to government departments, from universities to legal firms
- ❖ People with science backgrounds work in a wide variety of roles, for example: business and government executive roles; science and medical research; analytical and policy roles; administration and business; education, including school education; science communication, including journalism – and some roles arguably less predicted – musicians, artists, and religious ministers, for example
- ❖ For many people, work experience both draws upon and contributes to their backgrounds in science
- ❖ Scientists are lifelong learners, building upon their science background through ongoing reading and other pursuits
- ❖ Early influences are considered by many to have made important contributions to their science background, providing sources of inspiration and foundational learning

This chapter describes the range of workplaces and roles of people with backgrounds in science. It also provides an insight into the factors that contribute to a person's science background, beyond university study. Chapter 3 then further reports on the various intersections between science and society, describing the influences a science background has on individuals, at work and beyond.

A wide range of work environments

The survey asked people to describe their current occupations, using an open-response question with no pre-determined categories. Table 1 presents the range of roles described, grouped by organisation type – information drawn from the 'occupation' question (see Q15, Appendix 6) and also from more detailed information given in response to other sections of the questionnaire.

Nearly 40 per cent of respondents worked in either science and medical research organisations (27%) or science and engineering industries (12%) (Table 2.1). Within these groups, individuals' roles included research scientists, technicians, managers, and administrators.

A further 14 per cent of responses came from people working in the public service or other government positions (Table 2.1). This included roles not dissimilar to professional scientist roles in industry – 'toxicologist', 'environmental scientist', and 'atmospheric scientist', for example. In addition, many people with science backgrounds served in analytical and advisory roles for government, developing or advising on policy formulation.

Nearly one in six respondents (16%) worked in organisations categorised as 'business' (Table 2.1). This included a range of small businesses and consultancies, including equipment sales, financial businesses, media, and publishing. The role descriptions in these organisations were equally diverse – 'auditor' to 'mineralogist', 'human resources manager' to 'network engineer'.

Ten per cent of responses came from people working in healthcare, either in medical practice, hospitals or other health-related organisations (Table 1). Also included here were people working in animal health and in sports medicine.

Fewer than 10 per cent of respondents worked in each of education, excluding universities (7%) and mining and construction (4%) (Table 2.1). The latter group again included people working as professional scientists – 'engineer', 'geophysicist', for example – as well as people in management and executive roles.

People with science backgrounds also work in organisations not typically associated with science – law, for example, and religious organisations and other non-government organisations (Table 2.1).

A diversity of roles

Nearly half the survey respondents (47%) described their current roles in terms associated with research (e.g. research fellow; pathogens analyst) or with the professional application of science (e.g. ecologist; engineer; statistician)(Table 2.2). As noted earlier, people in such roles worked in a range of environments, including both small business and government organisations (see Table 2.1).

Many respondents worked in roles outside science, including occupations as diverse as financial advisors, reporters, policy analysts, farmers, and religious ministers (Table 2.2).

Respondents in the 'researcher or academic' group were the most likely to hold a PhD (Table 2.2). The profile of age and gender was, however, no different to that of the overall sample of respondents – males outnumbered females, and this was particularly true in the '40 years plus' age group.

The 'science-related professional' group was predominantly male (66%; Table 2.2). Nearly half the respondents in this category were males 40 years of age of more, in contrast to the 'research assistant or technician' group, that was predominantly younger females (57%). PhD qualifications were not common among either group, at 20 and 14 per cent respectively.

Table 2.1 Respondents' work environments and work roles

Category of organisation[1]	Respondents[2] number (total=796)	proportion of total
Science & medical research organisations	**217**	**27%**
Universities or other research institutions	196	
Medical or biomedical laboratories	21	
Role descriptions include: academic and researcher; atmospheric scientist; business development manager (technology transfer); computing systems administrator; hospital scientist; laboratory technician; manager; PhD student; physicist; research manager; research project officer; technical officer; university professor		
Science & engineering industries	**94**	**12%**
Science and technology industries	58	
Engineering	23	
Information and communication technologies	15	
Role descriptions include: agricultural scientist; analytical chemist; business development executive; CEO; company director; electrical engineer; engineer; geoscientist; IT manager; laboratory technician; mechanical engineer; pathogens analyst; physicist/system engineer; policy analyst; project manager; quality assurance manager; senior consultant; senior scientist; software engineer; technical writer; water treatment engineer		
Business	**124**	**16%**
Business – various, including small business	70	
Business - financial	14	
Consultancy	32	
Media and publishing	8	
Role descriptions include: accountant; auditor; banker; book editor; business analyst; buyer; consultant toxicologist; data analyst; environmental assessor; financial advisor; geographic information systems (GIS) professional; hedge fund manager; human resources manager; information architect; IT consultant; management consultant; mineralogist; network engineer; operations director; project manager; renewable energy project developer; reporter; sales manager; senior software developer; technical writer; web designer		
Government & public service	**114**	**14%**
Role descriptions include: atmospheric scientist; chemistry evaluator; defence scientist; ecotoxicologist; environmental policy advisor; government policy advisor; marine scientist; national parks area manager; naval officer; policy officer; project officer; public servant; quality assurance manager; research officer; risk analyst; senior environmental scientist; senior communications officer; spatial data manager; town planner		
Health	**79**	**10%**
Medical practice	39	
Hospitals	23	
Other health-related organisations	17	
Role descriptions include: aged care manager; anaesthetist; clinical educator; clinical psychologist; clinical technologist; general practitioner; genetic counsellor; health education facilitator; health systems research; healthcare analyst; paramedic; pharmacist; physician; physiotherapist; policy officer; psychiatrist; psychologist; registered nurse; speech pathologist; sports scientist; veterinarian		
Other education (universities included. under 'research organisations')	**57**	**7%**
Schools	46	
Other education organisations	11	
Role descriptions include: adult educator; curriculum development project officer; educational technology developer; first aid instructor; high school science teacher; manager; primary school teacher; principal of a secondary college; secondary teacher; tertiary learning advisor; TAFE instructor		

Table 2.1 Respondents' work environments and work roles (*continued*)

Mining & construction industries	**32**	**4%**
Mining and other geology-related industries	27	
Manufacturing industries	5	
Role descriptions include: geologist; geophysicist; GIS officer; hydrogeologist; laboratory manager; manufacturing engineer; mathematician; mining company director; occupational hygienist; project metallurgist; spatial services manager; strategy & operations executive		
Law	**22**	**3%**
Role descriptions include: commercial lawyer; contract manager; lawyer; judge's associate; patent attorney; patent examiner; policy officer; solicitor		
Food & agriculture	**10**	**1%**
Role descriptions include: biosecurity officer; calibration coordinator; environmental health officer; farmer; fruiterer; hatchery technician; manager		
NGOs & religious organisations	**10**	**1%**
Role descriptions include: manager of online content and systems (NGO); minister of religion; president of an NGO; policy officer (NGO); social worker; priest		
Organisation unclear or unstated	**66**	**8%**
Role descriptions include: archivist; administrator; animal behaviouralist; environmental scientist; historian; HR manager; manager science unit; inspector; instructional designer; meteorologist; network architect; OHS advisor; pastoral care officer; pilot; programmer; quality auditor; researcher; risk & safety engineer; science educator; software developer; statistician; system administrator; technical support engineer		

[1] 755 respondents provided occupation information under Question 15, with some people describing multiple roles, past and current. In addition, many people described their work organisation and/or role in their written responses to Questions 5 and 7. The categories of work organisation used in this table were derived from the coded responses, while the role descriptions listed are the verbatim descriptions of occupation (Q15).

[2] Where provided, respondents' current and past occupations are included. Some respondents were included in more than one category, as they described distinct concurrent occupations, or included information on both past and current work environments.

Females dominated in both the medical and education categories (Table 2.2). PhD qualifications were not common, although other post-graduate qualifications, such as Diploma of Education and graduate-entry medical qualifications were.

Many respondents (13%) described roles in association with management, and often in senior executive management. Half of this group were males 40 years or older, and one in four held a PhD.

Table 2.2 Respondents' current work roles, by gender, age, and qualification

Category of current occupation	Number (and proportion of all respondents, n=805) ALL	Survey respondents (proportion per category and *number*) Females <40 years	Females 40+ years	Males <40 years	Males 40+ years	Highest level of qualification Bachelor	Highest level of qualification PhD
Researcher or academic e.g. university lecturer; research fellow; post-doc	**159 (20%)**	**23%** *37*	**16%** *26*	**29%** *46*	**27%** *43*	**18%** *29*	**73%** *116*
Science-related professional e.g. ecologist; statistician; engineer	**177 (22%)**	**20%** *35*	**12%** *21*	**21%** *38*	**45%** *79*	**63%** *111*	**20%** *35*
Medical or health practitioner e.g. medical doctor; clinical physiologist; psychologist	**69 (9%)**	**49%** *34*	**14%** *10*	**20%** *14*	**13%** *9*	**58%** *40*	**13%** *9*
Other educator[1] e.g. school science teacher; health education facilitator	**63 (8%)**	**40%** *25*	**30%** *19*	**17%** *11*	**13%** *8*	**57%** *36*	**11%** *7*
Research assistant or technician e.g. technical officer; pathogens analyst	**37 (5%)**	**57%** *21*	**16%** *6*	**5%** *2*	**19%** *7*	**70%** *26*	**14%** *5*
Journalist, writer or related roles e.g. broadcaster; reporter; book editor; technical writer	**22 (3%)**	**45%** *10*	**36%** *8*	**5%** *1*	**14%** *3*	**50%** *11*	**27%** *6*
Various other roles e.g. financial advisor; lawyer; policy analyst; public servant; consultant	**203 (25%)**	**29%** *59*	**18%** *37*	**17%** *35*	**34%** *69*	**50%** *101*	**19%** *39*
Manager[2] e.g senior state government executive; engineering project manager	**105 (13%)**	**17%** *18*	**17%** *18*	**18%** *19*	**48%** *50*	**40%** *42*	**25%** *26*
Not in paid work e.g. retired; PhD student; home duties; unemployed	**67 (8%)**	**28%** *22*	**5%** *4*	**9%** *7*	**42%** *33*	**22%** *17*	**38%** *30*

[1] Other than universities, which are included under 'research organisations'
[2] Often listed in conjunction with another role

Early career scientists

A recently released study of university science enrolments has again raised questions about the future for research and innovation in Australia (Dobson, 2012*).* The study provides a critical analysis of the detailed university statistics reported to the Australian Government for 2002 to 2010.

Concerns have been expressed about Australia's ability to meet future demand for people working in science and technology fields, and with strong backgrounds in the enabling sciences (Dobson, 2012).

> *"We need a growing pool of science graduates to ensure Australia will be able to continue to compete on the international stage and develop scientific solutions to problems facing our nation."*
> (Chief Scientist for Australia, 29 February 2012)

A Background in Science does not directly examine this question. Rather, the study was designed to capture a snapshot of who in society currently identifies with a science background, and how they describe that background and its influence. The background data on age and current occupation does, however, enable a glimpse of the early career paths of science graduates – at least, of graduates who self-identify as having a science background.

282 respondents to the survey were under the age of 35. Twenty per cent were working in science or medical research, and a further 21 per cent in science-related professions (Table 2.3). These figures are consistent with the overall survey sample (see Table 2.2) and therefore give no hint of a change in the number of future, practicing scientists.

Table 2.3 Respondents currently in science-related occupations, by age group

		Survey respondents (proportion of age group[1], and number)		
		all ages	under 35 years of age	35 plus years of age
Current occupation[3]	**Total (100%)**	**805**	**254[2]**	**507**
Researcher or academic e.g. university lecturer; research fellow; post-doc		**20%** 159	**20%** 50	**21%** 104
Science-related professional e.g. ecologist; statistician; engineer		**22%** 177	**21%** 53	**24%** 120
Research assistant or technician e.g. technical officer; pathogens analyst		**5%** 37	**21%** 17	**4%** 18

[1] Not all respondents provided age information
[2] Excluding 28 postgraduate students (e.g. PhD; graduate-entry medicine)
[3] Does not included past occupations, and therefore omits people who have changed career or retired

Nor is there evidence of a change in the pattern of science study (Table 2.4). Among the under 35 years age group, the proportions studying chemistry and mathematics/statistics beyond first year were unchanged. The apparent difference in physics backgrounds was not statistically significant when the two age groups were compared to the survey population overall (GF: P>0.01).

Among the 50 respondents under 35 years of age and currently working in science or medical research, 60 per cent held a PhD, and just over half of these were in physics, chemistry, mathematics/statistics, or a combination (Table 2.5). The number of PhD holders was not significantly different when the two age groups are compared to the overall group of researchers and academics (GF P>0.05).

Table 2.4 Level of study in the enabling sciences, by age group

		Survey respondents (proportion of age group[1], and number)	
	all ages	under 35 years of age	35 plus years of age
Level of university study in the enabling sciences — **Total (100%)**	**805**	**282**	**507**
Studied mathematics/statistics beyond first year university	**61%** 489	**60%** 168	**62%** 313
Studied chemistry beyond first year university	**46%** 369	**45%** 127	**46%** 192
Studied physics beyond first year university	**34%** 275	**27%** 77	**38%** 192
Studied mathematics/statistics AND chemistry AND physics beyond first year university	**16%** 127	**12%** 34	**18%** 90

[1] Not all respondents provided age information

Table 2.5 PhD qualifications of researchers, by age group

		Survey respondents currently in research (science or medical) or academic occupations[1] (proportion of age group[2], and number)	
	all ages	under 35 years of age	35 plus years of age
Subject area included in PhD studies — **Total (100%)**	**159**	**50**	**104**
Any	**73%** 116	**60%** 30	**79%** 82
Mathematics or statistics	**9%** 14	**14%** 7	**6%** 6
Chemistry	**21%** 33	**14%** 7	**25%** 26
Physics	**20%** 32	**16%** 8	**21%** 22
Mathematics/statistics OR chemistry OR physics	**44%** 69	**36%** 18	**47%** 49
Biological sciences (including biomedical)	**25%** 39	**16%** 8	**29%** 30
Environmental sciences (including earth sciences)	**9%** 14	**6%** 3	**11%** 11

[1] Does not included past occupations, and therefore omits people who have changed career or retired
[2] Not all respondents provided age information

The data reported above does not indicate a change in the number of future scientists, nor a shift in their backgrounds away from the enabling sciences – yet. It should be stressed, however, that this is a small sample and the survey was not specifically designed to address this question. The data are presented here simply because the issue is a topical one.

Factors contributing to a 'background in science'

A background in science involves more than university study.

> *"My personal interest in science has led to me gain knowledge in areas I haven't formally studied, discussions with various people including classmates, friends and family, my work in admin solidifying and building on my research and data analysis skills. I'm not really sure it is possible to obtain a background in anything from just academic studies - studying leads to asking questions and considering new ways of viewing issues that arise in your life. I studied science because of what I learnt at home, in the media, at school, all of that forms my background."*
> (female; 25 years of age; working in university administration; currently enrolled in postgraduate study)

In order to better understand the nature of a 'science background', the survey asked people to describe any other experiences that they considered formed part of their background in science. The very fact that most survey respondents provided written comment (n=605 respondents; 75%) points to the importance placed on influences outside university study. The themes identified from these responses are presented in Table 2.6. It is worth noting that many people, like the respondent above, described multiple contributing factors.

The three most common themes – work experience; ongoing learning through personal interests; and childhood experiences and influences – are described in more detail below.

Work experience

Work experience was commonly cited as a factor contributing to a person's science background, particularly with reference to work in scientific research environments or applied science professions (Table 2.6).

> *"My activities as a research scientist continue to hone these skills."*
> (female; 51 years of age; university professor)

> *"I also did two years of scientific research at University College London, UK. My 40+ year career in engineering includes large elements of investigative research, design, development and problem solving, all of which are heavily based on scientific inquiry and principles, plus the need to do such tasks to schedule and budget restraints."*
> (male; 62 years of age; engineer)

> *"... working in the university sector teaching students has helped me to understand how to convey many scientific concepts - not just how I have learnt them or understood them."*
> (female; 33 years of age; university lecturer)

It is important to note that work was a factor both for people currently working in such areas, as well as people who cited past (and sometimes brief, but influential) involvement. Short term work experience alongside study was not uncommon.

> *"Work and life experiences are essential. While completing my degree I worked in industry as chemical analyst for a fertilizer manufacturer and then as part of a research team developing new analytical techniques in mineral chemistry during the early eighties. The chemists for both organizations helped develop my analytical and research skills by setting tasks that required sound science methodology. On completion of my degree this was further developed by working for an agricultural research team."*
> (male; 54 years of age; school science teacher)

> *"Vacation projects while I was an undergraduate – I obtained two scholarships to conduct short projects and the experience I gained from these was invaluable."*
> (female; 47 years of age; animal behaviouralist)

"I had lots of research experience (summer scholarships, etc) where I did pure research for no academic credit. I feel pure research really develops problem analysis and thinking skills in a way classroom learning can't. I had some work experience in a very large scientific organization similar to the CERN. This gave a perspective on what scientists do when they have finished their studies."
(male; 31 years of age; engineer)

Table 2.6 Factors contributing to respondents' science backgrounds

Themes identified from open responses to the following: *"Apart from university studies, please describe any other experiences that you consider form part of your background in science."*	Survey respondents[1] (number and proportion of total respondents, n=805)	
Childhood experiences and influences	**148**	**24%**
Family influence	**64**	**11%**
School influence	**54**	**9%**
Interests and hobbies, including: reading; watching documentaries; chemistry set	**33**	**5%**
Science activities, including: Science Olympiad; summer schools, museum visits	**26**	**4%**
Surroundings, including: growing up on a farm; time spent in the bush	**19**	**3%**
Work experience – type of work[2]	**300**	**50%**
Science-related research, including: applied research; research assistant work; post-doctoral research experience; research policy and management	**119**	**20%**
Professional and applied science, including: engineering; IT; environmental science; environmental health & safety; science consultancy; science equipment sales	**116**	**19%**
Science education and communication, including: teaching; journalism; Questacon	**55**	**9%**
Medical or other analytical laboratory work	**22**	**4%**
Health, including: health policy & management; health education	**18**	**3%**
Work-related experiences	**68**	**11%**
Participation in work-related events and training, including: conferences; workshops	**47**	**8%**
Exposure to scientific information or environments, including: law; policy; journalism (if not directly in science communication); business	**24**	**4%**
Other qualifications	**53**	**9%**
Vocational education, including: trade certificates, such as electrician qualification; technical diplomas; veterinary nursing; pilot courses; horticultural qualifications	**29**	**5%**
University study in non-science areas, including: economics; education; philosophy	**14**	**2%**
Further university studies in applied science areas[3], including: postgraduate medicine; engineering; nursing	**12**	**2%**
Ongoing learning – personal interests	**201**	**33%**
Continuing interest in science learning	**154**	**25%**
Learning through interests such as nature, technology, travel, and sports	**59**	**10%**
Personal situation	**100**	**17%**
Social environment, including through interactions with family, friends & colleagues	61	10%
Science as a "way of life", as part of "everything I do"	25	4%
Other experiences, including: interactions with the health system; faith	19	3%
Volunteer activities	**40**	**7%**

[1] Many respondents described multiple contributing factors
[2] Includes descriptions of past and current work, continuing and more casual (e.g. 'summer job') employment, and unpaid 'work experience'.
[3] Some respondents considered applied science separately from their 'science' studies at university.

Many people referred to the type of work – science-related research (20% of respondents), professional and applied science (19% of respondents), science education and communication (9% respondents), for example – as having contributed to their science background. It was also common for people to refer to specific experiences at work (11% of respondents), such as participation in conferences or workshops, or simply exposure to scientific information or environments (Table 2.6).

> *"I currently work with a range of researchers in my occupation. My role involves engaging scientific experts in various scientific fields to undertake research. I interpret and summarise the findings from scientific research on a daily basis."*
> (male; 33 years of age; public servant, water policy)

> *"My career as a patent attorney ensures that I am kept up to date with the latest developments in a wide range of technical areas."*
> (male; 44 years of age; patent attorney)

Ongoing learning through personal interests

Aside from work experiences, the most commonly cited contributor to a science background was ongoing learning, both purposefully and in conjunction with other interests and hobbies (33% of respondents; Table 2.6).

'Popular' science publications, documentaries, and public events and exhibitions were valued (n=74 respondents).

> *"I love museums (science, natural history, space etc) and have increased my scientific knowledge in literally hundreds of them over the years. I also love reading popular science magazines and watching science-based documentaries."*
> (female; 35 years of age; policy officer)

> *"Reading popular works in science, especially Stephen Jay Gould and Carl Sagan."*
> (male; 41 years of age; senior lecturer in chemistry)

Learning may also be of a more directed kind, through specific research in areas of interest (n=57 respondents).

> *"A keen interest in science – to want to read up on and investigate scientific developments and history in my own time.*
> (male; 25 years of age; geologist)

> *"A thirst for knowledge, and issues in my own family, has led me to follow up brain science/behavioural research closely."*
> (female; 39 years of age; senior software developer)

Ten per cent of respondents cited the influence of 'indirect' learning through their involvement in other activities, such as bushwalking, travel, or sports.

> *"My personal interest in Australian fauna and flora is part of my background in science. It was this which led me to university, although I was gaining knowledge before commencing my studies, and I continue to expand my knowledge through these endeavours, rather than through my position within a tertiary institution."*
> (female; 46 years of age; laboratory technician)

> *"Gardening and pottery. While I didn't really think about it earlier in the survey, gardening is surprisingly scientific with a multitude of 'cause-and-effects' operating, to the hour or to the season, and all vital to understand if you want a good backyard crop. Pottery, too, offers some very practical insights into material sciences and thermal physics! Glazes reward thorough study."*
> (male; 40 years of age; manager/analyst)

Indeed, a typical characteristic of people with science backgrounds is their continuing curiosity and interest in science and 'the way the world works', a theme further elaborated in Chapter 6.

Childhood experiences and influences

Many people also described influences early in life as part of their science background (Table 2.6). In part they were describing what led them to science. Yet they were also describing the 'roots' of continuing interests, and highlighting the difficulty of pinning down a particular starting point to a background in science. A science background doesn't, typically, begin with university.

These early influences were diverse, yet shared one thing in common. They all relate to sources of inspiration and encouragement to explore and learn.

Family influences can be important, both in providing general encouragement and – for the children of scientists – early immersion in science as a way of life.

> *"A mother who was a scientist and a science teacher, who gave me the gift of curiosity and the ability to understand science."*
> (male; 47 years of age; management consultant)

> *"Family encouragement to take an interest in nature. Uncle's influence (an astrophysicist). Aunt's influence (a zoologist)."*
> (female; 42 years of age; health policy analyst)

> *"My father was an engineer and so I was exposed from an early age to ideas about the scientific world and compelled to explain myself using logic, evidence and examples."*
> (female; 52 years of age; university academic)

Nine per cent of respondents cited the influence of school and school teachers (Table 2.6).

> *"Primary school teachers who introduced me to elementary but important and fun concepts of math, chemistry, general science and research project work. High school teachers who encouraged me to continue to pursue science subjects when the rest of my peers were more interested in arts."*
> (female; 41 years of age; senior management role in business)

> *"University science is more the end point - a 'background in science' starts in primary school."*
> (male; 36 years of age; physicist)

> *"I had some excellent science and mathematics teachers in my high school years. They tried to challenge me, and sustained the 'sense of wonder' in the world."*
> (male; 44 years of age; aviation software developer)

Other early influences included reading, science activities, and exposure to inspirational environments (Table 2.6).

> *"A keen interest in science from a young age and attendance at the CSIRO double helix club and the Investigator Science Centre in Adelaide. These really stimulated my interest in science."*
> (female; 31 years of age; medical scientist)

> *"Should I mention the home chemistry set that I received when I was 12 years old and used extensively until entry into research laboratories (MSc studies) met my experimental needs? Oh, and my great aunt was a pharmacist from whom I inherited books, and who allowed me to prowl in the stockroom."*
> (male; 74 years of age; semi-retired consultant chemist)

> *"Growing up in a family that was passionate about the small patch of bush behind our house, and that loved all forms of wildlife, without fear or favour."*
> (female; 44 years of age; book editor)

Chapter 3: Science knowledge and skills

People across Australian society identify with their backgrounds in science, as described in the preceding chapter.

How do people with backgrounds in science describe their science knowledge? And what skills do they have that they associate with their science background? This chapter examines each of these questions in turn.

Select findings

- Most people were confident in their knowledge of the fundamentals of at least two science subject areas
- People typically described having more specialist knowledge in only one or two areas
- The subjects in which respondents expressed the least confidence were physics and environmental systems
- Nearly one in five people lacked confidence in their fundamental mathematics knowledge
- Women were more confident in biology, while men were more confident in mathematics and physics
- While confidence levels rose with increasing levels of school or university study, the relationship was not absolute. Some people were confident in their knowledge of a subject despite never having studied the subject formally
- The skills most strongly associated with a science background related to analysis of problems, evaluation of evidence, and the ability to research new information
- There was much more disagreement or ambivalence concerning the development of collaboration or leadership skills through a science background

Areas of knowledge and expertise

The questions

The study explored the level of confidence people with a science background had in various areas of science knowledge. This was not the same as asking what they had studied. On the contrary, the survey question was prefaced with the following statement, seeking to ensure that respondents were considering their backgrounds in science holistically:

> *In this section, please consider the knowledge that you have developed as a result of your involvement in science, whether during your university studies or elsewhere.*
> (Preface to Part A of the online questionnaire; Appendix 6)

There were two separate questions. The first looked at understanding of fundamental principles, while the second at more specialised knowledge.

> *Through my background in science, I understand the fundamental principles of:*
>
> *Through my background in science, I have more specialised knowledge in some aspects of:*
> (Online questionnaire, Q3 and Q4; see Appendix 6)

For each question, five broad subject areas were listed: Biology; Chemistry; Physics; Mathematics; Statistics; and Environmental Systems. Responses were via a five point Likert scale of: Strongly Disagree; Disagree; Neither agree nor disagree; Agree; Strongly agree.

Fundamental principles

Generally, respondents were confident of their fundamental knowledge in science. For each subject area, a large majority of respondents agreed that through their background in science they had an understanding of fundamental principles in the subject (Fig. 3.1). The strongest agreement was for biology (44% strongly agreed), although this was not universal, as nearly one in 10 respondents disagreed or strongly disagreed. Fewer people were confident in their fundamental knowledge of physics or environmental systems. The levels of disagreement varied little between subjects: from 4 per cent for statistics to 11 per cent for physics.

Two out of three respondents (64%) were confident of their knowledge across the enabling sciences of mathematics, chemistry and physics, and two out of five (41%) expressed blanket agreement across all listed six subjects (Table 3.1).

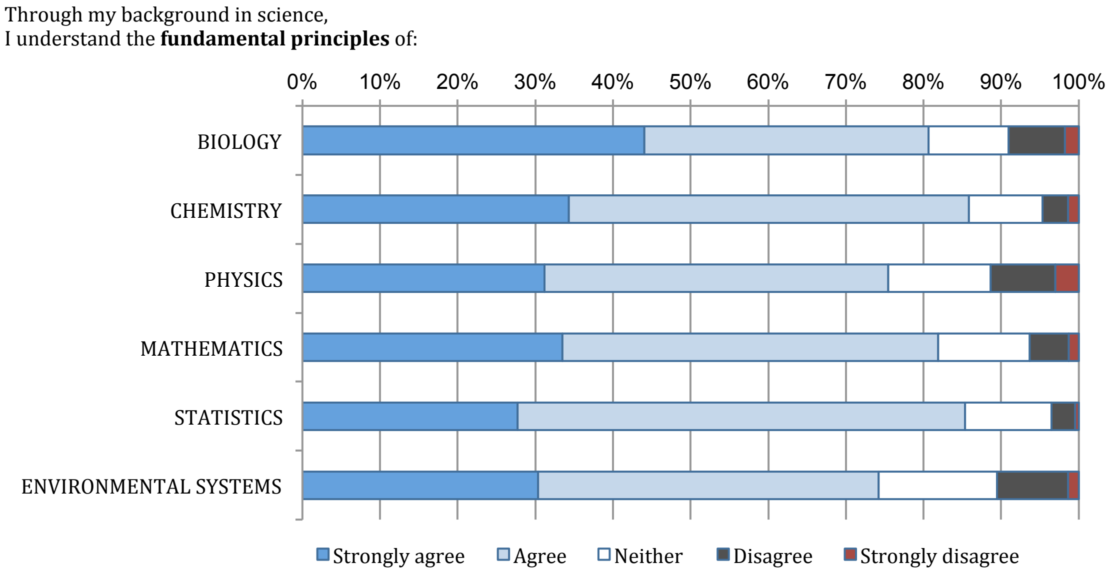

Figure 3.1 Fundamental knowledge developed through a science background
Level of agreement with each statement, on a five-point scale *strongly agree* to *strongly disagree*
(n=787-797 respondents per statement)

Areas of specialised knowledge

Collectively, the survey sample included specialist expertise in all six listed subjects (Fig. 3.2). Levels of agreement ranged between 55 per cent (for physics) and 68 per cent (for biology). Most people described specialised knowledge in only one or two subject areas (Table 3.1). Nearly one in six (16%), however, strongly agreed to specialised knowledge in aspects of all six subjects.

Differences by age and gender

Females expressed higher levels of confidence in biology than did males of the same age group (see Appendix 5). This was true for both fundamental principles and in areas of specialised knowledge. There was no significant age-based difference for either males or females.

Table 3.1 Knowledge in multiple subject areas

Select combinations of subject areas	Survey respondents to 'Agree' or 'Strongly agree' (% all survey respondents, n=805) Fundamental principles[1]	Specialised knowledge[2]
Mathematics and Chemistry	72%	40%
Mathematics and Chemistry and Physics	64%	34%
Mathematics and Chemistry and Physics and Biology	52%	22%
Biology and Chemistry	69%	46%
Biology and Statistics	68%	42%
ALL (Mathematics and Chemistry and Physics and Biology and Statistics and Environmental Systems)	41%	16%

[1] Based on level of agreement with Q3: 'Through my background in science, I understand the fundamental principles of … '
[2] Based on level of agreement with Q4: 'Through my background in science, I have specialised knowledge in some aspects of … ' (see Appendix 6)

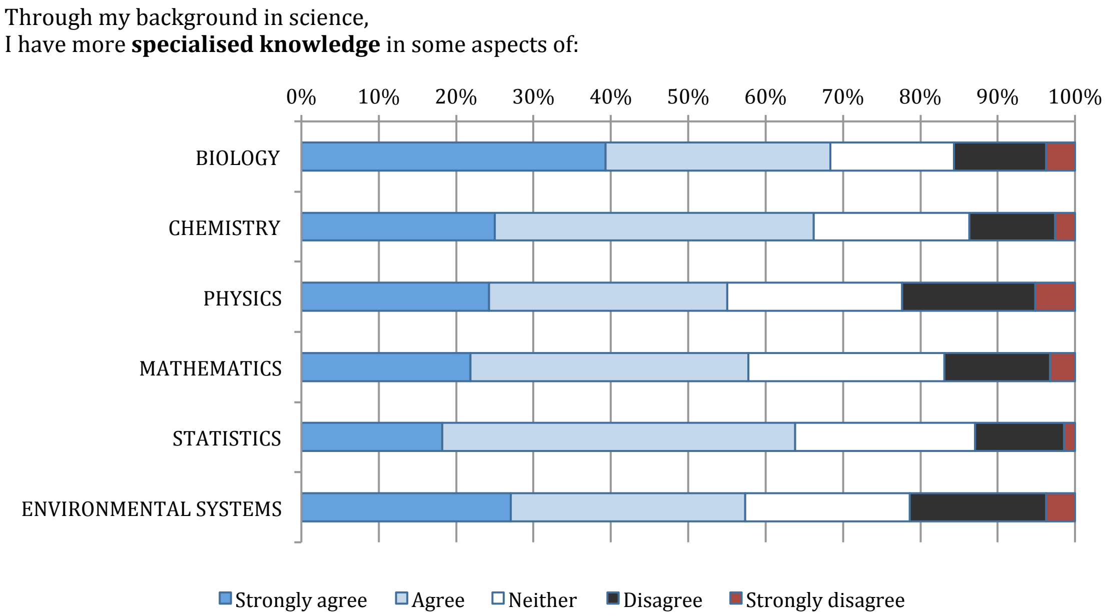

Figure 3.2 Specialised knowledge developed through a science background
Level of agreement with each statement, on a five-point scale *strongly agree* to *strongly disagree*
(n=771-779) respondents per statement)

The opposite was true for mathematics and physics (see Appendix 5) – males were significantly more likely to express confidence in their knowledge of fundamental and specialist mathematics and physics. The apparent age-based difference for females was not statistically significant (TI P>0.01 in for both fundamental and specialised knowledge).

The only age-based difference was detected for specialised knowledge of statistics. Younger women were less confident than the 40 years and over female group (see Appendix 5). There was no difference between the males and the older female group.

The 'study level – confidence' nexus

There was a relationship between higher level of study and level of confidence in the knowledge of fundamental principles but, unsurprisingly, it was not a perfect relationship. As described in the Chapter 2, for most people formal study was not the only contribution to their science background. Work environments, personal interests, and individual approaches to life-long learning also played an important role (see Table 2.6).

Table 3.2 show the patterns of agreement/disagreement for fundamental knowledge of physics and biology by highest level of study in the subject. Overall, the trend is as would be expected – with increasing level of study the level of disagreement falls and agreement rises.

Table 3.2 Knowledge of physics and chemistry, by level of study

	Through my background in science, I understand the fundamental principles of:					
	Physics % of each study category			**Biology**[1] % of each study category		
Highest level of study category	**Total** (100%)	Disagree[2]	Agree[3]	**Total** (100%)	Disagree[3]	Agree[4]
Never studied	**29**	**48%** 14	**17%** 5	**48**	**27%** 13	**44%** 21
School Years 7-10 (any)	**69**	**38%** 26	**28%** 19	**115**	**34%** 39	**41%** 47
School Years 11-12 (any)	**152**	**20%** 30	**63%** 95	**97**	**12%** 12	**68%** 66
Bachelor 1st year	**233**	**5%** 11	**82%** 191	**100**	**5%** 5	**80%** 80
Beyond Bachelor 1st year (e.g. 2nd-3rd year; Masters; PhD)	**275**	**1%** 2	**96%** 263	**411**	**<1%** 2	**98%** 403

[1] Level of study was listed as 'biological sciences (including biomedical)'
[2] Response of 'Strongly disagree' or 'Disagree'
[3] Response of 'Strongly agree' or 'Agree'

This data also points to knowledge developed outside formal study. In biology, for example, nearly half the people who never studied the subject formally were confident of their understanding of fundamental principles (44%, Table 3.2). The same was true in physics, albeit for a few people. These people had studied in other areas of science and some had PhDs. Their occupations were varied (e.g. national park ranger; lawyer; engineer; farmer; geologist), and many described themselves as avid readers and life-long learners.

> *"I have an interest in the outdoors and my science learning is just part of that. I am confident in questioning and knowing where to find answers to problems so quite enjoy when challenged by friends/family to find answers."*
> (39 years of age; public servant; 'agreed' to fundamental knowledge of biology; no formal biological sciences education)

"I read a lot of science books (cosmology, climate change, quantum mechanics, physics, chemistry) plus the New Scientist magazine. I teach my grandchildren about science and read them science books. I discuss science issues such as climate change with friends and acquaintances. Science permeates my attitude to life and living."
(68 years of age; retired from information technology; 'strongly agreed' to fundamental knowledge of biology; no formal biological sciences education)

"I continue to read science magazines, articles and books. …. (on other contributors to a science background) Reading, TV, visits to museums, science centres, natural sites."
(34 years of age; contract manager; 'agreed' to fundamental knowledge of physics; no formal physics education)

Skills developed through science

A background in science is associated with more than just a particular knowledge base. It is connected with skills, attitudes, and particular ways of approaching aspects of work and life more generally. As a first step to defining this, respondents were asked to consider the extent to which they associated their science background with a list of particular abilities.

It is important to recognise that these abilities are not unique to science. Indeed, some people found it difficult to separate the influence of their science background from other influences.

"These skills have much more to do with having a general high level of literacy and rigour in thinking. They are not unique to science. It is very difficult for me to attribute which come from science and which come from other training."
(31 years of age; expressed agreement with 5 of the 11 propositions below)

It was much more common, however, for people to associate skills and science directly, and many of the written responses to the survey overall were descriptions of such associations.

The question

Part B of the questionnaire asked respondents to describe the skills they had developed through doing science (see Appendix 6). As for the knowledge section (Part A), a series of statements was provided and level of agreement sought on a five point Likert scale of 'strongly agree' to 'strongly disagree'. The questions covered 11 'skills', presented in random order:

My background in science contributes to my ability to: develop a logical argument; research new information; make observations; analyse a problem; present ideas to others; develop creative solutions to problems; work independently; work collaboratively; provide effective leadership; evaluate evidence; understand the natural world
(Online questionnaire, Q6; see Appendix 6)

The results are described below. More nuanced descriptions of skills and attitudes emerged from responses to the various open questions of the survey. These are discussed further in Chapters 4 and 5.

Skills associated with a science background

The skills most strongly associated with a background in science related to analysis, evaluation and logic, and the ability to research new information, make observations, and (perhaps as a result) better understand the natural world (Fig. 3.3). The areas in which there was the highest ambivalence or disagreement related to leadership and collaboration abilities.

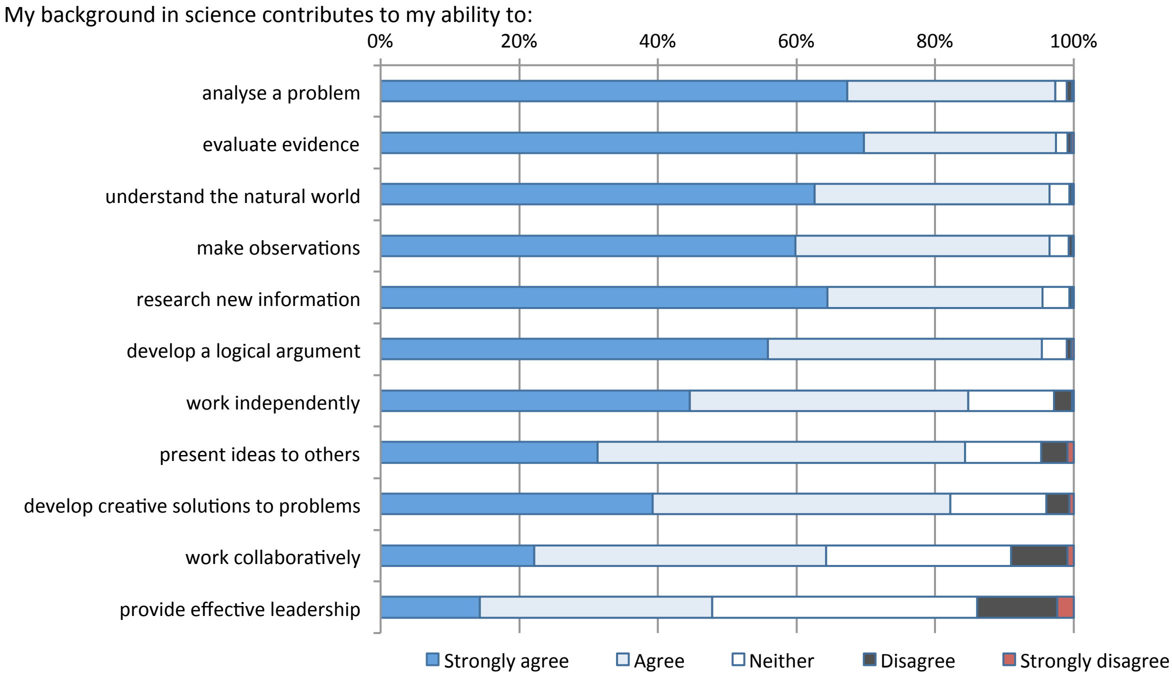

Figure 3.3 Skills developed through a background in science
Level of agreement with each statement, on a five-point scale *strongly agree* to *strongly disagree*
(n=799-805 respondents per statement)

Differences by age and gender

There was very little difference in response based on age and gender. The only area where a difference was detected related to creative problem solving. Among those over 40 years of age, men were more likely than women to agree (TI, $P<0.001$).

Differences associated with a research occupation

Research experience was often mentioned in connection with the application of skills and the development of a science background. For this reason, the data were examined for any difference based on whether or not people worked in research.

A total of 221 respondents were identified as working, or having previously worked, as scientific researchers. This was based on occupation descriptions and on written descriptions of the influence of knowledge and skills at work (see also Table 1.2). Included were researchers in science and technology organisations, and in medical research. People in technical or laboratory assistant roles were included if they described themselves as 'researchers'.

Researchers were more likely to strongly agree in four areas: analysing and solving problems, researching new information, and developing logical argument (Fig. 3.4).

My background in science contributes to my ability to:

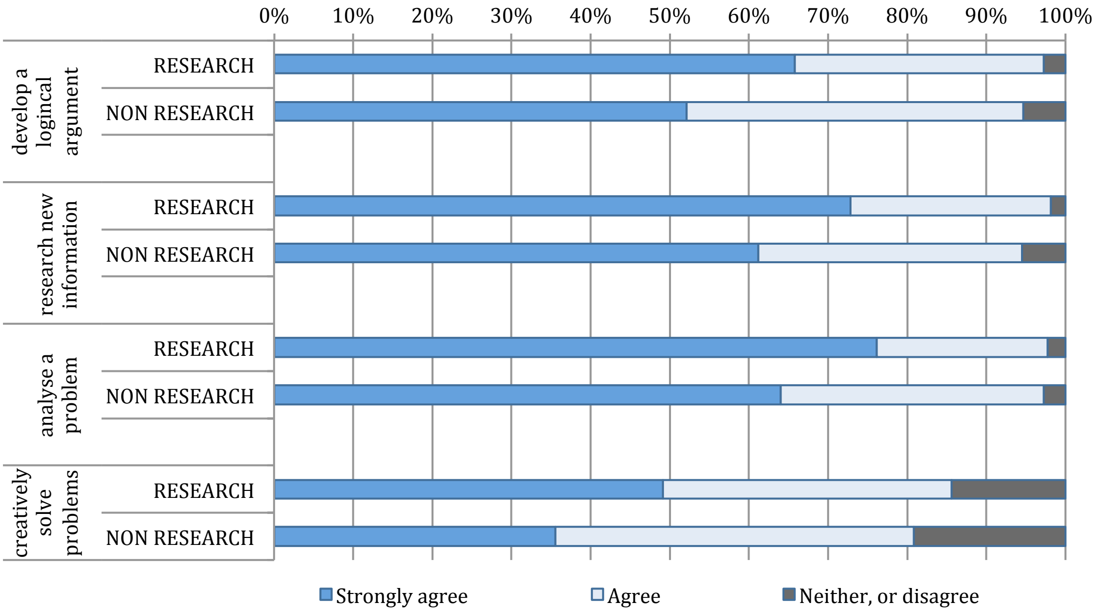

Figure 3.4 Science contribution toward specific skills, by occupation
Respondents employed as researchers (current or past) are more likely to *strongly agree* with each of the above statements (in each case, TI, P<0.001)

Chapter 4: The Influence of science knowledge and skills

One of the key aims of this study was to better understand the influence of a science background upon individuals. There is much anecdotal evidence that a background in science influences a person's approach to work, contemporary issues, and personal interests and pursuits. However, there has been limited analysis undertaken in this area, and most studies of science identity formation have tended to focus on gender or minority groups (e.g. Carlone & Johnson, 2007) and on school learning and education (e.g. Brown *et al.,* 2005).

Notes regarding methodology

This chapter presents the results gleaned from two types of survey question: check box lists of situations where knowledge and skills were used, accompanied by open questions asking for explanation and/or general examples (see Q5 and Q7, Appendix 6). All survey respondents answered the check box sections (100%), and most (82%) expanded on this with written explanation.

Written responses were coded by particular application. For example, 'nature-based hobbies' within 'personal interests and pursuits'; 'health' within 'providing advice to family and friends'; and 'climate change' within 'understanding contemporary issues'.

No attempt was made to correlate particular situations with the application of specific knowledge or skills – 'personal interests and pursuits' with 'mathematics' or 'research new information', for example. Such correlation would not have yielded meaningful data for two reasons. First, most written examples did not specify particular areas of knowledge or kinds of skills when describing the application of their science background. Second, those who did provide such detail did so by way of example. The questions asked for examples or explanations, not for exhaustive listings.

Quotes are used extensively in this chapter. They provide more than illustration. It is from people's written comments that the principal themes were identified, and therefore they represent the fundamental data.

Select findings

- Nearly all respondents recognised an influence from their science background at work, and beyond
- Both science knowledge and skills were utilised at work, and in all kinds of work environments
- In discussing the work environment, researchers were more likely to describe the role of knowledge and less likely to discuss the application of skills
- Nearly nine out of every ten respondents recognised a connection between their science background and their personal interests and pursuits
- People with science backgrounds tend to be lifelong learners, a theme identified in Chapter 2 and further discussed in Chapter 5
- An individual's science background has a flow on effect to society more broadly, through the advice and assistance they provide others
- For most respondents, their science background influenced their approach to contemporary issues in society. The application of science in understanding environmental issues and critiquing media reporting was given particular emphasis

Overview

People recognised an influence from their science background, at work and beyond (Table 4.1). This response was quite universal across the survey sample. There was no difference by age or gender. There was no difference by highest level of qualification, comparing PhD with Bachelor. Nor was there any difference between people working as researchers and those in other occupations.

Table 4.1 Situations utilising science knowledge or skills

	Survey respondents number, % all respondents (n=805)					
Situation	**Knowledge**[1] (K)	**Skills**[2] (S)	**K or S**	**K and S**	**K only**	**S only**
In my work	**743** (92%)	**773** (96%)	**781** (97%)	**736** (91%)	**7** (1%)	**37** (5%)
In my personal interests and pursuits (outside work and study)	**649** (81%)	**641** (80%)	**701** (87%)	**589** (73%)	**60** (7%)	**52** (6%)
In providing advice to friends and family	**610** (76%)	**567** (70%)	**666** (83%)	**511** (63%)	**99** (12%)	**56** (7%)
In my approach to understanding contemporary issues in society	**675** (84%)	**635** (79%)	**711** (88%)	**599** (74%)	**76** (9%)	**36** (4%)
Never	**5** (1%)	**12** (1%)				

[1] Ticked responses to survey Question 5 (In what situations do you draw upon your science knowledge?) (Appendix 6)
[2] Ticked responses to survey Question 7 (In what situations do you apply these skills?) (Appendix 6)

Science in the workplace

Nearly all respondents (97%) stated that they used their science knowledge or associated skills in their work (Table 4.1). Most cited both knowledge and skills (91%). A further five per cent, however, reported that they drew upon science-related skills but not knowledge. This was most common among people working in business or legal environments (Table 4.2), although numbers were small. Most people in business and law cited knowledge too as an influence at work.

Table 4.2 Work environments utilising science knowledge and skills

Category of work organisation, current or past[1]	Total 100%	Survey respondents (number, % respondents per category) Knowledge[2]	Skills[2]	Both knowledge[2] and skills[3]
Any work environment	**805**	**743** (92%)	**773** (96%)	**736** (91%)
Science & medical research organisations	**217**	**205** (94%)	**208** (96%)	**203** (94%)
Science & engineering industries	**94**	**92** (98%)	**92** (98%)	**90** (96%)
Business	**124**	**112** (90%)	**120** (97%)	**110** (89%)
Government & public service	**114**	**111** (97%)	**111** (99%)	**110** (96%)
Health	**79**	**75** (95%)	**78** (99%)	**75** (95%)
Other education[4]	**57**	**52** (91%)	**54** (95%)	**51** (89%)
Mining & construction industries	**32**	**32** (100%)	**32** (100%)	**32** (100%)
Law	**22**	**16** (73%)	**21** (95%)	**16** (73%)
Organisation unclear or unstated	**66**	**57** (86%)	**66** (100%)	**57** (86%)

[1] 755 respondents provided occupation information, with some people describing multiple workplaces. See also Tables 2.1 & 2.2 for further description of work organisations and roles.
[2] Ticked 'In my work' for survey Question 5 (*In what situations do you draw upon your science knowledge?*) (Appendix 6)
[3] Ticked 'In my work' for survey Question 7 (*In what situations do you apply these skills?*) (Appendix 6)
[4] Other than universities, which are included under 'research organisations'

The following quotes demonstrate the variety of workplace applications for knowledge or skills developed through science. Each of the respondents below ticked 'in my work' for both knowledge and skills.

> *"My degree focused on developing research skills and I am employed as a risk analyst by the government. I use all of the skills mentioned above in research and report writing."*
> (risk analyst; government organisation)

> *"I currently work as an Environmental Scientist, and use my science knowledge daily. My science degree directly influenced me getting this job, and in the skills I use everyday."*
> (environmental scientist – consultant; business organisation)

> *"I draw upon my science knowledge in the understanding of physiology and diseases of humans. As a clinician, I need to evaluate and analyse the health situation from a scientific, rational perspective."*
> (physician – cardiologist; health organisation)

> *"I work in a policy role so gathering the required evidence to support policy development and to inform decision making is an important part of my job. I use a range of tools/methods to gather and collate information and my science background means I am comfortable researching and analysing information as well as dealing with experts and reviewing technical information. … collaboration, evaluate evidence, analyse a problem, presents ideas to others – I have used these skills in the development, administration and implementation of a multi-disciplinary research grants program."*
> (marine biodiversity policy/project officer; government organisation)

"Statistical principles when analysing results - science studies gave me platform for analysis and development of logical arguments, which I use in my everyday work."
(accountant; business organisation)

"Professionally, my job is that of a Science & Technology manager designing, developing, integrating and fielding prototypes for the Department of Defense (overseas – country name removed)*. While much of what I do is engineering, my science degree provides me with foundation knowledge in the scientific method, theory and fundamental physics. All of these areas are vital to my ability to understand the science behind what we are designing and building, and to establish a solid foundation for the applied aspects of my job."*
(president/CEO, chief scientist/engineer; science & engineering industry/government organisation)

"I use my observation skills, analytical and conceptual skills, design of experiment, logic thought processes, attention to detail, recording outcomes as well as more specific knowledge such as chemistry as I work in a manufacturing environment where we do some chemical processing of materials."
(quality assurance manager; manufacturing industry / government organisation)

"Although I have never worked formally as a scientist, I have worked as a lawyer and as a mining executive, both of which have drawn heavily on my technical literacy and scientific knowledge. As a lawyer, my science knowledge was essential for matters involving intellectual property (e.g. patent drafting and advice), technical disputes, or general advice to clients whose business was technical/scientific in nature. Even when dealing with financial institutions, my knowledge of maths and statistics was invaluable. Within the mining industry, my science knowledge is used every day - including government negotiations on environmental and planning issues, assessment of new technology, interpretation of exploration results, strategic modelling with regard to future resource demand, analysis of climate change scenarios and the impact of various mitigation measures, and for everyday interaction with engineers, geologists, metallurgists, etc."
(previously lawyer, now mining executive; mining organisation)

Respondents were more likely to describe the application of specific skills if they were working in non-research roles (29% vs 17%; Table 4.3).

"I work in the law, where presenting argument logically is very important. I draw heavily on my science background to ensure that arguments I make or analyse follow logically and aren't fallacious. I am also able to assess probability and evidence rigorously in a courtroom setting. I often seek to explain my reasoning to others using techniques developed through science, e.g. diagrams, probabilistic assessments, logical steps etc."
(lawyer / judges associate; marked 7 of the 11 skills as *agree* or *strongly agree,* the exceptions being 'leadership', 'working collaboratively, 'working independently', 'research new information')

From within the world of research, science-related skills tend to be seen as simply 'business as usual'. The following comments were made in describing the application of skills developed through science.

"I am a research scientist, so there should be no need for further explanation in this regard."
(university professor; marked 10 of the 11 listed skills as *agree* or *strongly agree*, the exception being 'leadership')

"Since I work in science much of my work involves the skills outlined above."
(associate professor at university; marked 8 of the 11 skills as *agree* or *strongly agree,* the exceptions being 'leadership', 'working collaboratively, 'working independently'

"I think if one IS a scientist, taking an approach to life that is experimental, observation-driven and analytical is second nature."
(associate professor at university; marked all 11 listed skills as *agree* or *strongly agree)*

Table 4.3 Knowledge and skills at work, by occupation

	Survey respondents (% of occupation group, number)	
	researchers[1] (n=221)	**other occupations** (n=584)
Drawing upon science knowledge at work		
Indicated science-based knowledge used at work (tick box)	**98%** 217	**90%** 526
Discussed use of knowledge at work[2]	**80%** 176	**57%** 334
Discussed use of *specific* areas of knowledge at work	**34%** 75	**33%** 193
Application at work of skills developed through science		
Indicated science-based skills used at work (tick box)	**98%** 217	**95%** 556
Discussed use of skills at work	**27%** 59	**32%** 184
Discussed use of *specific* skills at work[2]	**17%** 38	**29%** 167

[1] Respondents employed as researchers (current or past)
[2] Goodness of fit test: P<0.001 [3] Goodness of fit test: P<0.01

Researchers were the most likely to discuss the connection between their science knowledge and their work (80% vs 57%; Table 4.3). This is unsurprising given that all science researchers are likely to be routinely drawing upon their science knowledge, while for many people in other occupations this would not be the case.

> *"My professional activities (I am a brain scientist). I rely directly on my background training in science - hence the tick for work."*
> (university professor; description of utilising science knowledge)

These differences in perspective extend only to discussions of work. There was no difference between researchers and others when discussing the influence of their science background beyond the work environment.

Influence on personal interests and pursuits

The majority of people identified a connection between their science knowledge or skills, and their personal interests and pursuits (87%, Table 4.1). This was true across age, gender, and extent of formal science qualifications.

Many people with a science background, irrespective of occupation, described a general and continuing interest in science (Table 4.4). They described drawing upon and furthering their science knowledge as a matter of personal interest. This tendency toward 'life-long learning' is a theme discussed further in Chapter 5.

> *"My interest in science flows into my interest in the world around me. I read science articles on astronomy, quantum physics, mathematics, meteorology, geology, genetics etc. Without some science background, much of what I read would be meaningless. It applies to other interests in life as well. With an understanding of science, much of what we observe about us, takes on a whole different understanding."*
> (maintenance engineer; male; 56 years of age)

> *"I have a wider interest in science that what I practice at work so I read a lot, particularly pop science books and journals/newspaper articles."*
> (research manager female; 35 years of age)

"I read a lot of science literature for pleasure; interested in many things scientific - will follow-up these interests through reading popular science and more formal research reports."
(adult educator and farmer; male; 40 years of age)

Table 4.4 Knowledge and skills utilised in personal interests

		Survey respondents number, % all respondents (n=805) Knowledge	 Skills
Utilisation in personal interests and pursuits[1]		**649** (81%)	**641** (80%)
Written examples or explanations provided		**328**	**47**
Themes described[2]	**A general interest in science** e.g. reading; documentaries	129	5
	Involvement in nature-based activities e.g. bushwalking; gardening	118	11
	Interest in specific areas in science e.g. astronomy; physics; health sciences	55	3
	Computer and other technology-based interests/hobbies	28	1
	Other e.g. cooking; sports; music	52	18
	Volunteer work	27	7

[1] Ticked 'In my personal interests and pursuits (outside work and study)' for:
Knowledge – survey Question 5 (*In what situations do you draw upon your science knowledge?)*
Skills – survey Question 7 (*In what situations do you apply these skills?)* (see Appendix 6)
[2]Themes identified from open responses to survey Questions 5 and 7 (see Appendix 6)

A second major theme to emerge from the written comments was the connection people made between their science knowledge and their interest in the natural and physical world (Table 4.4).

"I have a keen interest in the environment and biology which flows on to my love of nature, gardening and reading."
(female; 43 years of age; broad knowledge of fundamental principles, and specialist knowledge in biology, statistics, environmental systems, chemistry and physics)

"I have always had an interest in the environment - especially the geological environment and look with interest at landscapes wherever I go."
(male; 60 years of age; broad knowledge of fundamental principles, and specialist knowledge in chemistry, physics, mathematics and statistics)

"I have a keen interest in the natural world and my science degree to a large degree has framed my view of the world and taught me to question what I observe. It has also deepened this interest as I now have a better understanding of how and why things happen in the natural world."
(female; 28 years of age; broad knowledge of fundamental principles, and specialist knowledge in biology, chemistry and environmental systems)

People reported drawing upon their science knowledge or skills in a diverse range of other personal pursuits, including technology-based hobbies, sports, and cooking (Table 4.4).

"In terms of personal interests, I trained in physics and have a long standing interest in photography. This activity requires a reasonable knowledge of optics, and physics training gives one a leg up in that regard."
(female; 52 years of age; broad knowledge of fundamental principles, and specialist knowledge in biology, chemistry, physics, mathematics and statistics)

"I am a keen cook and baker and I use my knowledge of chemistry and troubleshooting gained from my science degree frequently in the kitchen."
(female; 29 years of age; broad knowledge of fundamental principles, and specialist knowledge in biology and chemistry)

"I'm a musician (maths and physics), a sailor (physics)."
(male; 53 years of age; broad knowledge of fundamental principles, and specialist knowledge in all areas listed)

"I use my research skills, creative problem solving and make observations of the world around me every day, whether I'm advising a friend on a product I've been researching, or writing a report at work, or making ice-cream at home!"
(female; 35 years of age; marked 10 of the 11 listed skills as *agree* or *strongly agree*, the exception being 'leadership')

Providing advice to family and friends

'Providing advice to family and friends' was incorporated into the design of the questionnaire following advice from several practicing scientists who highlighted this as an area of importance for them personally. It proved to be similarly important to the majority of survey respondents (Table 4.5). Most respondents indicated that they used their science knowledge and/or skills in providing advice to family and friends (83% Table 4.1). It can be concluded, therefore, that an individual's science background has a flow on effect to society more broadly.

Table 4.5 Utilising science in providing advice to others

		Survey respondents number, % all respondents (n=805)	
		Knowledge[1]	**Skills**[1]
Utilisation in providing advice to family and friends		**610** (76%)	**567** (70%)
Written examples or explanations provided		**292**	**89**
Themes described[2]	Health	88	16
	General, non-specific	82	52
	Educating family	65	12
	Environmental issues	61	10
	Other e.g the 'natural world'; technology; energy	64	3

[1] Ticked 'In providing advice to family and friends' for:
Knowledge – survey Question 5 (*In what situations do you draw upon your science knowledge?)*
Skills – survey Question 7 (*In what situations do you apply these skills?)* (see Appendix 6)
[2]Themes identified from open responses to survey Questions 5 and 7 (see Appendix 6)

It was common for people to describe themselves as the 'go-to person' on scientific matters, with family or friends seeking their help and advice.

They might be sought as sources of general science knowledge, or specialist expertise, or for their science-based skills and perspectives.

> *"I'm known amongst my friends as the 'go to' girl on scientific understanding and rationalising what's going on in their lives."*
> (senior project officer, state government)

> *"As a science graduate I am asked to provide advice about how things work and to explain concepts that are raised in the media and elsewhere."*
> (pilot)

> *"My area of work also makes me the 'go-to person' in my family and amongst my friends when scientific issues are to be discussed."*
> (academic)

> *"Family and friends often seek my advice on matters which require a level of scientific knowledge. … Others often lack the underpinning knowledge required to understand technical issues which concern them and turn to me for advice."*
> (first aid instructor)

> *"I provide detailed advice to family and friends on many science issues, but particularly Climate Change."*
> (atmospheric scientist)

> *"Friends sometimes seek clarification on issues that they feel I may have a better grasp of than themselves. On many occasions my involvements with service clubs and committees see me asked to explain the value and/or meaning of some pamphlet or letter that has been presented to the group. (eg further insight into prostate problems including prostate cancer, and why many men die with it rather than of it.)"*
> (pharmacist)

> *"My family and friends are always seeking my advice in my profession and often in any scientific discipline."*
> (microbiologist)

> *"I'm the one who answers questions about why the sky is blue."*
> (manager, innovation and commercial development)

In addition to the 'information sharing' illustrated in the quotes above, people also described providing advice and opinion, often in the context of applying science-based skills.

> *"My friends and family often ask my opinion as I gather all the facts, take an unbiased view and then give my opinion in a logical manner, which can help provide a good mitigation. They also believe I know a lot more than they do in many areas because of my science degree."*
> (business owner / IT contractor)

Some people described active promotion of a 'more scientific approach' among family and friends.

> *"I talk to friends and family about science, challenge their beliefs and apply scientific principles to gather evidence to help make decisions."*
> (executive coach)

> *"Along with other examples I have often had to debunk internet conspiracy theories based on voodoo science, and address the outlandish claims of cosmetic companies, alternative health products etc."*
> (managing director of a consultancy)

> *"I occasionally disabuse friends or family of urban myths that contradict known biology, chemistry, or physics."*
> (public servant)

"Giving advice about whether advertising claims are plausible or whether they are impossible to implement without violating the laws of physics."
(ICT-based occupation)

"The general scientific principals that I learnt at school and in university form a basis for many of the discussions I have with my family and friends - although I have found it hard to influence people who don't have a similar background - as the respect and understanding of science is not always prevalent. I provide logical evidence and analyse problems when providing advice to family and friends."
(program manager – exploration/geoscience)

The most commonly described area of advice related to health (Table 4.5). For example, assisting family and friends to: make informed decisions about nutrition; understand medical conditions and treatment options; or make sense of product claims and media reports.

"Friends and family often ask me to explain biological or chemical advice they get, especially from the doctor".
(textile artist)

"With regards to my family, because of my education I am able to help 'translate' health information for my mum with type 2 diabetes. While I am not clinically trained, through my studies and training I do have the ability to identify accurate health information for my family and friends."
(research program development coordinator)

"Use my broad medical science knowledge in most aspects of daily life but particularly to help others identify bogus 'claims' made to market products."
(health manager)

"It is amazing how many of my friends ask for advice after reading about some new 'wonder drug' on the internet. After I ask them about clinical trials and population numbers, and verified results, they are a little more aware of the many scams and pseudo-science that abound in this medium."
(tutor)

"When discussing medical issues, the ability to develop a logical argument is most valuable. To be able to link symptoms to anatomical or physiological basics and explain in terms of symptoms is of undeniable benefit."
(laboratory technician)

A second theme to emerge from the examples was explaining the science behind everyday events, particularly in educating children.

"I have always brought my family and friends into situations where appreciation of the physical environment (i.e. the physics driving natural processes and systems) is both enjoyable and creates an interest into how nature works. I always attempt to explain the physics, chemistry and biological systems which interact with day to day life for my family and friends."
(public servant, science and environmental regulation)

"Teaching my young daughter about science – i.e. explaining what a shadow is, what is thunder etc., rather than lying by making up an untrue story to reduce her fears."
(senior consultant)

Influence on approach to societal issues

> *"My science background has profoundly influenced my 'world view' and encompasses every aspect of my life, including my belief systems and reference points for decision-making."*
> (male; 49 years of age)

The fourth situation listed for the potential use of knowledge and skills was 'in my approach to understanding contemporary issues in society' (see Appendix 6). Again, the majority of respondents agreed that their science background was an influence in this situation (88%, Table 4.1). There was no difference by age, gender, or level of formal science education and training.

The examples given often overlapped with examples of advice to family and friends (see Table 4.5). People used their science background both to understand an issue, and to present explanations, interpretations and views to others.

Environmental issues were the most common examples given (Table 4.6), arguably a direct reflection of the topical nature of environmental debates in the media. In making sense of environmental issues and alternative energies, respondents particularly emphasised the value of their science knowledge (Table 4.6). Science-related skills, on the other hand, tended to be discussed more in terms of appraisal of media reporting or a person's general 'world view'.

> *"My approach to societal issues is a science-based approach - systematic, analytical and rigorous."*
> (male; 56 years of age)

Table 4.6 Influence of science on approaches to contemporary issues

		Survey respondents number, % all respondents (n=805)	
		Knowledge	**Skills**
Influence upon approach to understanding contemporary issues in society[1]		**675** (84%)	**635** (79%)
Written examples or explanations provided		**296**	**195**
Themes described[2]	Environmental issues	142	30
	General, including general 'world view'	102	105
	Appraisal of media reporting	88	75
	Energy and other technologies	42	2
	Health	31	16
	Government policies	28	13

[1] Ticked 'In my approach to understanding contemporary issues in society' for:
Knowledge – survey Question 5 (*In what situations do you draw upon your science knowledge?)*
Skills – survey Question 7 (*In what situations do you apply these skills?)* (see Appendix 6)
[2]Themes identified from open responses to survey Questions 5 and 7 (see Appendix 6)

Understanding of an issue

Science knowledge, including knowledge of fundamental principles, may be called upon in the understanding of contemporary issues. Some respondents stressed need for a science background in order to 'make sense' of certain issues.

> *"Basic scientific knowledge I think is imperative to understanding many of the issues confronting all of us, including climate change and the loss of biodiversity etc."*
> (female; 49 years of age)
>
> *Global warming, water resources, pollution, waste recycling, sound abatement - none of these can be even contemplated without a basic knowledge of science."*
> (male; 44 years of age)
>
> *"I draw on my scientific knowledge to understand and share my knowledge of contemporary issues in society, especially Global Warming, and other environmental issues such as extinction and deforestation."*
> (female; 47 years of age)
>
> *"Virtually every current issue has a scientific aspect to it, and it's great to be able to understand what's behind the sensationalist news stories."*
> (male; 34 years of age)

Objectivity and evaluation

In describing their approaches to contemporary issues, many respondents emphasised objectivity over emotion, and a need to evaluate the relevant data before accepting opinions or forming their own.

> *"I rely in what the evidence shows rather than what people feel when forming an opinion on contemporary issues."*
> (male; 35 years of age)
>
> *"In understanding contemporary issues I am interested in the evidence that is presented and can carry out my own investigations into the robustness of the evidence, its credibility and the way it is used to support or refute a particular claim or proposal."*
> (female; 52 years of age)
>
> *"I am strongly interested in the scientific aspects of current affairs, especially the promotion of clean energy. Throughout my life I have attempted to lake rational and logical decisions, and have generally managed to avoid being influenced by beat-ups and social panics."*
> (male; 75 years of age)

For some, this involved 'seeing beyond the politics'

> *"Some contemporary issues such as the politics and activism surrounding climate change require an understanding of natural sciences and objective assessment and evaluation."*
> (male; 60 years of age)
>
> *"I am able to see through the politics on issues such as climate change and make a more informed decision when I vote."*
> (female; 27 years of age)

Science, however, may be only one of several factors influencing their views.

> *"In considering some contemporary issues in society e.g. responses to climate change, water management etc., I use my knowledge of science research to weigh the value of information provided. My knowledge of economics and my personal ethics and values, however, are equally important in relation to my views on solutions to contemporary issues."*
> (female; 43years of age)

Scepticism and forming opinions independently

A questioning – and oft times highly sceptical – approach to media reports, political commentary and other forms of public information was common (Table 4.6).

> *"I am very analytical in my approach to societal issues and will usually not simply accept journalism reporting or opinions as gospel."*
> (male; 31 years of age)

> *"An analytical approach to understanding the issues of the day provides a deeper insight into the complexity of interactions, variously conflicting and complementing each other, than many a typical "media analysis" -- even in the broadsheets."*
> (male; 40 years of age)

> *"I think I use a rational and logical approach when hearing about contemporary issues, and I am very aware that there is probably a lot of complexity/unknowns to any issue, and we cannot come to quick conclusions based on a newspaper article. I trust the peer review process of scientists so I trust research backed findings e.g. as they relate to climate change."*
> (female; 28 years of age)

> *"The newspaper reporting is so limited and rarely discusses issues to the depth I wish to understand them. I feel confident in my ability to research issues further myself and be discerning about references."*
> (female; 36 years of age)

Confidence to share knowledge, persuade, and engage in debate

Some respondents went on to describe how their scientific approach to an issue gave them the confidence and 'tools' to share their views and, in some cases, participate in public debate.

> *"My science studies have made that the framework through which I look at contemporary issues and I guess then I feel confident and comfortable to share and argue my views and opinions."*
> (female; 30 years of age)

> *"I am highly active in environmental and social justice activism. I use my science background to understand the issues at stake, and to rationally discuss and attempt to persuade others with my logic."*
> (female; 29 years of age)

> *"I enjoy participating in media debate about scientific issues and use my experience and knowledge - particularly of statistics and the principles of scientific proof - to write newspaper articles for pleasure."*
> (female; 29 years of age)

Some frustration with communication, information sharing and decision-making

In discussing the influence of their science background on their approach to contemporary issues, some respondents expressed concerns that extended beyond frustration with the quality of information in the media. A few examples are provided below. No attempt was made at a thematic analysis – the examples were too specific and varied. They simply demonstrate concerns regarding the effectiveness of communication and information sharing in society.

> *"I am concerned that we seem to not have a mechanism for discussing how we want Australia to look in the future; our current system of government does not do this. I am also concerned that we don't have good ways for people to get the information they want, and the information they need."*
> (male; 47 years of age)

"I use my science background to understand climate change - but I also have an intense interest in understanding why the science alone is not sufficient to drive behavioural change in societies. ... I am an integrator of ideas across disciplines. Is this due to my science background?? In some ways it is a reaction to the narrow focus that some science based disciplines (and individuals) display."
(male; 52 years of age)

"I find my willingness to undertake an academic argument sometimes not widely accepted, or even occasionally intimidating to people who are not familiar with robust discussion (uneducated or not higher tertiary qualified) on the fors and against a particular point or theory. This can sometimes be personally frustrating and feels like it is hindering to progress, both personally and professionally."
(female; 60 years of age)

"I can get frustrated at times, when a simple solution to a problem is presented to society and politics gets in the way of achieving a desirable outcome."
(female; 29 years of age)

Influence on other aspects of life

Across the four situations described above, three additional themes were identified (Table 4.7). Both knowledge and skills were associated with 'making choices', 'increased confidence', and 'communication of science'.

Table 4.7 Influences of science upon various aspects of everyday life

		Survey respondents number, % all respondents (n=805)	
Written examples or explanations provided of influence upon other aspects of everyday life[1]		**Knowledge**	**Skills**
Themes described[2]	**Communication**, including: advocacy; public education; interactions with scientists	60	36
	Making choices, including: work choices; setting priorities; 'everyday' choices; purchasing decisions; financial planning	58	61
	Increased confidence, including in: understanding issues; providing advice to others; researching and learning	16	18

[1] Written responses not included under: 'Work' – Table 4.2; 'Personal interests '– Table 4.4; 'Advice to family & friends' – Table 4.5; or 'Contemporary issues' – Table 4.6.
[2] Themes identified from written responses to survey Questions 5 and 7 (see Appendix 6)

Chapter 5: Personal benefits from a science background

The previous chapter described the various ways in which a background in science influences individuals and, through them, their workplaces and communities. The survey also asked people to describe what they most valued about their background in science.

What do you most value from your background in science? was presented as an open question, with no prompts other than advice to consider this in terms of their 'personal priorities' (see Q8, Appendix 6). The response rate was high, at 94 per cent – this was clearly a topic about which respondents felt strongly.

Select findings

- Scientific 'ways of thinking' were among the most highly valued outcomes from a background in science
- Other valued skills included research and problem solving skills
- One in four respondents referred to the importance of their science knowledge, including knowledge of the scientific process
- One in three respondents described the development of their personal capacities and abilities, such as their ability to 'better appreciate the world around them'
- People also valued the opportunities their backgrounds in science afforded, including opportunities for rewarding employment and a chance to make a positive contribution to society

Several common themes emerged from the written descriptions (Table 5.1). Each of the four most dominant themes is further described below. The first three – 'ways of thinking', 'other skills', and 'knowledge' – can all be considered as descriptions of learning outcomes. The fourth theme relates more to the consequences of this learning. There was no difference in the pattern of responses by gender, nor between researchers and people in other occupations. Illustrative quotes are included. In each case the person's full response to the question is given. Many responses were coded against multiple themes.

Ways of thinking

More than half the respondents (58%, Table 5.1) described skills that can be collectively considered 'ways of thinking'. Several categories were derived from the various terms and expressions used, the following being the most common:

Analytical (34%; analytical, logical, critical, systematic, structured, clarity of thought)
A way of thinking through an issue that is rigorous and careful, attentive to detail, and looks to connect information.

Questioning (22%; questioning, evaluative, independence of thinking, reasoning, sceptical)
A tendency to look beyond the surface of things, to evaluate information, and to derive one's 'own conclusions'.

Objective (14%; objective, non-emotive, evidence-based, rational, factual)
A way of responding to information or situations that is based on data and evidence, rather than emotion, philosophy, or ideology.

Table 5.1 Most personally valued aspects of a background in science

	Themes identified from open responses to the question: *"What do you most value from your background in science?"*	Survey respondents[1] number	% of respondents to this question (n=758)
LEARNING OUTCOMES	**Ways of thinking**	**438**	**58%**
	Analytical; logical; 'critical thinking'; systematic; structured	254	34%
	Questioning; evaluative; independence of thinking; reasoning; sceptical	167	22%
	Objective; non-emotive; evidence-based; rational	105	14%
	Open-minded; aware of different perspectives; accept own fallibility	28	4%
	Innovative; creative thinking; lateral thinking	22	3%
	Other, comments including: interdisciplinary or multidisciplinary thinking; innovative, creative, lateral thinking	34	4%
	Other skills	**295**	**39%**
	Research skills; learning skills; enquiry; independent learning	119	16%
	Problem-solving skills, including: find root causes; identify concepts; derive solutions	118	16%
	Technical skills, including observation skills, experimentation, and quantitative skills	79	10%
	Presentation skills; ability to develop an argument; communication skills	42	6%
	Work practice skills, including project management, collaboration skills, independence	26	3%
	Knowledge	**205**	**27%**
	The scientific method; science as a process; philosophy of science	66	9%
	Specified subject areas or depth of knowledge	66	9%
	General comment: 'the knowledge'; 'the intellectual framework'	42	6%
	Fundamental science concepts and principles; vocabulary of science	38	5%
	Breadth of knowledge across a range of science areas	20	3%
Capacity or ability		**267**	**35%**
To better appreciate the world / natural world; to see the 'bigger picture'		145	19%
To better understand events/activities/issues/how things work		81	11%
Other, including ability to: transfer knowledge/skills; feel confident or 'empowered'; deal with complexity		74	10%
Opportunities		**108**	**14%**
For employment; interesting/rewarding employment		63	8%
Other, including to: share knowledge or teach; contribute to society/knowledge; gain respect in the workplace; undertake further study; pursue personal interests		58	8%
Experiences		**86**	**11%**
Wonder; excitement; enjoyment; curiosity		71	9%
Other, including: social, working or communicating with particular people or groups; intellectual stimulation and rigour		27	4%

[1] Many respondents described multiple aspects

> *"Better understanding of the natural world. Critical thinking. Appreciation of interconnectivity between disciplines. Appreciation of the value of evidence and ongoing questioning."*
> (male, 60 years of age, environmental planner with local government)

> *"To be able to use the knowledge I have gained through Uni and the workplace to question all that is presented to me - it becomes second nature."*
> (female; 49 years of age; analytical chemist)

Other skills

While 'thinking skills' were the most widely cited of the benefits of a science background, the development of other skills also featured strongly (Table 5.1). These included:

Research skills (16%), including the ability to identify the necessary information, to locate and make sense of it.

> *"The deep understanding I gained of the world and how it works. And the capacity to delve deeply into what I don't understand and turn that position around."*
> (male, 52 years of age; business consultant)

Problem-solving skills (16%), while often simply described as 'problem-solving', some respondents explained this in terms of identifying root causes or the associated, fundamental concepts, and deriving possible solutions.

> *"The ability to translate a real world problem into an abstract framework where it may be partly or wholly solved, and then to translate that abstract solution back into action in the real world."*
> (male, 64 years of age, retired academic)

Technical skills (10%) was a varied grouping, and many responses also reflected a way of thinking and seeing the world – 'attention to detail' (n=37), 'an experimental approach' (n=20), and quantitative skills (n=16), for example. In addition, some people described the ability to work with charts and numeric data, or skills in the use of technology.

> *"The ability to look at all the facts without bias, to look at a problem in a unique way and experiment with solutions rather then only relying on the current business prescribed methodology. Oh and the joy of finding things out!"*
> (female, 34 years of age; senior consultant)

> *"The ability to apply the technical knowledge that I learnt to the work I do. Even though technology changes all the time, the fundamentals are still relevant."*
> (female, 43 years of age, project manager)

Knowledge

More than a quarter of respondents (27%, Table 5.1) described the value they placed in knowledge gained through science. An understanding of the scientific process (9%) was cited as often as knowledge in a specific field or depth of knowledge (9%).

> *"Knowledge of how science works - considering what is known, experimental design, reliable measurement, application of statistics, drawing conclusions. This feeds into a scientific approach to education - it IS possible to find out what works. I also value the factual information I gained (much of which has been updated of course), but it was a starting point for understanding scientific progress."*
> (female, 65 years of age, associate professor in education)

Capacities or abilities

Many respondents (35%, Table 5.1) identified their science background with a general development of their personal capacities or abilities. For many, this was described in terms of 'a better appreciation of the world around them' (19%, Table 5.1).

> *"An appreciation of uncertainty and how it is to be valued, not feared. An appreciation of the awesomeness of the natural world in so many ways."*
> (female, 58 years of age, freelance copy editor)

> *"That I understand something more about the world. Sometimes the depth and beauty of how it all works is overpowering."*
> (female, 57 years of age, head science school teacher)

> *"The knowledge I came out with after leaving university has made me appreciate the world from a more involved perspective than previously. I was mature age before entering university and looking back in comparison I felt in my own world and not in society. I now embrace society and I feel as a scientist I am giving back, being my piece in the big community puzzle."*
> (male; 34 years of age; microbiologist)

The ability to better understand particular issues, events or activities was also highlighted (11%, Table 5.1).

> *"Understanding the world around me, and the technical aspects of contemporary political issues."*
> (male; 41 years of age; policy officer)

Opportunities

People also valued the opportunities afforded by their background in science (14%, Table 5.1) – for example, opportunities for rewarding employment, to pursue personal interests, and to contribute to society.

> *"That it has made it possible for me to find my niche in the workplace and happy in my job that I can now 'make a difference' and make a contribution to the community."*
> (female, 68 years of age, risk analyst)

Experiences

Finally, respondents also described aspects of their experience as highly valued, both past and continuing experiences – wonder, curiosity, intellectual stimulation, and social networks, for example (11%, Table 5.1).

> *"I value having experienced what it is to be a researcher - to have been at the cutting edge, and to know what it is like to create 'new' knowledge. The ability to deconstruct - and reconstruct - a problem is also invaluable and generalises very nicely. Its very difficult to teach or learn these particular skills in any other way but for the scientific context - I've found them to be invaluable, for instance, in setting organisational or business strategies."*
> (male, 40 years of age, manager)

> *"Rational approach to life and ongoing curiosity about the world around - the more you know the more exciting it is to find out more."*
> (female; 30 years of age; solicitor)

Chapter 6: Developing the scientific mindset

This study was based on the premise that there is such a thing as a 'scientific mindset' – that people with science backgrounds, irrespective of their career paths, are likely to share particular ways of thinking and working.

> *"The training provides a mind set that cannot be picked up and put down depending on where you are."*
> (female; 57 years of age)

Characterisation of a 'scientist'

In summary, people with science backgrounds tend to be analytical, objective, evaluative and questioning (Table 6.1). They are also life-long learners, and confident in their problem-solving abilities.

Table 6.1 Traits most frequently attributed to a background in science

	Traits most frequently associated with a background in science[1]	**Survey respondents to describe this trait** number, % of all respondents (n=805)
Characteristics related to ways of thinking	**Analytical**: think through issues in a systematic and critical way, looking for the underlying logic	**433** (54%)
	Objective: try to avoid emotive responses to issues, favouring instead an evidence-based approach	**225** (28%)
	Evaluative: assess information, examining the validity of the data and reliability of the source	**212** (26%)
	Questioning: take an investigative approach to issues and a questioning approach to assertions by others	**147** (18%)
	Open-minded: interested in all sides of a debate, aware that there is always more to be learned	**62** (8%)
Other skills and characteristics	**Life-long learners**: inherently curious, and equipped with the skills and knowledge to investigative and learn	**268** (33%)
	Problem-solvers: confident in facing new challenges, with the skills to identify problems and develop solutions	**190** (24%)
	Observant and experimental: attentive to detail, addressing questions by forming and testing hypotheses	**106** (13%)

[1] Themes identified from written responses to Questions 5, 7 and 8 (see Appendix 6)

A Background in Science set out to discover the ways in which people who identify as having science backgrounds described such backgrounds (Chapter 3), viewed the influence upon their lives (Chapter 4), and what it is that they most valued (Chapter 5).

Importantly, the data also provides insight into the scientific mindset by identifying the traits that people most commonly identify with science and scientists.

The data in Table 6.1 was drawn from written responses across three survey questions – respondents' descriptions of using knowledge, application of skills, and the aspects of their science background most valued.

This view of the scientist was independent of both level of science qualification and occupation. There was no difference in the pattern of responses between those with a PhD and those whose highest science qualification was a bachelor's degree, nor between people working in research roles and those in other occupations.

The remainder of this chapter relates to the development of such a scientific mindset. Specifically, what respondents considered fundamental to a university science education.

The fundamentals for university level science education

The characteristics described above are the key traits associated with a science background, broadly defined. People recognised these as the characteristics of a scientific mindset. These are the attributes that people with science backgrounds most valued. While they also emphasised that a science background typically involves more than the study of science at university, it seems fair to conclude that university science education should continue to give the development of such attributes high priority.

In addition, the study specifically asked people to describe what they considered fundamental to a university science education. Again, the response rate was high (n=742; 92% of all respondents). Table 6.2 presents the themes that emerged.

Learning outcomes

Most of the comments related to learning outcomes – what graduates should know or be able to do by the end of their studies – and these are grouped under three broad headings: knowledge; ways of thinking; other skills (Table 6.2).

Knowledge

More than half the respondents (57%) emphasised the fundamental importance of knowledge (Table 6.2). For some this involved knowledge in a particular subject area, with mathematics being the most commonly mentioned (16%). Knowledge of the process and philosophy of science featured (17%), as did calls for breadth of knowledge across a range of subject areas (17%).

Ways of thinking

As emerged for other parts of the survey, various descriptions of ways of thinking featured as prominent themes (38%, Table 6.2). Analytical, logical, critical (17%) and evaluative, questioning and reasoning (13%) were the typical descriptors used.

Other skills

'Thinking skills' aside, many people described other skills they considered fundamental (41%, Table 6.2). These included presentations skills (17%), research skills (14%), various technical skills (10%) and problem-solving skills (7%).

Table 6.2 Fundamental priorities for university science education

	Themes identified from open responses to the question: *"What do you think should be considered fundamental to a university science education?"*	**Survey respondents**[1] number, % of respondents to this question (n=742)	
LEARNING OUTCOMES	**Knowledge**	**423**	**57%**
	Knowledge in a specified subject area	225	30%
	Mathematics 118 16%		
	Physics 76 10%		
	Chemistry 71 10%		
	Statistics 68 9%		
	Biology 58 8%		
	Other science subjects inc'. History of Science; Ethics: Environmental Systems; Geology	89	12%
	The scientific method; science as a process; philosophy of science	126	17%
	Breadth of knowledge across a range of science areas	127	17%
	Broad first year, with specialisation later	33	4%
	Fundamental science concepts and principles; vocabulary of science	74	10%
	Science & society; relevance & importance of science; the 'business' of doing science	54	7%
	Depth of knowledge; specialisation in at least one area	36	5%
	Some subjects outside science	18	2%
	Ways of thinking	**282**	**38%**
	Analytical; logical; 'critical thinking'; systematic; structured	127	17%
	Questioning; evaluative; independence of thinking; reasoning; sceptical	94	13%
	Interdisciplinary or multidisciplinary thinking; systems thinking; synthesising	46	6%
	Objective; non-emotive; evidence-based; rational	38	5%
	Open-minded; aware of different perspectives; accept own fallibility	33	4%
	Innovative; creative; lateral thinking	27	4%
	Other skills	**306**	**41%**
	Presentation skills; ability to develop an argument; communication skills	124	17%
	Science communication 43 6%		
	Writing - general 31 4%		
	Writing– scientific writing; report writing 22 3%		
	Oral presentation 18 2%		
	Research skills; learning skills; enquiry; independent learning	107	14%
	Problem-solving skills, including: find root causes; identify concepts; derive solutions	55	7%
	Technical skills inc'. experimentation, observation skills, and computing skills	76	10%
	Work practice skills inc'. leadership entrepreneurship, collaboration skills	46	6%
Curriculum design		**171**	**23%**
Application of theory to real life situations		55	7%
Practical component; fieldwork; 'hands on' experience		40	5%
Internships; study abroad; work experience; building industry/professional networks		23	3%
Flexibility; choice in subjects; opportunities for individuals to explore ideas & interests		25	3%
Other comments, including: problem-based learning; group projects; research projects; relevance to diverse employment outcomes		48	6%
Overall experience		**69**	**9%**
Inspirational; exciting; enjoyable; encouraging curiosity		37	5%
Rigorous; intellectually challenging; high standards expected/demanded		13	2%
Other comments, including: exposure to the latest thinking/technology/approaches; excellent teaching staff; encouraging of diverse graduate aspirations & outcomes		28	4%

[1] Many respondents described multiple aspects

Curriculum design

One in four respondents described some aspect of curriculum structure or design (23%, Table 6.2). These suggestions ranged from connecting theory to practice, including through internships and other 'hands on' experiences, to opportunities for choice, and the inclusion of research projects.

Overall experience

Finally, some respondents stressed the importance of the overall experience (9%, Table 6.2). This included calls for education that was inspirational, rigorous, and with exposure to the latest in scientific thinking and approaches.

With few exceptions, the patterns of responses to this question were independent of age, gender, qualification or occupation. One exception related to specific knowledge areas: people who had studied university biology were more likely to consider biology as fundamental (GF, $P<0.01$). There was no such effect seen for other subject areas, including mathematics. The second exception was for curriculum design: for both age groups, females were significantly more likely to make comments relating to curriculum than males (GF $P<0.01$).

Just some of the many voices

Coding responses to complex survey questions is a powerful method to uncover themes, their range and relative prominence. It does, however, mask the voice of participants, stripping away the emotion and nuance of comments. As a counterpoint, therefore, the following quotes are included.

These quotes illustrate some of the themes described in Table 6.2. They are just a small sample of hundreds of comments, yet they show some of the diversity of views and suggestions offered by survey respondents. The voices are united in one respect – they emphasise the importance of university science education to the future of science and society.

On the process, questioning, and the importance of broad science literacy

> *"Understanding of the science process - use of evidence; build on previous ideas; theories only our best approximation to that point and may not be correct. Build a healthy scepticism. Challenge everything. Broad based science education – sound understanding of chem/ phys plus some biology/ geology for everyone before specialization. Hugely important that we create a broadly scientific literate population".*
> (male; 60 years of age; manager)

On ways of thinking, and science communication

> *"Teaching people ways to be critical of information, but not closed to the possibilities of new ideas. I think people need to be taught how to identify their own subjectivity and biases, and recognise that science is not entirely objective, and that is okay. People need to learn how to give and take criticism in the spirit of intellectual discovery, not personal attacks. There should also be an element of communicating science to non-scientific people (maybe only a minor thing for most students, but with the option of continuing for those with a talent for it). We need more scientists who can talk to the general public."*
> (female; 29 years of age; policy officer)

On problem-solving

> *"To develop an understanding of taking a problem from first principles through varying degrees of complexity. The mechanics of deriving solutions is not as useful as understanding the principles which lead to a final result. That is, knowing and understanding WHY is more important than HOW."*
> (male; 52 years of age; geoscientist/manager)

On relevance to diverse employment outcomes

"The applicability of the knowledge. Be it as an academic or in other fields of work. The transferable skills that are developed in science are not really known to most employers and they still consider science graduates to be boxed in only research roles."
(female; 28 years of age; investment intern)

On innovative thinking, and science and society

"Encourage free thinking. Society and the science arena is being overtaken with policy, politics and surface knee jerk reactions to issues. A sense that science has a lot to contribute and a pride in that ability is critical. Science has never had the type of confidence that areas like engineering encourage."
(female; 58 years of age; manager science unit)

On fundamentals, and the development of thinking skills

"How to evaluate causality. Students are under-educated in how to evaluate different types of evidence. They need to be able to understand the difference between associations and causality. Moreover, their understanding of different types of evidence needs to be applied to what they encounter in everyday life. Therefore, there should be a general science course in every science degree that teaches them basic principles in science and asks them to apply it to, for example, statistics reported in the media and advertisement. These types of courses will have a considerable influence on how students then think about their world when they leave university."
(female; 33 years of age; clinical psychologist)

On the scientific process, systems thinking, and wonder

"The power of the scientific method, peer review and dissemination of knowledge to overcome human irrationality and selfish motivations. The ability of scientific technology to reveal the wonder and complexity of the universe, at all scales of investigation and to provide conceptual frameworks that can link physical phenomena across all those scales from sub-atomic, through terrestrial to galactic. The yin/yang of reductionism versus systemic understanding of physical/chemical/biological/ecological processes. The interplay of order and chaos, predictability and randomness. It's just awesome!"
(male; 60 years of age; town planner)

On multidisciplinary thinking and communication skills

"Collaboration with other disciplines – science alone rarely provides the best solution in practical and human terms. It may provide technical input which contributes to the solution. Communication and leadership training is essential. To achieve outcomes based in science it is essential that scientists can communicate with lay persons and understand, value and respect the contribution and potential of other disciplines."
(female; 43 years of age; policy officer)

On independent and creative thinking, and breadth of learning

"The most fundamental aspect of a university education is the ability to think independently, critically, and creatively. This is something that is implicit in all disciplines, but it might be good to make it more explicit. Perhaps all students should take a Critical thinking class. A basic knowledge of both Scientific and Humanities approaches to the world would also be good."
(male; 39 years of age; university lecturer)

On thinking skills

"As I was instructed at my first day at uni; "You are not here to learn facts. You are here to learn how to think, how to question, how to analyse and critique assertions." The number of number-crunching students I have met who are skilled at addressing problems within an extremely narrow domain, but who lack the ability to think critically, to link between causes, to exercise proper, systematic and repeatable analysis is of very real concern."
(male; 49 years of age; public servant – science and environmental regulation)

On the importance of transferable science skills

"The skills that make you an effective scientist but that can be applied to a wider field as not all science students end up in science. Such as logic, problem solving, team work and people skills."
(female; 39 years of age; quality assurance manager)

On an early broad grounding, and thinking skills

"A well rounded general introduction to science well before any specialisation occurs. A good generalist will, on balance, always beat a specialist when confronted with a complex problem that lies outside an area of specialisation. The training in 'thinking' as opposed to 'thought' using the historical tenets of the scientific method."
(male; 50 years of age; industry specialist IT)

On ways of thinking, and keeping an open mind

"Problem solving and "lateral" thinking skills. Inquisitiveness and interest in the world. The ability to be patient and hear another's point of view or hypothesis, to evaluate with an open mind and to base a decision based on the facts known at the time. The understanding that an opinion or "knowledge of a fact" may change when new evidence is provided."
(female; 53 years of age; previously industrial R&D laboratory technician)

On mathematics, questioning, and systems thinking

"I believe mathematics underpins a lot of what science involves. However, what is considered fundamental is teaching students, through all science subjects, to question where the information came from and what purpose does it serve. To make connections between concepts and to know that science and 'laws' can be constantly questioned. To prove or disprove theories, to gain a better understanding of how our world functions and inter-relates."
(female; 29 years of age; senior fire ranger)

On logic, objectivity, and the scientific process

"Integrity. To dispassionately argue on the basis of evidence showing clearly the logic, the description from the observations, the predictions the description makes, and that the predictions were validated. Honesty to state that (with rather few exceptions) science is not absolute, it is a system of useful descriptions and that new evidence may lead to a new description. To relate scientific endeavour to the society we share. Perhaps tricky for theoretical areas, but even there, the aim is to build better understanding for improved prediction. Science must be conducted dispassionately, but as a conscious choice noting the human context, not by ignoring our humanity. Humility, it is a privilege to work in science."
(male; 47 years of age; senior air scientist)

Chapter 7: Case studies

Case Study 1: On biology, policy, and the skill of question-making

Science knowledge and skills in the development of policy

"I studied zoology and am working in the field of wildlife policy for the government. In addition to using my science knowledge, I draw extensively on the skills I developed through studying university-level science. You cannot publish a scientific study (or even submit a thesis) without practising the development of a logical argument. I draw on this skill daily in my preparation of policy – i.e., why there is need for the policy, analysis of what has been done elsewhere, what the limitations are to any existing policies, and therefore what needs to be implemented."

"Science has also taught me to observe without bias or influence – or at least seek an understanding of the bias or influence that is present and take it into account."

Developing skills in ongoing learning

"The information that I gained in my degree and the process for understanding the world enable me to answer questions I've had for years before university and new ones that come up daily."

"Science has given me a way to find answers. I think anyone with a questioning mind may find themselves frustrated by a limited knowledge of a given field, particularly when it's not obvious where to seek answers. However, since studying science, I understand how to find answers and – more importantly – how to frame questions. I now know not to take unreferenced reports as truths – something I think children should learn at school."

Understanding the natural world

"I use my knowledge of natural systems to understand the world of which I am a part."

"My understanding of natural systems helps me talk about climate change, plants and animals. I teach my children with the knowledge I gained from my science degree and teach them how to find answers to their questions. The scientific method, a knowledge of how to read and understand research, combined with an enquiring mind lets me ask questions and seek answers, particularly when it comes to issues relating to climate change, irrigation/environmental water, threatened species, ecosystems, etc."

"I can look out my window and see birds' courtship displays, hear birdcalls and notice the temporal partitioning of sound-space (and even notice this phenomenon in my own house as my husband and I communicate between our children's screeches and squawks). It makes me smile that I can apply understanding of a natural system to my own day-to-day existence."

BACKGROUND INFORMATION	
Areas of knowledge	Broad knowledge of fundamental sciences (except physics), with specialist knowledge in areas of biology, environmental systems and statistics
Personal details	Female, born 1971
Occupation	Senior Policy Officer
Current residence *(ABS classification from postcode)*	Inner regional Australia
University science qualification	Bachelor's degree with Honours, 2004

Case Study 2: On curiosity and a fascination for the natural world

"As a reporter I use my education to understand issues that involve science, but more commonly my scientific training is used as a framework that assists evidence-based analysis and reporting on non-science issues.

"I love observing the natural world and interpreting it through my scientific understanding. I try to share my scientific knowledge with my children at every opportunity."

From local political issues to life philosophies, my scientific knowledge informs my viewpoint."

The most personally valued aspects of a science background

"The ability to understand the world around me in an informed and sophisticated way. Everywhere I look I can see evolution, physiology, physics, chemistry etc. It makes the world fascinating, inspiring and deeply satisfying."

Priorities for university science education

"A history of ideas and their development would provide an appreciation of the value of scientific knowledge and an understanding of those who are threatened by scientific knowledge. A broad overview of the major scientific disciplines designed to inspire the curiosity of students in areas of science other than their chosen interest."

BACKGROUND INFORMATION	
Areas of knowledge	Knowledge of fundamental life sciences, with specialist knowledge in biology and environmental systems
Personal details	Male, born 1974
Occupation	Reporter
Current residence *(ABS classification from postcode)*	Remote/Very Remote Australia
University science qualification	Bachelor's degree with honours, 2003

Case Study 3: On science plus economics in the public service

"Since completing a BSC majoring in chemistry, I have had the privilege of being able to see the world around me through the lens and objectivity of the scientist and knowing the value of empirical observation."

The combination of science and economics
"I later obtained a Bachelor of Economics and the two combined provide a rich insight into how the worlds of science and economics can influence public policy. During my economics studies I was able to view the teaching of the subject through the eyes of scientific training. Most of my career has been in the public service. I have also been a lobbyist, a regulator, and Managing Director of a specialist consulting practice."

"As a regulator introducing a new piece of law, I had a much more clear eyed view of the fact that the law was perturbing a system largely in equilibrium and that therefore I could observe (and make predictions on) how the system (i.e. elements of the Australian economy) would respond. While some of this required the insights of the economist, it is the combination of the two that provide such a strong insight."

"Statistics is useful in understanding correlation versus causality. Combined with science they have always helped in the art of approximation, the concepts of significance and non-significance in figures and the changes in them."

Interests and insight into contemporary issues
"As to personal interests, my science background has informed my strong interest in theories of evolution, genetics/DNA/inheritance, and the history of ideas (either scientific or more broadly). It provides insight into the debate around the scientific evidence for human caused climate change and much more. My training in biology and chemistry has helped me see the abysmal nature of the debate on climate change in Australia. Objective observation and modeling has rarely been used in rational debate, which instead has been dominated by highly charged, emotional claim and counter claim."

The most personally valued aspects of a science background
"A much more clear-eyed view of the world. The ability to try to observe scientifically, to form hypotheses, and to look at ways of testing them."

"Even when studying economics some years after the science degree, the latter was a great asset when it came to differentiating ideological position from more objective stances in economic debate. Whether resolving mechanical problems with a car or trying to fix or repair domestic equipment (electronic or mechanical), the analytical processes from the scientific background always help."

BACKGROUND INFORMATION	
Areas of knowledge	Broad knowledge of fundamental sciences, with specialist knowledge in biology and chemistry
Personal details	Male, born 1952
Occupation	Consultant in data protection; Managing director of a specialist consulting practice
Current residence *(ABS classification from postcode)*	Major cities of Australia
University science qualification	Bachelor's degree, 1974

Case Study 4: On science communication and social change

"You're never not a scientist. You always assess information for its quality, and double check things to be sure that's really how they're working, and ask questions about interesting things that you see or that happen, and look for answers to those questions. It's a pervasive way of life.

I work as a science communicator, translating scientific information for a range of audiences."

A commitment to social change
"I am strongly committed to environmental work and social change to improve our impact on the earth. I use my physics and environmental understanding to learn more about processes, situations, options for change and to promote useful solutions to people in appropriate situations. This has included leading botanical walks as a volunteer, preparing material for newspaper articles and radio and television shows, working as a project manager in an environmental non-profit to develop alternative water solutions and communicate those to both specialist audiences and the general community, helping friends develop sustainable gardens, supporting my local Transition Towns group, and lots more."

The most personally valued aspects of a science background
"My basic understanding of physics, which is just fascinating all round and never grows old. I love the field. The broad understanding of many areas of science, which lets me work as a science communicator. The ability to read effectively and understand scientific materials and place those in their correct context. A more precise understanding of statistics (which most humans are really awful at perceiving) and the ability that comes from that to accurately assess risks, probabilities – I sometimes buy a Lotto ticket anyway and just consider it a donation!"

BACKGROUND INFORMATION	
Areas of knowledge	Broad knowledge of physical sciences, with specialist knowledge in physics, mathematics, statistics, computer science and environmental systems
Personal details	Female, born 1974
Occupation	Full-time mum, part-time science communicator / environmental change activist
Current residence *(ABS classification from postcode)*	Major cities of Australia
University science qualification	Bachelor's degree, 2000

Case Study 5: On an academic's science beyond the university

"I work as a university lecturer teaching physics and astrophysics to undergraduates and undertaking research in astrophysics."

The power of physics knowledge
"I find that my science background influences the way I approach all sorts of questions and issues. When I exercise I understand the basic mechanics and physics and how (in principle) to get the most efficient use from muscles. I frequently get questions on science topics from friends and family and talk to them about them, including things like energy efficiency, solar power etc."

The importance of critical evaluation
"Since I work in science much of my work involves the skills associated with science – logic, analysis, evaluation, for example. These skills are useful beyond the work context though and I frequently find myself critically evaluating statements or interviews from the media on the basis of my knowledge of the topics they discuss and trying to determine if there are logical flaws or inconsistencies in the views/information they give."

"When it comes to understanding contemporary issues in society I often find myself despairing at the low level of scientific literacy in the community and the media and the desire of many people to ignore scientific evidence or studies because it doesn't suit their personal interests.

For a science graduate I think that critical thinking is a core competency that they all should have. The ability to look at data collected, or reported in the published literature, and critically evaluate whether that data is consistent or supports a particular hypothesis or not."

BACKGROUND INFORMATION	
Areas of knowledge	Broad knowledge of fundamental sciences, with specialist knowledge in physics, mathematics and chemistry
Personal details	Male, born 1969
Occupation	Associate professor at a university
Current residence *(ABS classification from postcode)*	Inner regional Australia
University science qualification	Bachelor's degree, 1990 PhD, 1995

Case study 6: On science learning as fundamental to life on the farm

Science on the farm

"From a farmer's perspective we are scientists at work in each and every situation – making observations, problem solving, identifying solutions, the application of scientific principles. For example: the application of physics in the construction and operation of farm machinery; understanding electrics and electronics in auto-steer and GPS technology (though I am not that good at this type of thing!); chemistry in the mode of action when using pesticides, reactivity of metals, biology at work with crop diagnostics, nutrition, and disease; sheep nutrition, disease and animal husbandry."

"An understanding of the scientific principles involved allows one to be more confident in explaining problems, how to repair breakages (we don't have the luxury of mechanics and shops nearby, so improvisation is the norm), symptoms, chemical processes. The list is endless. Researching information to solve a problem is made easy as I usually have a basic understanding of the issue to start with and you have a good idea of where to start looking or who to contact and ask the right questions to get an answer. I believe a science background is an essential for all farmers....it makes farming a lot easier!"

"Most importantly it is essential that one continues to learn, is open to new ideas and ready to adopt and adapt to change, reads widely and is well informed."

Communicating with researchers

"When discussing issues facing growers with researchers or some problem with plants or animals, you are on the same planet as them and they are more likely to respect your opinion and acknowledge your experience if you have a science background....you are not just a 'simple' farmer." This is invaluable when involved with research, development, extension or adoption. I have a perspective from both sides."

The personal rewards of a background in science

"The ability to think laterally; an effective problem solving ability; a desire to learn new things; the ability to critically evaluate data and information; an open mind to new processes, technology, products; the joy of sharing understanding of how things work and why they work with others ... the sharing of knowledge to make people's lives better; the comfort of understanding how most things work (at a basic level) ...... knowing the things that you can influence while also recognising the things you cannot change, like the weather."

Priorities for university science education

"The ability to learn how to learn is imperative. There is far too much to know, so the knowledge and skills on how to source information and learn is most valuable. Problem solving skills, except I think this needs to be taught in the home and built on in the primary years and then developed at university. An ability to think laterally when faced with a situation, again though probably a skill to be learned in primary school and further developed. Excellent written and oral communication skills are essential for a scientist. For science graduates to have knowledge, and the ability to communicate using everyday language (without dumbing down) is very important. The confidence to be proactive, inform society and be prepared to comment when politicians, the media or others aren't telling the whole story or only focusing on facts and information that suit, so that debates on issues that impact on us all are well informed and debates are based on fact not emotion. Raising the profile of science and scientists so it is out there in the mix, with football, cricket, religion ... maybe science could be the next opiate of the masses!

BACKGROUND INFORMATION	
Areas of knowledge	Broad science knowledge, both of fundamental principles and in specialist aspects of a range of disciplines
Personal details	Female, born 1957
Occupation	Farmer
Current residence *(ABS classification from postcode)*	Outer regional Australia
University science qualification	Bachelor's degree, 1982 Diploma of teaching (secondary science and mathematics)

Case Study 7: On assessing the validity of information

"Information is something with which we are constantly bombarded and it is essential in almost everything that we do or think to be able to assess the reliability and significance of that information. This is not confined to work or any other particular area of life, but is essential for everything."

"My work involves dealing with people in a range of occupations from the land – farming and grazing – to mining, mostly hard rock mining. I am also a member of the HREC for area health services west of the Great Dividing Range in NSW. A sound knowledge of the fundamentals of the physical sciences is essential for my life and interpersonal dealings, especially when some matters may be of life or death."

"My personal interests still have components of contemporary developments in the physical sciences. Scientific knowledge is certainly helpful in making all sorts of family and other decisions and it is just fun to talk about it, and about some of the rubbish that purports to be science in the contemporary media. I try to keep up with current affairs and it is fundamental to understanding what is happening in the climate that one understands both the reach and limitations of science and statistical projections."

The most personally valued aspects of a science background

"My science education at school was under the old Leaving Certificate system in NSW which was very specific, fundamental, and experimental, with a concentration on the basics essential for all scientific enquiry. I then completed a BSc with honours in Physics, with a lot of Maths and a full year of chemistry."

"The fundamentals of collecting data that is reliable (and repeatable) have been drummed into me. I now find myself asking a series of questions about a lot of information — who measured it? where was it measured? when was it measured? how was it measured? why was it measured? Correlation does not establish a causal relationship. Good theory is essential in assessing information and claims of causal associations. Theory must be understood and must make sense within the well established relationships of the physical sciences."

BACKGROUND INFORMATION	
Areas of knowledge	Broad knowledge of physical sciences, with specialist knowledge in physics, mathematics, statistics and chemistry
Personal details	Male, born 1947
Occupation	Priest
Current residence *(ABS classification from postcode)*	Outer regional Australia
University science qualification	Bachelor's degree with honours, 1970

Case Study 8: On finding the right niche

"My degree focused on developing research skills and I am employed as a risk analyst with the government. "

"An interest in science has been part of my life for as long as I can remember and my studies consolidated my interests and abilities in this realm. I have finally found my niche after many years in the workforce. This was not as a result of making unwise choices, but rather the previous lack of an opportunity to study science and graduate."

A way of thinking valued in the workplace
"I am valued in my position and have been told by an executive that I bring 'a different approach' to issues. I am better able to understand, argue and make decisions (if necessary) about contemporary issues because of Philosophy 101 in first year and the focus on critical thinking as part of the research process in my studies."

Learning to work with team dynamics
"My course provided valuable information regarding team work and collaboration. For example, learning to work with very talented students with strong ideas about the way things should be done, others who contributed as little as possible, etc. It was a valuable lesson in project management regarding what is really important in order to achieve a result in the time allocated. On a personal note, it made me realise that if you truly believe in something, you must persevere in getting your point across, if not the first time, then later."

The most personally valued aspects of a science background
"That it has made it possible for me to find my niche in the workplace and be happy in my job. That I can now 'make a difference' and make a contribution to the community."

Advice to students of science
"Be creative. Science is the perfect environment for people with creative thinking abilities to be innovative, and to generate new ideas using their unique problem solving skills. And simply maintain the curiosity of a child about 'how things work', 'what makes people tick', etc. – a general interest in the world and its people."

BACKGROUND INFORMATION	
Areas of knowledge	Knowledge of the fundamental principles of biology and statistics, with specialist knowledge in areas of biology, chemistry, physics and statistics
Personal details	Female, born 1943
Occupation	Risk analyst
Current residence *(ABS classification from postcode)*	Major cities of Australia
University science qualification	Bachelor's degree with honours, 2002

Case Study 9: On a career in the management of research and development

"I have a PhD in chemistry, and spent the first seven postdoctoral years in academic positions where the application of my science training was fundamental. I then spent 25 years in manufacturing industry, where I held a number of positions in research management and product development. A background in academic science was important in being able to manage scientists, and also in pursuing collaborative research with bodies such as universities and CSIRO."

Forming a link between diverse professions

"I found that a strong mathematical background (more the mindset than specific technical skills) was invaluable when analyzing financial and business strategy issues. Although my primary formal roles in industry usually had an obvious science basis ("Research Manager", "Innovation Manager" etc) I typically found myself in a multidisciplinary liaison role, acting as a link to senior management, marketing/sales/customers, production, finance, outside R&D providers, lawyers etc., because R&D touches all these aspects of corporate life and strategy. A few years into my management career, I undertook a part-time postgraduate management course which helped me better understand the perspectives of these other disciplines."

Providing advice to family and friends

"From time to time, friends and family ask for my opinion or assistance in matters which may have a mathematical or scientific aspect, or which may simply require a disciplined and formal approach. A science background trains one to think critically, logically and objectively about any issue. One learns not to be too quickly swayed by superficialities, but to look more deeply for fundamental drivers."

"What I most value from my science background is the ability to translate a real world problem into an abstract framework where it may be partly or wholly solved, and then to translate that abstract solution back into action in the real world."

Priorities for university science education

"Most importantly students should be taught the process of scientific thinking. This encompasses a wide range of processes from careful experimentation through to very abstract theorizing, and individual students will have varying aptitude for these skills. What is common to all branches of science, however, is a respect for objective data and the power of rigorous logical analysis; and also the understanding that uncertainty can never be eliminated entirely, so one must always keep an open mind to the possibility of new interpretations."

"At a practical level, I think some basic exposure to statistics should be mandatory for all science students. I also think that science students should be encouraged to take as much mathematics as they can cope with. These two disciplines underlie all science, but they have application in many other fields as well."

BACKGROUND INFORMATION	
Areas of knowledge	Broad fundamental science knowledge and specialist knowledge in areas of chemistry, physics, and mathematics
Personal details	Male, born 1947
Occupation	Retired
Current residence *(ABS classification from postcode)*	Inner regional Australia
University science qualification	Bachelor's degree, 1968 PhD, 1974

Case Study 10: On honing skills through multi-disciplinary training

Skills developed through science

"Evaluating evidence, analysing problems and developing creative solutions are valuable skills which I largely attribute to my science background. In particular, in law (my other discipline) there is a lot of 'dogma' and long-established systems that don't necessarily achieve what they are intended to achieve. Wearing my scientist hat, I step back to see the purpose of the system, assess whether it is working and why, and think about other ways to achieve the same purpose. "

"Analysing problems by synthesising ideas and information from multiple sources is also a skill I developed in science – but probably also in law, where there is a lot of reasoning by analogy."

"Also in my science degree we were specifically taught how to critique scientific journal articles to assess the quality of the experiment and the validity of the conclusions. This was a really helpful skill to learn and I apply it often in other areas."

The application of science knowledge within a legal context

"I have a double degree in law and science, and have had cause to draw directly on my science knowledge. I previously worked on a legal reform project concerning the responses of the criminal justice system to crimes committed by people with mental disorders (mental illness, intellectual disability, brain injury etc). My physiology/ neuroscience background assisted me in interpreting clinical journal articles and developments in the research regarding treatment for people with such disorders – insight that was highly relevant for assessing the quality of research about rehabilitation and risk management of offenders."

The most personally valued aspects of a science background

"Rational approach to life and ongoing curiosity about the world around - the more you know the more exciting it is to find out more."

The priorities for university science education

"Fundamentals of maths, statistics, physics, chemistry and evolutionary biology. Understanding the principles of these disciplines, it is relatively easy to pick up other scientific disciplines. I started with a physics/chemistry/maths focus and switched later to major in human physiology. I am very grateful for the broad scientific education I received and I think multi-disciplinary training is very important. I think there is a danger where undergraduates overspecialise, eg science students who only do biology without also understanding basic physics/chemistry and maths, or who focus entirely on the physical sciences to the exclusion of the biological ones."

"Many recent breakthroughs have come about through cross-disciplinary work eg mathematical analysis of calcium signaling in the brain led to discoveries about astrocyte involvement in epilepsy, and computer gamers recently helped determine the structure of a protein which had puzzled researchers for over a decade."

"I also think science students should be required to do a couple of units of something else (e.g. history, politics, law, commerce) to ensure that they have a broad world view and assist with communicating ideas. Double-degrees are a great way to do this but even a requirement to do one or two units in other faculties would assist in this regard."

BACKGROUND INFORMATION	
Areas of knowledge	Broad knowledge of fundamental sciences, with specialist knowledge in biology, chemistry, physics and mathematics
Personal details	Female, born 1981
Occupation	Solicitor
Current residence *(ABS classification from postcode)*	Major cities of Australia
University science qualification	Bachelor's degree, 2004; Post-graduate diploma, 2006

Case Study 11: On understanding the environment through continual learning

"My work is related to environmental sciences. I have worked in natural resource related research, various aspects of protected area management, and policy roles related to protected area management (marine and terrestrial) and biodiversity conservation, including threatened species conservation.

Some of the biggest issues facing society are climate change and sustainability. My background in science helps me to understand this. It also helps me to understand the influence of the environment on past societies, which helps in predicting how environmental change may affect humans and biodiversity into the future."

Application of skills in the workplace

"In my work I am required to analyse and critically evaluate a lot of information that is applicable to protected area management and biodiversity conservation. It is important to base decisions on facts, be able to research information, and develop logical and persuasive arguments based on this information. I am required to work collaboratively (often in multidisciplinary teams), and also independently. My undergraduate degree gave me a grounding which has been important in further developing these skills."

The most personally valued aspects of a science background

"I value the knowledge I gained from my background in science, and where it has led me in life. I think it has encouraged me to continue learning formally and informally and to pass on some of my knowledge and enthusiasm to other people who may not have thought science was interesting. I was already interested in the natural environment and that is why I chose environmental sciences, and my science background has further stimulated my interest in the wonders of the natural world and the world more broadly.

I am interested in natural history and do a lot of scuba diving and am therefore very interested in the marine environment and observing and experiencing it. My interest in science has seen me continue to learn more about the natural environment, outside of that required for my work." My science background has also been an asset in my postgraduate studies which have included social research, particularly with respect to developing methodology, my approach to analysis of data and presentation and publication of this information.

Priorities for university science education

"A basic grounding in all aspects of science is important as it all fits together. For example, to understand ecological and biological processes it is important to have some basic knowledge of chemistry and geology. It is also important to have a grounding in maths/statistics because this information is crucial to research methods and analysis.

Communication is also an important and often overlooked aspect. Many universities focus only on scientific writing, which is undoubtedly important, however, it is also important for science graduates to develop skills in communicating effectively and being able to engage the broader community."

BACKGROUND INFORMATION	
Areas of knowledge	Broad knowledge of fundamental sciences, with specialist knowledge in biology and environmental systems
Personal details	Female, born 1962
Occupation	National Parks Area Manager
Current residence *(ABS classification from postcode)*	Major cities of Australia
University science qualification	Bachelor's degree, 1983; Master's degree, 2011; PhD, 2012

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Appendices

Appendix 1 Structure and logic of the questionnaire design

The questionnaire was prepared and distributed online[1]. A downloaded 'print' copy of the questionnaire is provided as Appendix 6.

Members of ACDS provided feedback on the draft questionnaire, including suggestions for the subject areas listed.

Part A – The nature and influence of your science knowledge

This section sought information on respondents' level of confidence in their knowledge across six broad subject areas: biology, chemistry, physics, statistics, mathematics, and environmental systems. The question was prefaced with a reminder to consider their science background overall, and not to focus only on their university studies. The order of listing was randomised, both between individual respondents and between questions for an individual (e.g, see Q3 and 4, Appendix 6).

Respondents were then asked to indicate the situations in which they drew upon their science knowledge, and to provide explanation or examples (see Q5).

Part B – The skills you have developed through doing science

Here the focus was on identifying the skills people associated with their science background and on where they applied these skills. A list of 11 'skills', or abilities, was provided (see Q6). These skills represent the range of graduate attributes typically associated with a university education, and with science in particular. They are not necessarily unique to science. Rather, people were asked if their science background made any contribution to the development of these skills. As for the subjects in Part A, the items were presented in random order.

Again, respondents were asked to indicate the situations in which they applied these skills, and to provide explanation or examples (see Q7).

Part C – Your views on the priorities for science education

This page of the survey comprised two open questions. Respondents were asked what they most valued from their own background in science. In a separate question, they were then asked their views on what should be considered fundamental to a university science education.

Part D – Some background information about you

In addition to basic demographic information, this section was intended to gather further insight into what people consider as the contributors to their background in science.

Occupation was asked as an open text box, rather than – for example – a census-like listing of employment categories. The intent was to encourage people to use the language that they felt best described their occupation, and to allow the categories of 'work roles' to emerge from that data.

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[1] Hosted through SurveyMonkey®, https://www.surveymonkey.com/mp/aboutus/

Appendix 2 Details of survey promotion

Universities contacting alumni

Eight Australian universities agreed to assist in the promotion of the survey. The universities covered seven states and territories (all except the Northern Territory), and institutions of different types, based on their grouping or network affiliation (2 Group of Eight; 1 Australian Technology Network; 2 Innovative Research Universities; 3 unaligned).

The universities used various means to contact their graduates, including alumni newsletters and direct email of invitations. They were asked to focus on graduates who:

- studied unit/subjects in any of a range of science-related fields of education[2];
- completed their degrees no later than 2008 – and, ideally, as long ago as possible;
- graduated with a Bachelor's degree or above, including higher research degrees; and
- were not currently enrolled at the university.

Employer or association networks

Assistance in promoting the survey was also sought from several employers and associations, including CSIRO staff association, a state government department responsible for environment and heritage, and a non-for-profit conservation foundation. Lions Club International, Australia also assisted, providing a way of reaching people in a wider range of occupations, age groups, and locations.

Advertising

Three complementary forms of paid advertising were used to maximise the promotion of the study to the wider Australian population.

The survey was promoted in both print and online versions of the NewScientist magazine, Australia. The logic was that this publication had a diverse audience of predominantly university graduates[3], and that many readers would identify as having a 'science background'.

The social networking website 'Facebook' was used to promote the survey across Australia, to graduates from any Australian university. Two targeted 'campaigns' were run, both restricting advertising to university graduates living in Australia. One campaign included anyone 30 years of age or more, while the other was specific to graduates with a university major in science, and was without age limit.

The professional networking website 'Linkedin' was employed as a different form of online advertising. Here the aim was to particularly focus on recruiting people from a range of professions. Campaigns targeted people based in Australia and working in science-related industries (including the options of: Information Technology & Services; Mining & Metals; Oil & Energy; Farming; Defence & Space), management, government administration, and legal roles.

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[2] Field of Education (FOE) is a category used for Australian Government reporting purposes, and is therefore a classification used for institutional student records. The following FOEs were suggested to universities as a basis for compiling a mailing list: 01 Natural and Physical Sciences ; 02 Information Technology; 05 Agricultural, Environmental and related studies; 0601 Health – Medical Studies; 0609 Health – Optical Science; 0611 Health – Veterinary Studies. The request was for a maximum of 1000 invitations per university, with no more than 200 to graduates with 'health only' (coded 06)

[3] http://www.newscientist.com/data/html/ns/mediacenter/aus/audience.jsp

Appendix 3 Residential location of survey respondents

Nearly all respondents provided either a current residential postcode in Australia or name of country of residence if living overseas (Table A3). 696 respondents provided Australian postcode information.

Table A3 Residential location of respondents at the time of the survey

Australia[1] Total = 696				**Other countries** Total = 93	
State or territory		**Remoteness Area**		**Region**	
Victoria	240	Major cities	542	Europe (including UK n=19)	34
New South Wales	172	Inner regional	143	North America	32
Queensland	90	Outer regional	87	Asia (including Singapore n=8)	18
Australian Capital Territory	86	Remote	11	New Zealand	7
South Australia	37	Very remote	6	Latin America	2
Tasmania	33				
Western Australia	28				
Northern Territory	2				

[1] Based on postcode information.

Postcodes were used to derive both state/territory and the Remoteness Area category, based on the Australian Standard Geographical Classification (ASGC) (Pink, 2006). Some postal areas (POAs) span states, and encompass more than one RA classifications (e.g. Remote and Very Remote; Major city and Inner Regional). Responses with such POAs were counted for both RAs.

Appendix 4 Respondents' fields of study details

Table A4.1 Highest level of university study for a range of broad science subject areas, by each of four age+gender groups

		Number of respondents, and proportion of age + gender group[1]																	
Age + Gender	**Highest level of study**	**Biological sciences** (inc biomedical)		**Physics**		**Chemistry**		**Mathematics or Statistics**		**Environ'. science** (inc Earth science)		**Engineering or computing sciences**		**Health sciences**		**Veterinary Science**		**Behavioural science** (inc Psychology)	
Female < 40 yrs (n=237)	Not at uni	**42**	18%	**112**	47%	**36**	15%	**21**	9%	**98**	41%	**160**	68%	**121**	51%	**207**	87%	**124**	52%
	Bach. 1st 2nd or 3rd	**119**	50%	**100**	42%	**167**	70%	**164**	69%	**83**	35%	**51**	22%	**58**	24%	**10**	4%	**70**	30%
	Bach. Hons	**32**	14%	**6**	3%	**13**	5%	**23**	10%	**16**	7%	**6**	3%	**15**	6%	**0**	0%	**7**	3%
	Masters/GD/PhD	**39**	16%	**8**	3%	**10**	4%	**17**	7%	**28**	12%	**3**	1%	**29**	12%	**2**	1%	**22**	9%
	SUBTOTAL	*232*	*98%*	*226*	*95%*	*226*	*95%*	*225*	*95%*	*225*	*95%*	*220*	*93%*	*223*	*94%*	*219*	*92%*	*223*	*94%*
Female 40+ yrs (n=128)	Not at uni	**24**	19%	**48**	38%	**21**	16%	**12**	9%	**45**	35%	**61**	48%	**67**	52%	**101**	79%	**58**	45%
	Bach. 1st 2nd or 3rd	**53**	41%	**59**	46%	**85**	66%	**80**	63%	**42**	33%	**36**	28%	**24**	19%	**3**	2%	**38**	30%
	Bach. Hons	**17**	13%	**2**	2%	**10**	8%	**11**	9%	**12**	9%	**6**	5%	**5**	4%	**1**	1%	**3**	2%
	Masters/GD/PhD	**30**	23%	**10**	8%	**6**	5%	**17**	13%	**14**	11%	**9**	7%	**13**	10%	**2**	2%	**15**	12%
	SUBTOTAL	*124*	*97%*	*119*	*93%*	*122*	*95%*	*120*	*94%*	*113*	*88%*	*112*	*88%*	*109*	*85%*	*107*	*84%*	*114*	*89%*
Male < 40 yrs (n=161)	Not at uni	**68**	42%	**49**	30%	**38**	24%	**14**	9%	**82**	51%	**60**	37%	**101**	63%	**144**	89%	**101**	63%
	Bach. 1st 2nd or 3rd	**54**	34%	**75**	47%	**89**	55%	**97**	60%	**42**	26%	**61**	38%	**30**	19%	**7**	4%	**38**	24%
	Bach. Hons	**17**	11%	**8**	5%	**14**	9%	**28**	17%	**16**	10%	**23**	14%	**10**	6%	**0**	0%	**2**	1%
	Masters/GD/PhD	**20**	12%	**25**	16%	**16**	10%	**17**	11%	**17**	11%	**11**	7%	**11**	7%	**1**	1%	**13**	8%
	SUBTOTAL	*159*	*99%*	*157*	*98%*	*157*	*98%*	*156*	*97%*	*157*	*98%*	*155*	*96%*	*152*	*94%*	*152*	*94%*	*154*	*96%*
Male 40+ yrs (n=259)	Not at uni	**121**	47%	**37**	14%	**37**	14%	**9**	3%	**107**	41%	**62**	24%	**177**	68%	**196**	76%	**147**	57%
	Bach. 1st 2nd or 3rd	**67**	26%	**148**	57%	**161**	62%	**184**	71%	**58**	22%	**110**	42%	**20**	8%	**4**	2%	**54**	21%
	Bach. Hons	**15**	6%	**18**	7%	**14**	5%	**28**	11%	**21**	8%	**24**	9%	**4**	2%	**2**	1%	**0**	0%
	Masters/GD/PhD	**36**	14%	**39**	15%	**30**	12%	**21**	8%	**37**	14%	**31**	12%	**11**	4%	**2**	1%	**15**	6%
	SUBTOTAL	*239*	*92%*	*242*	*93%*	*242*	*93%*	*242*	*93%*	*223*	*86%*	*227*	*88%*	*212*	*82%*	*204*	*79%*	*216*	*83%*

ALL (n=805)	*TOTAL*	*754*	*94%*	*744*	*92%*	*747*	*93%*	*743*	*92%*	*718*	*89%*	*714*	*89%*	*696*	*86%*	*682*	*85%*	*707*	*88%*

[1] Not all respondents provided information on age, gender, and highest level of study in each subject area.

Table A4.2 Highest level of university study in the enabling sciences by respondents who studied applied sciences beyond first year Bachelor's degree

		Number of respondents, and proportion of applied science group[1]							
	Highest level of study	**Physics**		**Chemistry**		**Mathematics or Statistics**		**All of Physics, Chemistry, and Mathematics or Statistics**	
Engineering or Computing sciences study beyond 1st year Bachelor's degree	Not at uni	**40**	18%	**65**	29%	**10**	4%		
	Bach. 1st year	**49**	22%	**62**	27%	**18**	8%		
	Bach. 2nd or 3rd	**67**	30%	**66**	29%	**123**	54%		
	Hons or post graduate	**66**	29%	**30**	13%	**70**	31%		
	Bach. 1st year or above							**144**	63%
	TOTAL	*222*	*98%*	*223*	*98%*	*221*	*97%*		
Health sciences study beyond 1st year Bachelor's degree	Not at uni	**76**	39%	**26**	13%	**17**	9%		
	Bach. 1st year	**66**	34%	**60**	31%	**63**	32%		
	Bach. 2nd or 3rd	**27**	14%	**79**	40%	**52**	27%		
	Hons or post graduate	**17**	9%	**21**	11%	**52**	27%		
	Bach. 1st year or above							**104**	53%
	TOTAL	*186*	*95%*	*186*	*95%*	*184*	*94%*		

[1] Not all respondents provided information on all subject area.

Appendix 5 Confidence in subject knowledge, by age and gender

Levels of agreement for the questions regarding fundamental and specialist knowledge (Questions 3 and 4, respectively) were tested for any differences between age and gender. Statistically significant differences were detected for biology, physics, mathematics and statistics. The results are shown below.

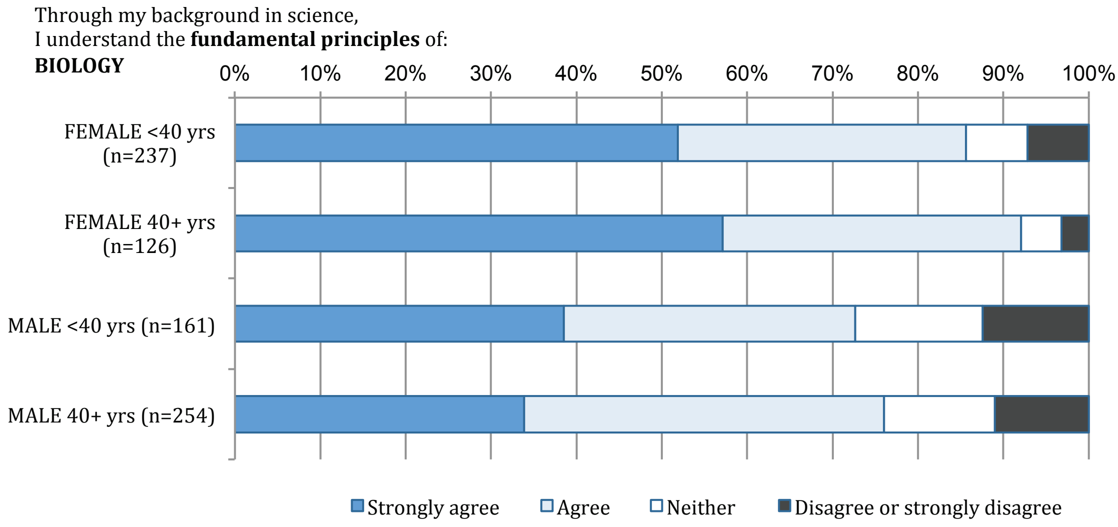

Figure A5.1 Fundamental knowledge in biology, by age and gender

In both age groups, females are more likely than males to *agree* or *strongly agree* (TI: P<0.01 for <40 years group; P<0.001 for 40+ years group)

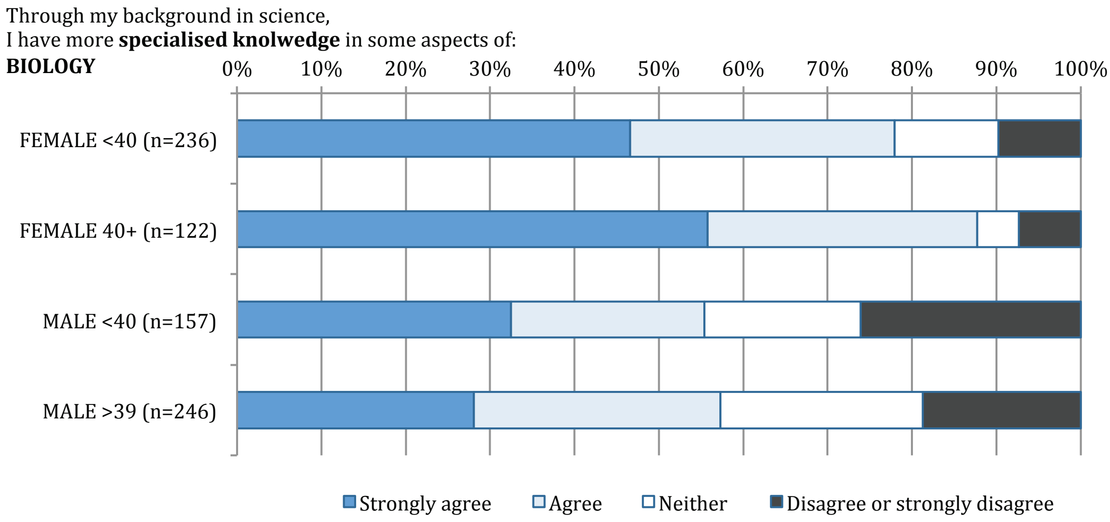

Figure A5.2 More 'specialised knowledge' in biology, by age and gender

In both age groups, females are more likely than males to *strongly agree* and less likely to *disagree* (TI: P<0.0001 for <40 years group; P<0.0001 for 40+ years group)

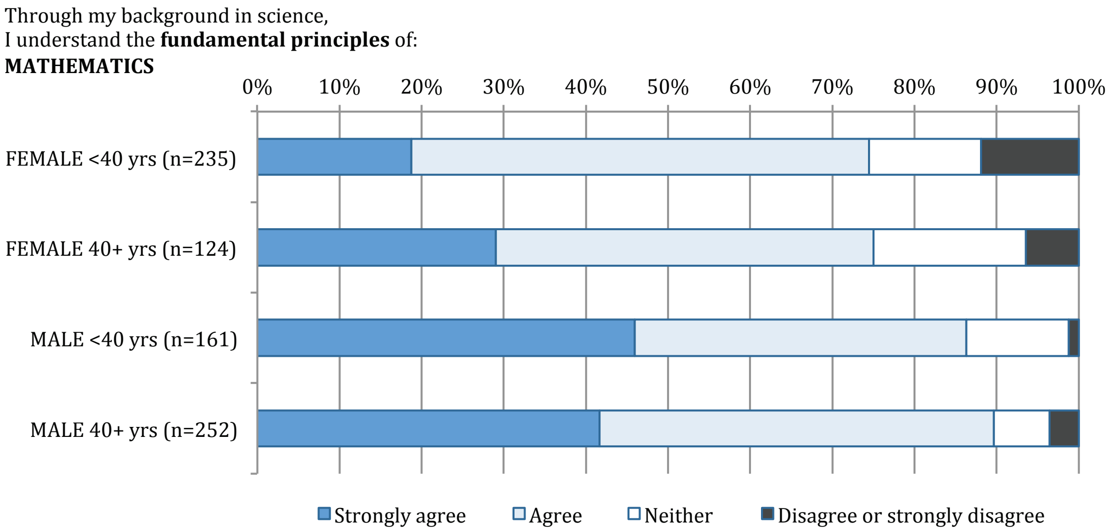

Figure A5.3 Fundamental knowledge in mathematics, by age and gender

In both age groups, males are more likely than females to *agree* or *strongly agree* (chi-squ test of independence: P<0.0001 for <40 years group; P<0.01 for 40+ years group)

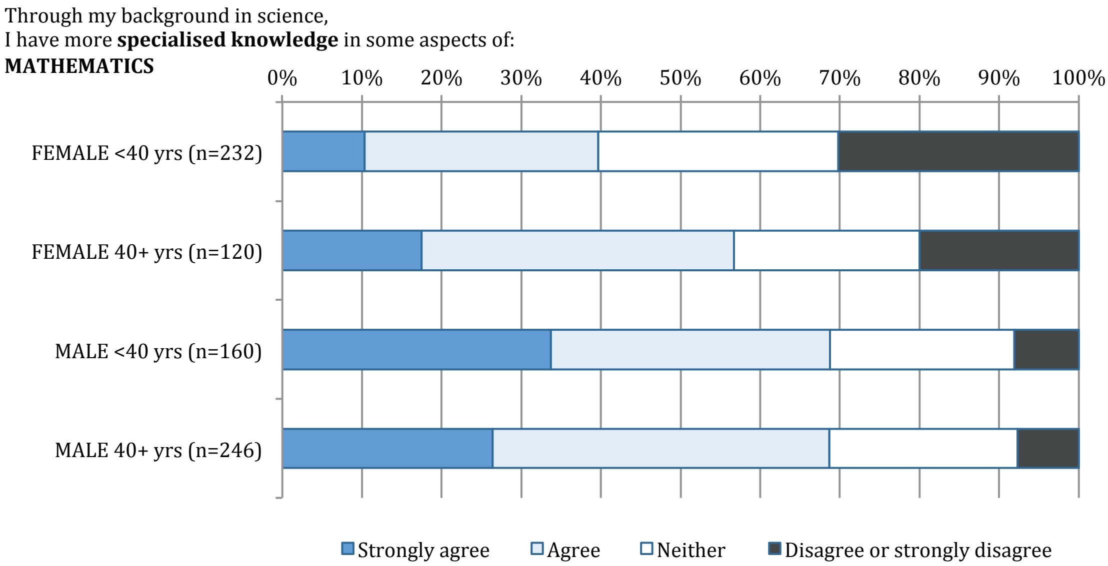

Figure A5.4 More 'specialised knowledge' in mathematics, by age and gender

In both age groups, males are more likely than females to *agree* or *strongly agree* (chi-squ test of independence: P<0.0001 for <40 years group; P<0.01 for 40+ years group)

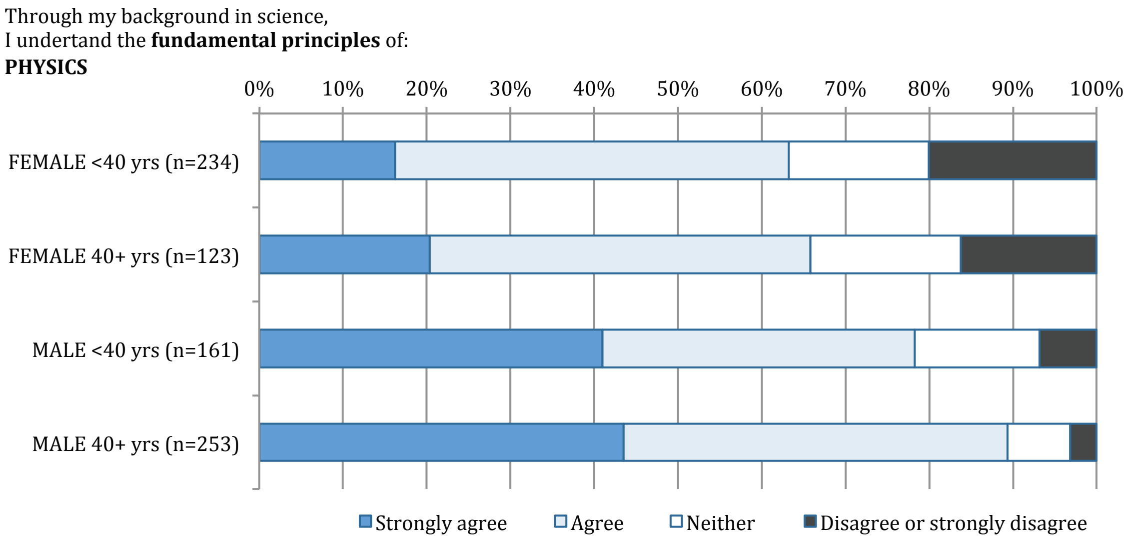

Figure A5.5 Fundamental knowledge in physics, by age and gender

In both age groups, males are more likely than females to *agree* or *strongly agree* (chi-squ test of independence: P<0.0001 for <40 years group; P<0.0001 for 40+ years group)

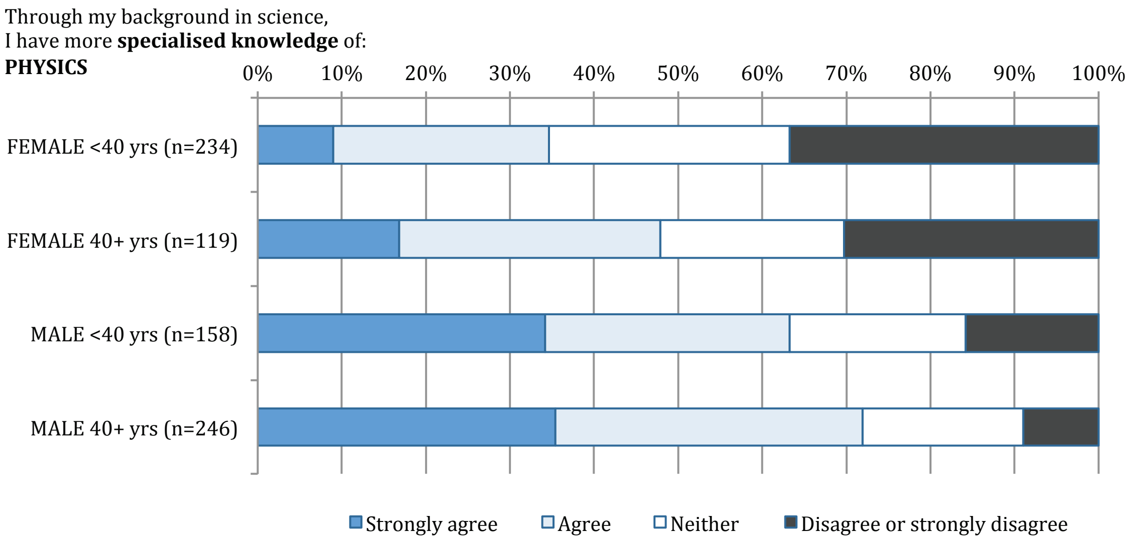

Figure A5.6 More 'specialised knowledge' in physics, by age and gender

In both age groups, males are more likely than females to *agree* or *strongly agree* (chi-squ test of independence: P<0.0001 for <40 years group; P<0.0001 for 40+ years group)

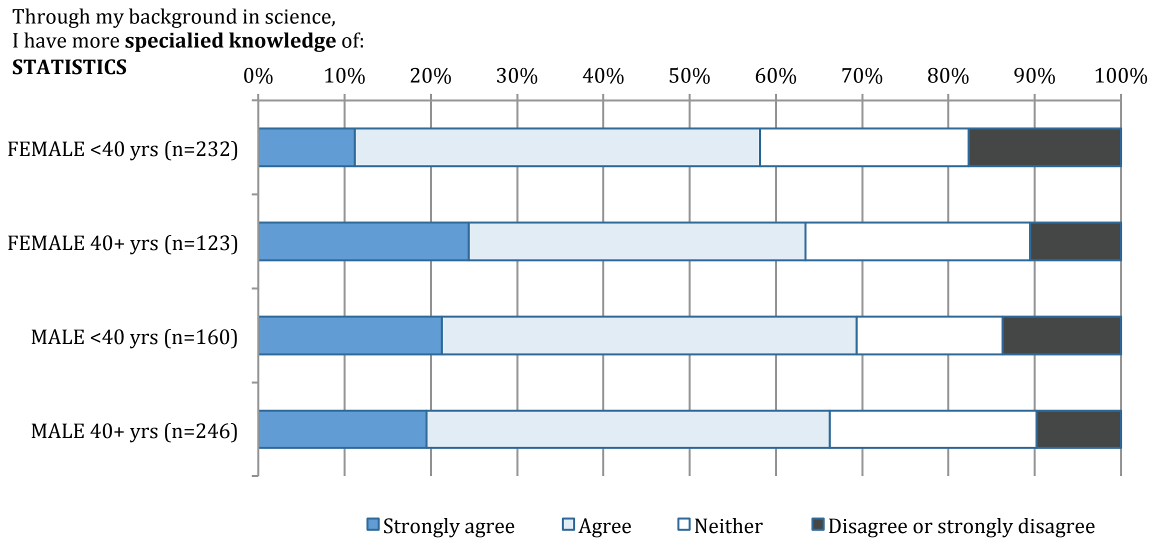

Figure A5.7 More 'specialised knowledge' in statistics, by age and gender

Among females, those under 40 years are less likely to *strongly agree* and more likely to *strongly disagree* (chi-squ test of independence: P<0.01 for females)

Appendix 6 Survey questionnaire

The questionnaire was online, hosted on SurveyMonkey. Inserted here is a downloaded 'print' version of the questionnaire, showing the style and organisation of questions.

Part A: The nature and influence of your science knowledge

In this section, please consider the knowledge that you have developed as a result of your involvement in science, whether during your university studies or elsewhere.

3. Please indicate your level of agreement with each of the following statements.

Through my background in science, I understand the fundamental principles of:

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
statistics.	◯	◯	◯	◯	◯
biology.	◯	◯	◯	◯	◯
mathematics.	◯	◯	◯	◯	◯
environmental systems.	◯	◯	◯	◯	◯
chemistry.	◯	◯	◯	◯	◯
physics.	◯	◯	◯	◯	◯

4. Please indicate your level of agreement with each of the following statements.

Through my background in science, I have more specialised knowledge in some aspects of:

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
chemistry.	◯	◯	◯	◯	◯
physics.	◯	◯	◯	◯	◯
biology.	◯	◯	◯	◯	◯
mathematics.	◯	◯	◯	◯	◯
statistics.	◯	◯	◯	◯	◯
environmental systems.	◯	◯	◯	◯	◯

5. In what situations do you draw upon your science knowledge? (please tick all that apply)

- ☐ In my work
- ☐ In my personal interests and pursuits (outside work and study)
- ☐ In providing advice to friends and family
- ☐ In my approach to understanding contemporary issues in society
- ☐ Never

Please provide an explanation and/or a general example for each situation ticked above.

For example, in answering Question 5 (above) you might like to consider how your science background has influenced: your choice of occupation and your interests outside work; your particular contribution in the workplace; your approach to collaboration, at work or elsewhere; and the ways you approach problem solving.

Part B: The skills you have developed through doing science

In this section, please consider the types of skills that you have developed as a result of your involvement in science, whether during your university studies or elsewhere.

6. Please indicate your level of agreement with each of the following statements.

My background in science contributes to my ability to:

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
make observations.	◯	◯	◯	◯	◯
understand the natural world.	◯	◯	◯	◯	◯
evaluate evidence.	◯	◯	◯	◯	◯
present ideas to others.	◯	◯	◯	◯	◯
work collaboratively.	◯	◯	◯	◯	◯
provide effective leadership.	◯	◯	◯	◯	◯
develop a logical argument.	◯	◯	◯	◯	◯
develop creative solutions to problems.	◯	◯	◯	◯	◯
work independently.	◯	◯	◯	◯	◯
research new information.	◯	◯	◯	◯	◯
analyse a problem.	◯	◯	◯	◯	◯

Other (please specify)

7. In what situations do you apply these skills? (please tick all that apply)

- ☐ In my work
- ☐ In my personal interests and pursuits (outside work and study)
- ☐ In providing advice to family and friends.
- ☐ In my approach to understanding contemporary issues in society
- ☐ Never

Please provide an explanation and/or a general example for each situation ticked above.

Part C: Your views on the priorities for science education

Please take a moment to consider your personal priorities, and to describe your views on the value of a science education.

8. What do you most value from your background in science?

9. What do you think should be considered fundamental to a university science education?

Part D: Some background information about you

The following questions ask you to describe your science background, and to provide some basic demographic information.

10. Have you studied at a university?

- ○ Yes, in Australia
- ○ Yes, in another country
- ○ Yes, in both Australia and another country
- ○ No, I have not studied at university

Part D (continued): University qualifications

11. For each university qualification you have completed, please select the year of completion.

	Year of completion
Bachelor degree	
Masters degree	
PhD	

Other (please specify)

12. Please indicate your highest level of study in each of the following broad science subject areas.

	Never studied	School - Year 7-10 (any)	School - Year 11-12 (any)	Bachelor - 1st year	Bachelor - 2nd-3rd year	Bachelor - honours level	Masters/GradDip	PhD
Biological sciences (including biomedical)	○	○	○	○	○	○	○	○
Physics	○	○	○	○	○	○	○	○
Chemistry	○	○	○	○	○	○	○	○
Mathematics or statistics	○	○	○	○	○	○	○	○
Engineering or computing sciences	○	○	○	○	○	○	○	○
Health sciences	○	○	○	○	○	○	○	○
Veterinary science	○	○	○	○	○	○	○	○
Behavioural science (including Psychology)	○	○	○	○	○	○	○	○
Environmental science (including Earth sciences)	○	○	○	○	○	○	○	○

Any other comments

Part D (continued): Experiences in science outside university

13. Apart from university studies, please describe any other experiences that you consider form part of your background in science.