Supply, demand and approaches to employment by people with postgraduate research qualifications in science and mathematics:

Literature Review and Data Analysis

Report to the Australian Government
Department of Education, Employment and Workplace Relations

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Executive Summary

This report is the first stage in a larger project that will investigate the demand for and supply of people with science and mathematics postgraduate qualifications in Australia. Scientists and mathematicians are essential to the economic progress and wellbeing of Australia. Building an understanding of the labour market demand for skilled scientists and mathematicians and the patterns of supply of graduates is essential for informing policy that will contribute to the future success of the scientific community in Australia. This report is divided into two main parts: a literature review and a data analysis.

Literature Review

This literature review section of this report encompasses a range of research projects, key stakeholder reports and specialist commentaries that cover issues relating to supply, demand, employment and training of students in the science and mathematics fields. It concentrates particularly on those with higher degree research qualifications (Masters by research and PhD). The research outlined in this review informs the data analysis section of this report, as well as the consultations and 'best practice' examinations that form other key elements of this research project.

Supply

Overall, international research into the employment of science and mathematics postgraduates indicates that while the output of graduates exceeds the demand for such qualifications among employers, there still appear to be substantial labour force shortages. The key reasons for this are twofold: first, a perceived lack of quality of graduates among employers; and second, the fact that many graduates choose not to follow a pathway into a traditional science and mathematics occupation. Supplies of people with science and mathematics qualifications come from various sources, including the higher education system (both domestic and international students) and migration.

In higher education, postgraduate supply in the science and mathematics fields in Australia has fluctuated over the past few decades; however, the general trend has been towards increased numbers of doctoral students. The overall numbers of higher education postgraduate completions in these fields in Australia are relatively small compared to those in countries such as the US and China, but in the past few decades there has been substantial growth. Australia has experienced a large growth relative to many established western countries (including the US, Germany and the UK) over the past 15 years.

However, while there has been a notable growth in the supply of science and mathematics PhD completions in Australia, such change has been experienced across the whole Australian university sector – and many other fields of education have experienced far greater growth than the science and mathematics fields. Hence, while the international comparisons show that supply in Australian science and mathematics completions is relatively healthy, the detailed Australian picture shows that in the context of the entire higher education sector, mathematics and the sciences have fallen behind somewhat.

In addition to higher education, a robust skilled-migrant program in Australia has fuelled population growth and increased labour market expertise in a number of areas since the mid-1990s. Analysis shows there were net gains from migration to Australia in Chemists, Geologists and Geophysicists, Life Scientists, Environmental and Agricultural Scientists, and Mathematicians and statisticians between 1998 and 2003.

As shown in a number of Australian studies, the vast majority of growth in Australian university enrolments over the past few decades has resulted from the influx of international students. While these figures suggest potential growth in supply for the Australian workforce, at the PhD level, few appear to stay in Australia on completion of their degree. Data indicate that this is in contrast with the large numbers of bachelor and masters international students who remain in Australia following graduation.

Predicting future supply at the domestic level is difficult, and contingent on a number of factors. The key issue in assessing future supply domestically concerns evaluating trends in the numbers of school participants in mathematics and the sciences. In Australia, the available literature suggests that there is declining participation in these fields. There are numerous reasons cited for the decreasing numbers of school enrolments, including a lack of understanding of career prospects, the perception that the subjects are too difficult, and possibly most crucial – quantity and quality problems with science and mathematics teachers. Addressing each of these issues is crucial to ensuring that supply of students into undergraduate courses and through to the postgraduate level is maintained.

Demand

Evidence relating to demand for postgraduates in the science and mathematics fields suggests that, as with supply, it has continued to be strong throughout the past few decades, despite the changing priorities of governments and industry. International research indicates that, in many parts of the world, supply has not been satisfying demand. Interestingly, this is not an issue of unbalanced numbers, but rather relates to dissatisfaction among employers with the quality of graduates in the market.

There are suggestions that this demand-side problem may actually be a perception problem among employers rather than an actual skills-shortage issue. Lowell and Salzman (2007, p. 36) claim that employers 'may be voicing unrealistic expectations of experience, more than skills or education' of new graduates.

European research has shown that while 'there were no quantitative shortages of scientists', there were substantial imbalances in demand within some specific fields and within some countries (Pearson, Jagger, Connor, & Perryman, 2001, p. 3). Likewise, UK research has found no general shortages in the quantity of graduates, despite 'continuing reports of some employers experiencing difficulties in recruiting technically-qualified graduates' (Mason, 1999, p. 1).

In the Australian context, there is also evidence of some oversupply of qualified scientists and mathematicians, but in general the evidence of current un-met workforce demand in these areas for people with higher degree qualifications is relatively limited. However, local research suggests that more investment will be required in order to address demand issues in these fields in the coming years. This is primarily due to the increasing proportion of older persons in the Australian workforce and the impending retirement of the baby boomer generation.

As a result of the difficulties in assessing demand, there are very few studies that provide an indication of the dimensions of demand for postgraduates within the science and mathematics fields. The two main reasons for the difficulty in predicting demand relate to quality of graduates and destinations of graduates. If employers perceive graduate quality to be low, then they are likely to argue that there are shortfalls with supply. Likewise, if graduates perceive science and mathematics employment prospects to be poor, and instead choose to find employment outside their field of expertise, then demand within the science and mathematics fields for these skills may increase. However, predicting the trends in these perceptions is difficult.

Employment outcomes

In general, the literature on the workforce destinations of postgraduates in the science and mathematics fields indicates that degree holders have relatively good employment outcomes. Numerous studies show that the higher the level of degree in the sciences, the more likely a graduate is to be employed and working in their field. In Australia, the postgraduate destination employment figures in the science and mathematics fields are also relatively robust. However, details from an annual survey undertaken by Graduate Careers Australia of graduate destinations in the six months following completion of a degree show that within the sciences, there are some differences in employment outcomes.

Across international research, it appears that most graduates in science and mathematics follow an employment pathway that is closely related to their qualification. At the postgraduate level in Australia, the link between employment pathway and field of qualification is relatively strong.

While these outcomes tend to illustrate a relatively successful articulation into their fields for science and mathematics graduates, there is still concern that the skills that postgraduates are acquiring in their studies are not keeping up with the rapidly changing pace of the job market, and thus there are a number of new challenges being faced by young doctoral graduates in mathematics and the sciences. In addition, within some literature, there is a noted concern that many of the 'best and brightest' young scientists and mathematicians are not actually following a traditional science employment pathway. Instead graduates are moving into other, potentially more lucrative occupations, where their skills need to be adapted but their qualification can still be utilised.

The academic workforce

Academe is a key destination point for substantial numbers of science and mathematics higher degree research graduates. The training provided to most science and mathematics doctoral students is inherently focused towards this sort of employment pathway.

The key issues emerging from the literature on academic professions in mathematics and science relate to the aging of the academic workforce and changes in the employment opportunities for young researchers – in particular, a decline in tenured positions and increase in contract and post doctorate positions. The trend in Australia is similar to that occurring in other parts of the world, where 'there has been a significant contraction of academic positions available to PhDs and increases in contract and grant-based employment' (McInnis, Hartley, & Anderson, 2001, p. 5). This situation means that higher degree postgraduates are spending increasingly long periods of time on temporary or short-term contracts linked to specific research projects and do not have the opportunity to build their profiles through engagement in long-running research and teaching.

The issues relating to problems of articulation into tenured academic postings are well documented in the US, UK, European and Canadian literature. It is argued that although increases in post doctorates provide some opportunities for graduates with higher degrees, in reality they are no longer serving their intended purpose, which is to provide a stepping-stone to a tenured position.

The issues regarding a lack of career trajectory and limited tenured opportunities for higher degree graduates in the mathematics and science fields are somewhat in contrast to the demographic reality facing the academe over the coming years. In all fields, there are large swathes of retirements within academic ranks anticipated in the near future. While there is widespread acknowledgement of these issues, there has been little change in funding or recruitment strategies to ensure that impending retirements of senior academics are countered by the introduction of young researchers.

How to better match supply and demand

The issues for higher degree graduates in science and mathematics in Australia and the rest of the world are relatively uniform. As the literature shows, there are problems with oversupply, but lack of perceived quality; importance of research, but lack of career pathways and remuneration; and increasing demand, but seemingly decreasing incentives for students to follow a science career.

Establishing a better balance between supply and demand in these fields is seen by most who have conducted research in this area to revolve around creating effective links between universities and industry both in the adaptation of curricula that increase the work readiness of graduates as well as the facilitation of work-integrated learning placements within enterprises that are employers of scientists and mathematicians. Within the university sector, there is evidence to suggest that career pathways need to be more clearly articulated for new postgraduates, and that quality researchers be offered tenured positions rather than moved from one post-doctoral position or short-term contract to the next.

However, some emphasise caution in this kind of interaction, warning that there is a fine balance between generalisation and specialisation within universities. They acknowledge the important role of industry in shaping employment pathways for young graduates but warn that universities should not specialise their science programs to cater to industry needs at one particular point in time.

Raising the profile of scientists and mathematicians is also regarded as important in addressing supply issues. It is argued that increasing awareness of the kinds of jobs that are available through a science degree is an important step in increasing the quality and enthusiasm of science candidates.

Data Analysis

The second part of this report, the data analysis, builds on the findings of previous studies identified in the literature review by utilising a wide range of data sets to explore the supply and demand dynamics of science and mathematics postgraduates. This is the first such study in Australia to combine these sources to examine this group. The findings presented below are discussed in the context of the key themes that emerged from the literature review. They show that many of the issues exposed in the international data are also being experienced in Australia.

Supply

Doctorate completions in the natural and physical sciences in Australia increased 25 per cent overall between 2001 and 2006. Compared to the growth in all other fields of education (53 per cent), natural and physical sciences growth is relatively small indicating that the output of postgraduates in the sciences is not keeping pace with outputs in other areas. There has been growth in both domestic and overseas student completions between 2001 and 2006, but the international student growth (34 per cent) was substantially larger than the growth in domestic student completions (13 per cent). Again, the growth in this field is smaller for both domestic and international student completions when compared with other fields of education.

International comparisons of higher degree completions in the mathematics and science fields indicate that Australia's comparative position in the international supply of science and mathematics doctorates is strong when population size is taken into account. However, in terms of total world output, the Australian figures are relatively small. For example, Australia was producing one postgraduate completion for every 10 postgraduate completions in the US in 2005.

Australian Overseas Arrivals and Departures data have been used in this report to track the 'brain drain' and 'brain gain' of science professionals between 2002 and 2007. The data reveal that there has been an overall growth in the number of people in science and mathematics professions both entering and exiting Australia on a long term basis between 2002 and 2007. Overall, Australia has maintained and increased its 'brain gain' position during this period. One of the key reasons for this 'brain gain' position being maintained is the growth in the number of 'long term visitor' arrivals to Australia during this period.

The arrivals and departures data show that the main ages in which gains of persons in these occupations occurred during the 2002 to 2007 period was in the 25 to 34 and 35 to 44 year age groups. These age groups are most important because they consist of persons moving into key areas of responsibility and impact during this period of their lives.

In 2006 there were nearly 50,000 people living in Australia who had postgraduate degrees in the natural and physical sciences. The largest individual discipline within this field was the biological sciences, comprising nearly 30 per cent of all postgraduate science degree holders. Overall, migrants comprise more than half of all persons with a postgraduate qualification in the natural and physical sciences in Australia. Nearly one-third of all people living in Australia with these qualifications are from non-English speaking countries. The 2006 Census data also shows that in Australia, males far out-number females in most of the science disciplines when postgraduate numbers are examined.

Employment

Employment among persons with postgraduate qualifications in the natural and physical sciences in 2006 was relatively high (79 per cent) and the unemployment rate for these people was only 2.8 per cent. Among those with postgraduate qualifications in these fields who were employed in 2006, the majority were working in professional occupations. Overall, a large proportion of postgraduates in the science and mathematics fields appear to be employed in a science-related discipline.

The most common specific occupation of employment for this group was university lecturer or tutor. Across the cohort, 11 per cent were employed in this occupation in 2006. However, there is notable differentiation within the individual disciplines in the propensity to be employed as a university lecturer or tutor.

Among the recently qualified higher degree postgraduates in the natural and physical sciences, the rate of transition to full-time work is relatively high. Overall, for the 2006 graduation cohort, 77 per cent were in full-time employment in the months following completion of their qualification. This is a more positive result than the average across all other fields of education for higher degree research completions (68 per cent).

Of the large proportion of recently completed science and mathematics postgraduates who were employed, the range of occupations they were engaged in is vast. Overall, for this group, the salaries across disciplines generally match the median salary for postgraduates in all other fields of education ($60,000).

The Graduate Destination Survey data also indicate that of the science and mathematics postgraduate completers in 2006 who were employed in 2007, 21 per cent were working outside of Australia. Further analysis of this issue has found (as might be expected) that this is more common among former international students than among former domestic students. More than half of all international higher degree research completers who were employed following graduation found employment outside of Australia. Therefore, it appears that the market should not rely on the growth in international student numbers in these higher research degrees to satisfy domestic workplace demand.

Demand

Nearly one-third of all postgraduates in the science and mathematics disciplines are aged over 55. This group is at, or will reach, retirement age over the next decade. Behind this group are a large number of 40 to 55 year olds, who as a group are currently assuming leadership positions in their respective fields. This cohort will remain in the labour force for the next 15 to 25 years and will fill many of the high-level positions left by the older age cohort. Figures in this report suggest that there is a healthy proportion of 30 to 39 year olds among the stock of persons with postgraduate qualifications in these fields, who are in the early to mid-career stage, and who will help replace the older cohorts over the coming decades. Given that domestic supply of postgraduate completions in these fields increased 25 per cent over the 2001 to 2006 period, there also seems to be an indication that present levels of supply can be maintained over the longer term.

While these figures appear to be relatively good, it is worth noting that the science and mathematics fields might have a harder job in the short term in dealing with impending retirements than other areas of the labour market. The proportion of postgraduates in the natural and physical sciences who are over 55 years old is larger than the share of this age group among all postgraduates and much larger than the share of these people in the professional labour force.

Using the Skilled Vacancies Index trend data, this report shows that following an apparent sharp downturn in demand between May 2001 and May 2003, the number of jobs advertised in the professional science fields has generally increased. Among the states, different levels of demand, as measured by job advertisements, are apparent. The trend data show that for the past five years, Western Australia has had almost double the number of average job vacancies per month compared with other states. In the past couple of years, the vacancy numbers for Queensland have also grown larger than those for the more populous states. These figures are indicative of strong growth in demand for geologists, stemming directly from the recent mining boom.

The academic profession

The academic workforce in the natural and physical sciences in Australia experienced growth during the 2002 to 2006 period. However, within individual disciplines, the data used in this report suggest that there was a decline in the numbers of mathematical science, chemical science, and earth science academic positions over this period. The data indicate there were substantial increases in the biological sciences.

In 2006, 31 per cent of academics employed in Australia had completed their highest qualification outside of Australia. For academic 'cross-pollination' of knowledge and methodology, this appears to represent a healthy situation for Australia. Analysis over time shows that the proportion of the workforce in these fields that have obtained their highest qualification overseas has been slowly increasing.

The age structure of the academic workforce in the mathematics and science fields in 2006 shows a relatively large bulk of academics aged between 30 and 49, with a tapering into the older age groups. This age distribution suggests there are a relatively healthy number of early and mid-career academics currently in these fields. However, this does not conceal the fact that the academic workforce in the natural and physical sciences is ageing. Between 2002 and 2006, the proportion of academic staff aged over 55 in Australia grew, while the proportion of academics aged below 35 remained relatively stable.

As outlined in the literature, the key to ensuring that retirements in the academic workforce do not result in severe workforce shortages in the natural and physical sciences is to retain young scientists and mathematicians in universities. An important element in retaining these young academics is to provide adequate career pathways. However, in concordance with the international literature on this subject, the findings of this report reveal that in Australia, the number of short- and fixed-term contracts for academics in the natural and physical sciences grew between 2002 and 2006, which is a worrying development.

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List of Acronyms

ABS	Australian Bureau of Statistics
ACER	Australian Council for Educational Research
ANZCO	Australian and New Zealand Standard Classification of Occupations
ASCED	Australian Standard Classification of Education
ASCO	Australian Standard Classification of Occupations (former classification)
CRC	Collaborative Research Centre
DEEWR	Department of Education, Employment and Workplace Relations
DEST	Department of Education, Science and Training (former federal department)
DIAC	Department of Immigration and Citizenship
GCA	Graduate Careers Australia
GDS	Graduate Destinations Survey
ICT	Information and Communication Technology
NSW	New South Wales
OECD	Organisation for Economic Co-operation and Development
STEM	Science, technology, engineering and mathematics
SVI	Skilled Vacancies Index
UK	United Kingdom
US	United States of America

Note

This report is one of four which make up a project examining the supply, demand and employment opportunities for graduates with higher degree research qualifications in the science and mathematics fields in Australia. Each report is intended to stand alone as an independent piece of research. However, in order to gain an overall perspective of the factors influencing supply and demand for this group it is important to consider all the reports in this project. In addition, the report findings highlighted here are based on information available at the time. These findings can be expected to vary with changing circumstances.

The four reports comprising the project are: 1) Literature Review And Data Analysis , 2) Consultation Report, 3) Case Study Report and 4) Final Report. These are available on the DEEWR website and can be accessed at: http://www.workplace.gov.au/workplace/Publications/ScienceEngineeringandTechnologySkills-Publications.htm.

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1. Literature Review

Introduction

This literature review is the first stage in a larger project that will investigate the demand and supply of people with science and mathematics postgraduate qualifications in Australia. This particular group of skilled individuals is of great importance to the innovative development of Australia and its future as a leader in research and development across the globe. However, there has been only limited research conducted in relation to this group to date.

Forming an understanding of labour market demand for these skills and the patterns of supply of graduates is essential in being able to formulate policy that will contribute to the future success of the scientific community in Australia. This literature review encompasses a range of research projects, key stakeholder reports and specialist commentaries, which cover issues relating to supply, demand, and employment and training of students in the science and mathematics fields. It concentrates particularly on the high-end of this market – those with higher degree research qualifications (Masters by research and PhD).

The findings of existing research outlined here in this review will inform other parts of this research project. Initially, the key themes emerging in the literature will be tested using the most recently available data relating to these issues available in the Australian context. The findings of this data analysis are presented in the second part of this report. In addition, this project will tap into the views and experiences of stakeholders from the industries employing higher degree graduates in science and mathematics in Australia. This will take the form of consultation with employers, recruiters, trainers (i.e. universities) and graduates. The outcomes from the review of the literature and the analysis of new data will be used to inspire, inform and add weight to the views that are garnered from the consultation process in this project. Finally, all of these findings and experiences will be used to identify best practice in the employment of science and mathematics research postgraduates in Australia. A number of employers will be used to highlight best practice outcomes in the hope that their models can be utilised more widely to promote excellent employment pathways for science and mathematics postgraduates.

This literature review synthesises the findings and views of a vast array of interested parties in the science and mathematics fields. It encompasses both Australian research and research from the around the world, particularly the US, UK, Canada and Europe. Interestingly, while there are nuances of difference between countries, there is a relatively uniform story that emerges when issues of demand and supply in the science and mathematics fields are evaluated – the key message is that while supply is perhaps more plentiful than may be sometimes promoted (in fact, the raw numbers appear to show there is more than enough supply to meet demand), the numbers themselves do not necessarily reveal the full picture. It may be that despite the apparent numerical balance, the postgraduates coming out of the science and mathematics areas are not necessarily fulfilling market demand. This is due to numerous reasons; the most prominent being a perceived lack of quality by employers and a lack of interest in science and mathematics-specific employment among graduates.

This report begins with some discussion of context and then outlines the 'Big Picture', looking at the issues relating to science and mathematics generally and investigating trends both internationally and within Australia. It then explores research relating to graduate outcomes of those with higher degree research qualifications in the mathematics and science fields and examines investigations that have matched these outcomes with workforce demand for such graduates. Following this, specific issues relating to the academic workforce in these areas are detailed, drawing particularly on international research. The literature review concludes by examining research that discusses ways in which supply and demand can be effectively identified, and how policy can be implemented to ensure a better match between the two.

Context

Scientists and mathematicians are essential to the economic progress and wellbeing of Australia. They function effectively in a number of industries and across a range of occupations. The skills of scientists and mathematicians are utilised in solving long term environmental problems facing the globe, identifying improvements in productivity, the development of new products, identification of new areas of technological advancement, and advances in communication, among numerous others (Braddock, 1992). Essentially, research, development and innovation in these areas drives ‘knowledge-intensive economies’ and it is these economies that are currently flourishing and are likely to continue to remain strong well into the future. Such economies ‘tend to create well-paying jobs, to contribute high-value output, and to stimulate economic activity generally. The global nature of these developments compels governments to take part in them or be left behind, to the detriment of a country’s economic standing and wellbeing’ (National Science Board, 2008, pp. overview -8).

It is therefore important to understand labour force outcomes for people with higher degree qualifications in these areas. Information about the current and future supply of workers in these fields, and matching this with the current and projected demand can be essential in ensuring that funding, policy emphasis and the satisfaction of postgraduates in these areas is enhanced to best fit a nation’s needs.

Each of the educational and occupational fields under the broad heading of science and mathematics have their own communities, employers, clusters and stakeholders. They are far from a homogenous group (Pearson et al., 2001) and yet are closely interlinked through the faculties in which university training for these disciplines begins. For the purpose of this analysis, the disciplines within this broad area are mostly discussed as one. However, in cases where more discipline-specific information is available, the discussion does focus on a particular field within the sciences.

At the other end of the spectrum, the science and maths disciplines are often grouped into a larger collective of broad areas. A substantial amount of the literature available relating to science and mathematics groups these fields with the areas of engineering and technology. The fields of science, technology, engineering and mathematics (often referred to as STEM) are commonly grouped in analyses of supply and demand. However, the aim of this project is to focus specifically on the science and mathematics areas and therefore, while literature relating to the STEM fields is used, the emphasis drawn from these studies is primarily from specific breakdowns of the fields of science and mathematics.

In addition to these issues, in reviewing the evidence for supply and demand of graduates in the science and mathematics fields, it is often difficult to distinguish between first (or bachelor) degree graduates and postgraduates. Where evidence relates specifically to postgraduates, this is specifically stated in the discussion.

The Big Picture

Overall, international research into the employment of science and mathematics postgraduates indicates that while the output of graduates exceeds the demand for such qualifications among employers, there still appear to be substantial labour force shortages. The key reasons for this are twofold: first, a perceived lack of quality of graduates among employers; and second, the fact that many graduates choose not to follow a pathway into a traditional science and mathematics occupation. From robust analyses undertaken in the US, UK, Europe, Canada, Australia and other parts of the globe, it appears that at a broad level this situation is common across the world. The more specific pictures emerging in the literature from key comparative countries are explored below.

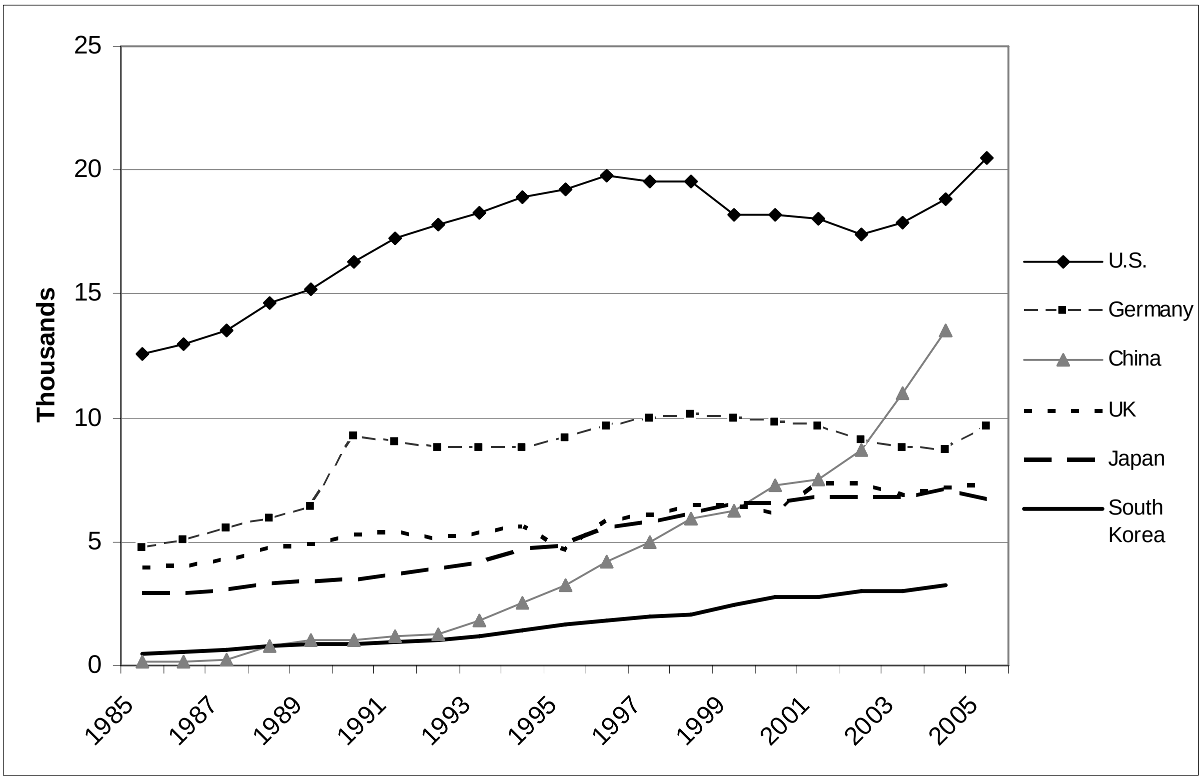
Supply

Higher Education

Across the globe, science enjoyed a massive boost in popularity, perceived relevance and, as a result, funding in the mid to late 1960s (Barrow & Germann, 2006; Braddock, 1992; Briley, 2008; Leggon, 2001; Paldy, 1994). This period was sparked by the space race (Briley, 2008) and emerging new technologies, and helped to establish a large network of university science faculties and a plentiful supply of jobs for those with science and mathematics PhDs. Since then, the global economy has changed substantially and so have the drivers of supply and demand.

Postgraduate supply in science and mathematics fields has fluctuated over the past few decades. The general trend has been towards increased numbers of doctoral students. Unfortunately, there is no internationally comparable published data illustrating the growth of doctoral graduates in science and mathematics. The best indicator is found in data compiled by the National Science Board in the US for the number of individuals awarded doctoral degrees in ‘Science and Engineering’ (a broad field that also includes mathematics) across a number of countries since the mid-1980s (National Science Board, 2008). The data in Figure 1 shows that the US is by far the largest producer of science and engineering doctorates in the world. In the US, there was massive growth in supply between the mid-1980s and mid-1990s, followed by a slight yearly decline until the early 2000s, from which time there has been an increase. The final year of the series, 2005, has the highest number of doctoral awards in these fields in the US.

Figure 1: Natural sciences and engineering doctoral degrees awarded, by selected country, 1985–2005



Source: National Board of Science, *Science and Engineering Indicators 2008*

Fluctuation in supply can also be seen in the UK and Germany between 1985 and 2005. In the UK, in spite of fluctuations, there has been an upward trend, albeit relatively slow since the 1980s. In Germany, Figure 1 shows there was a substantial jump in numbers at the end of the 1989–1990 (probably an artificial increase as a result of the reunification of Germany and the access to figures from the former East

Germany). The 1990s saw a slight growth in numbers, with a peak in the late 1990s followed by a slight decline. The trajectory of completions in science doctorates in Germany appeared to be back on the increase by 2005.

In the Asian countries displayed in Figure 1, there has been a continuous upward trajectory in the number of science and engineering PhD completions since the mid-1980s. Of particular note is the marked growth in China, which experienced a strong increase in completions beginning in 1993, followed by further substantial growth beginning in 2000. China's position as a key provider of science PhDs is now well established. In addition, it should also be noted that this growth for China does not include the substantial number of Chinese science and engineering doctoral students graduating from higher education institutions outside of China, particularly in the US and the UK.

While Australian figures of supply are not displayed in the US National Science Board publication, a comparison of the data in Figure 1 with Australian numbers is possible using some findings from Australian research (Dobson, 2003, 2007). The Australian figures differ from the US National Science Board numbers in some of the disciplines (in particular the Australian figures do not include engineering completions). However, the data in Table 1 is relatively comparable and indicative of trends across a number of countries since the late 1980s. The table shows that while the overall numbers are smaller, science research degree completions have grown substantially in Australia over this period. Of the countries listed here, only China and South Korea had larger growth in these areas. Interestingly, Australia has experienced large growth relative to the other established western countries (the US, UK and Germany) over this period.

Put in perspective, the figures in Table 1 show that Australian production of PhD students in the sciences is miniscule on a global scale, and that growth has come from a low base in comparison to the US, UK and Germany. However, looking at the growth in overall numbers, Australia has caught up with the rest of the world in terms of supply over the past few decades. As will be outlined in the data analysis, Australia's share of science and mathematics PhDs is impressive when per capita figures are examined.

Table 1: Science and mathematics PhD completions by selected country, 1989–2004

	US	*Germany*	*China*	*UK*	*Japan*	*South Korea*	***Australia***
1989	15,200	6,370	1,000	4,940	3,380	890	**472**
1993	18,250	8,800	1,790	5,360	4,200	1,200	**604**
1997	19,560	9,950	4,980	6,090	5,770	1,950	**1,043**
2001	18,030	9,620	7,530	7,360	6,790	2,760	**1,119**
2004	18,810	8,720	13,550	7,200	7,100	3,260	**1,180**
Number change 1989 to 2004	3,610	2,350	12,550	2,260	3,720	2,370	708
Percentage Change 1989 to 2004	23.8	36.9	1255.0	45.7	110.1	266.3	**150.0**

*engineering numbers included in figures other than for Australia

Sources: National Board of Science, *Science and Engineering Indicators 2008*; Dobson [2003], *Science at the Crossroads;* and Dobson [2007], *Sustaining Science*

While there has been a notable growth in the supply of science and mathematics PhD completions in Australia, such change over this period has in fact been experienced across the whole Australian university sector. Figures from Dobson's reports for the Australian Council of Deans of Science (2003, 2007) show that natural and physical sciences PhD completions, as a proportion of all PhD completions in Australia, have declined. In 1989, 39 per cent of all completions in Australia were in the sciences, yet by 2004, the share of this field had declined to 24.1 per cent of all PhD completions. This fact was also noted in the Australian Government's *Audit of science, engineering and training skills* (Department of Education Science and Training, 2006). Hence, while international comparisons show that supply in Australian science completions is relatively healthy, the detailed Australian picture shows that in the context of a rapidly growing higher education sector, the sciences have fallen behind somewhat.

Migration

At the domestic level, supply of persons with science and mathematics postgraduate qualifications and experience can also be accommodated though migration programs. In Australia, a robust skilled-migrant program has fuelled population growth and increased labour market expertise in a number of areas since the mid-1990s (Birrell, Rapson, Dobson, & Smith, 2004). The *Audit of science, engineering and training skills* (2006, pp. 45-46) investigated in Australia the flow of professionals in science and mathematics occupations into and out of Australia over a five-year period up until the mid-2000s. It found that migration had resulted in net gains to Australia in Chemists, Geologists and Geophysicists, Life Scientists, Environmental and Agricultural Scientists, and Mathematicians and Statisticians between 1998 and 2003. These increases ranged from a 15 per cent growth in Life Scientists to a 5 per cent increase in 'stock' of Environmental and Agricultural Scientists. Growth in these areas was consistent with migration-led increases in most professional occupations. However, the *Audit* revealed that there was some net loss within science occupations as a result of migration movement. In occupations classified as 'Other Natural and Physical Science Professions', there was an 11 per cent decline in numbers over the 1998 to 2003 period. This was the only professional occupation to experience a net loss of personnel over this time span.

Among PhD qualified persons in the science and mathematics fields, a detailed analysis of skills movement between 1996 and 2001 by Birrell et al. (2004, p. 43) reveals that net loss of domestic PhD completers in these fields was relatively small. Using a range of Census and Higher education completions data, Birrell et al. estimated a net loss of 70 domestic science and mathematics PhD students between 1996 and 2001 in Australia. Given this figure, the authors state: 'there has been only a very small loss of recently qualified PhDs from Australian institutions in the science fields, including mathematics – the field where representatives of the discipline have been the most vocal in claiming Australia is experiencing a serious brain drain of recently qualified talent'. Birrell et al. note that the small outflow of PhD talent in the science and mathematics fields is in contrast to other fields such as engineering, education, and management and commerce, where the loss of PhDs 'is substantial relative to the number of completions' (2004, p. 44).

In other parts of the world, particularly the US, the 'brain gain' of recently qualified PhD graduates in the mathematics and science fields is relatively substantial. While no specific figures relating to the movement of domestic students out of the US are available, there are substantial gains to the US via migration of qualified scientists and mathematicians. According to the National Science Foundation, among those within the US labour force who hold doctoral degrees in the sciences, immigrants comprise 29 per cent of those conducting research and development (Johnson & Regets, 1998; Kannankutty & Burrelli, 2007).

International students

The role of international students in facilitating demand has become increasingly important in many western countries over the past few decades. As the supply literature outlines, migration to Australia is a key source of supply of highly skilled scientists and mathematicians, and likewise, the proportion of PhD holders in these fields in the US who are foreign born is increasing. In many circumstances, the key reason for the large flow from migration is linked to the relatively recent growth in international students within universities in the US, UK, Canada and Australia (National Science Board, 2008). The role of international students in boosting the supply of scientists and mathematicians in many western countries has been of crucial importance (Kannankutty & Burrelli, 2007).

As a result of this, the input of university students in Australia and other developed countries over the past few decades has changed substantially. Therefore, the simple overview of the broad figures in PhD completions outlined above can be potentially misleading. As shown by a number of Australian studies (Birrell, Edwards, Dobson, & Smith, 2005; Birrell et al., 2004; Department of Education Science and Training, 2006; Federation of Australian Scientific and Technological Societies, 2008), the vast majority of growth in Australian university enrolments over the past few decades has been a result of an influx of international students. This situation is not unique to Australia. In the US and UK, similar trends have occurred. Virtually all of the recent growth in PhD completions in science and mathematics in the US has been a result of increases in international student numbers and not growth at the domestic level (Corley & Sabharwal, 2007; Johnson & Regets, 1998; National Science Board, 2008). In Europe there is a similar situation in some countries, in particular England. However, in other parts of the continent, where there have been large expansions of higher education systems in the past few decades, strong growth in the natural sciences appears to be driven at the domestic level. In particular, this appears to be the case in Ireland and France (Pearson et al., 2001).

US research into the employment outcomes of international students following the completion of their degrees suggests that there are positive outcomes for the US economy and for the supply of scientists and mathematicians, with large numbers remaining in the US rather than returning with their new skills to their country of birth (Kannankutty & Burrelli, 2007; National Science Board, 2008). Corley and Sabharwal (2007) also acknowledge the positive impact on the US economy in general, but at the same time warn that many former international PhD students working in the US find themselves on lower wages and less satisfied with their jobs than their US-born colleagues. Nevertheless, the proportion of foreign born scientists in the US has increased over the past few decades, with the transition of international students into the workforce being an important element of this growth (National Science Board, 2008).

However, it appears that this situation is not replicated in the Australian context. Data from Birrell et al. (2004) indicate that in contrast with the large numbers of bachelor and masters international students who remain in Australia following graduation, only a small number of international student PhD completers seek permanent residency following graduation. As a result, it is important to be careful in using international PhD students in Australia in any measurement of the supply coming from Australian higher education institutions in the science and mathematics fields.

Anticipating future supply

While the international market has been a strong supplier of PhD graduates, there is a need to address supply issues at the domestic level (Birrell et al., 2005; Birrell et al., 2004). This is related to the lower level of articulation of these postgraduates into the Australian economy as outlined above, but also due to a slowing in the supply of international students to Australia and other key feeder countries as a result of increased university infrastructure in the main source countries for international students (Australian Education International, 2007). The National Science Board in the US has noted that investment in research and development outside of the OECD has grown substantially in recent years, thus potentially limiting international supply of scientists and mathematicians to western countries in the future (National Science Board, 2008). In addition, the figures in Table 1 and Figure 1 clearly show the emergence of domestic training in these fields in the key international student market of China.

Predicting future supply at the domestic level is difficult, and contingent on a number of factors. Some of the Australian and international literature provides hints of expected levels of supply in the future. Overall, the research paints a somewhat pessimistic view. This evidence is important but should also be viewed in the context of the supply growth that is shown to have occurred in the last 15 to 20 years.

One key issue in assessing future supply domestically – be it in Australia, the UK or the US – is evaluating trends in the numbers of school participants in the sciences and mathematics. In Australia, a large amount of literature suggests there is declining participation in these fields (Chinnappan, Dinham, Herrington, Scott, & Australian Association for Research in Education, 2008; Churach & Rickards, 2005; Department of Education Science and Training, 2006; Leech, 2006; McInnis et al., 2001; Wood & Smith, 2007). In particular, there is concern about participation in science and mathematics at the senior advanced levels, which are generally prerequisite subjects for entering science degrees at university (Chinnappan et al., 2008; Hughes & Rubenstien, 2006). Similar concerns are apparent in literature from the UK, Europe and the US (Biermans, de Jong, van Leeuwen, & Roeleveld, 2005; Convert, 2005; Coopert & D'Inverno, 2004; Lowell & Salzman, 2007; Mason, 1999; TAP, 2008).

There are numerous reasons cited for the decreasing numbers of school enrolments in science and mathematics, including a lack of understanding of career prospects (Chinnappan et al., 2008; Praeger, 1993; Tytler, Osborne, Williams, Tytler, & Cripps Clarke, 2008; Wood & Reid, 2006), the perception that the subjects are too difficult (Brinkworth & Truran, 1999; Convert, 2005), and possibly most crucial, quantity and quality problems with science and mathematics teachers (Biermans et al., 2005; Chinnappan et al., 2008; Convert, 2005; Coopert & D'Inverno, 2004; Mackenzie, 2002; Mason, 1999; McInnis et al., 2001).

Addressing each of these issues is crucial to ensuring that supply of students into undergraduate courses and through to the postgraduate level is maintained. As noted in the literature, there is widespread recognition of these issues across the world. Initiatives to improve participation and increase the quantity and quality of supply are slowly being undertaken; for example, the Australian Government’s 2008/09 Budget included provision of $562 million to encourage students to undertake education degrees in mathematics and the sciences (Department of Education Employment and Workplace Relations, 2008). The success of such initiatives will be revealed over the following decades.

Demand

Evidence relating to demand for postgraduates in the science and mathematics fields suggests that, as with supply, it has continued to be strong throughout the past few decades, despite the changing priorities of governments and industry. However, the key to assessing demand is the extent to which it fits with supply. As the international research outlined below indicates, in many parts of the world, supply has not been satisfying demand. Interestingly, this is not an issue of unbalanced numbers, but rather relates to dissatisfaction among employers with the quality of graduates in the market.

To a certain extent, Lowell and Salzman (2007) illustrate this paradox well in relation to the problem in the US. Like the evidence above, their analysis shows increasing numbers in science and mathematics graduates – in particular they argue that the US has a healthy share of graduates in these areas relative to other parts of the world. In fact, Lowell and Salzman argue that there is an oversupply of graduates in these fields in the US. Examining university completions, they argue that the US has been producing three times more graduates in the science and engineering fields each year than there are jobs available in these fields. However, despite this perceived oversupply, they find there is still a problem with the demand-side of the science employment equation.

Lowell and Salzman (2007) believe that this demand-side problem may actually be a perception problem among employers rather than an actual skills-shortage issue. These researchers refer to their previous findings, revealing that when probed about the lack of available workers, managers in these fields conceded that they were actually voicing concerns about a sufficient number of 'brilliant' workers in the 'pool' rather than a shortage of suitably qualified or skilled applicants (p. 36). Lowell and Salzman argue that the shortage issue is mainly raised by individual employers who 'may be voicing unrealistic expectations of experience, more than skills or education' of new graduates (p. 36). In particular, they believe that the extent to which these 'skills crisis' issues articulated by employers actually exist is evidenced only in lower skilled retail or clerical jobs in the industry, and therefore do not exist in the highly skilled job areas occupied by PhD graduates.

Other international research into demand and supply issues within the science and mathematics fields has found that despite supply being plentiful, there remain issues with workforce demand. A European study by the Institute for Employment Studies found that new growth in demand for scientists was coming particularly from smaller firms and the service sector, but that overall, modelling suggested supply would exceed employer needs across the EU. Overall, this finding was particularly pertinent for the natural sciences field. Yet despite the fact that 'there were no quantitative shortages of scientists' there were substantial imbalances in demand within some specific fields and within some countries (Pearson et al., 2001, p. 3). The econometric modelling carried out by researchers on individual occupations within individual countries suggested that in Denmark, Germany and the Netherlands there may be impending problems in the supply of natural scientists 'unless significant labour market adjustments take place' (p. 3). In addition, the research found that within the life sciences, demand remained low. In particular, for doctorate graduates in the life sciences in France, unemployment, under-employment and under-utilisation of skills was becoming common.

Research by Mason (1999) in the UK found there were no general shortfalls in quantity in regards to the number of science graduates being produced each year and the number of jobs available for scientists and mathematicians, but that there were 'continuing reports of some employers experiencing difficulties in recruiting technically-qualified graduates' (Mason, 1999, p. 1). A National Science Foundation study in the US (Johnson & Regets, 1998) indicated that substantial funding increases in research and development between the mid-1980s and late 1990s led to a boost in demand for scientists and mathematicians, but that this had not resulted in workforce shortages due to the large cohort of postgraduates available in these areas.

In the Australian context, there is also evidence of some oversupply of qualified scientists and mathematicians (Borthwick & Murphy, 1998), and in general the evidence of current un-met workforce demand in these areas for people with higher degree qualifications is relatively limited. The *Audit of science, engineering and training skills* (Department of Education Science and Training, 2006) in Australia shows strong employment growth in most sciences and mathematics occupations between 1996–97 and 2004–05, but this appears to have occurred in conjunction with the growth in supply to these areas, therefore not resulting in any substantial workforce shortfalls.

The *Audit* identifies two types of demand: ‘new’ demand and ‘replacement’ demand. ‘New’ demand results from the creation of new technologies and new jobs, while ‘replacement’ demand occurs as an outcome of demographic change, such as retirements resulting from an ageing workforce (Department of Education Science and Training, 2006). Both these elements of demand are difficult to forecast, but the ‘new’ demand side is particularly difficult due to problems predicting where new technologies and innovations will occur. As noted by Anderson, McInnis and Hartley (2003, p. 61), ‘science and technology is a dynamic and ever changing field. The difficulty in predicting the direction of scientific advance, and the economic opportunities that arise in areas of that advance, as driven by market demand’, are increasingly challenging. One example of this, from the perspective of geologists alone, are the increasing changes to the earth science profession as a result of emerging issues such as salinity management, water shortage, climate change and geo-hazards (Cawood, 2008).

A forecast of workforce demand and supply within science, engineering and technology occupations undertaken by the Centre of Policy Studies at Monash University as part of the *Audit* predicted that within the science and mathematics fields, Australia needs to invest more energy into addressing replacement demand than new demand in the coming years. This is primarily due to the increasing proportion of older persons in the Australian workforce and the impending retirement of the baby boomer generation.

The Monash forecast predicts that employment growth between 2004–05 and 2012–13 will continue, but in many disciplines will not be as strong as it was in the 1996–97 to 2004–05 period. The exceptions to this were in chemical sciences, where employment growth between 1996–97 and 2004–05 was 5.4 per cent, but projected growth for 2004–05 to 2012–13 is 28.6 per cent; and physics and astronomy, where growth is predicted to increase from 33 per cent in the earlier period to 49.6 per cent in the future (Department of Education Science and Training, 2006, p. 5). In a different set of projections, based on annual job growth, the Monash model predicts strong future growth for mathematicians, statisticians and actuaries, and agricultural and environmental scientists (p. 6).

Independent of these figures, but in some ways complementary, there are concerns being voiced within the science and mathematics disciplines of impending demand issues within these fields. In particular, a review into mathematics skills in Australia found that unless investments were made across the education spectrum, including within universities, the future of mathematics in Australia would be in dire straits (Hughes & Rubenstien, 2006). Similarly, there are reports of impending shortages in environmental sciences (Canberra Times, 2008) and evidence to suggest a strengthening demand for graduate chemists (Royal Australian Chemical Institute, 2006).

However, in all these cases, there is a large element of guesswork involved. US research by Braddock (1992), in which projections of workforce demand were made as an attempt to inform policy relating to supply of graduates, concluded that while certain assumptions could be made, ‘simple comparisons of projected degrees with estimates of job openings cannot be used to identify supply and demand imbalances’ (p. 39).

As a result of these difficulties in assessing demand, there are very few studies that provide an indication of the dimensions of demand for postgraduates within the science and mathematics fields. In addition to the Monash predictions from the *Audit of science, engineering and training skills* in Australia, the *Occupational Outlook Quarterly* (Bureau of Labor Statistics, 2004) in the US provides occupational growth predictions. While the details relating to the numbers of workers for individual occupations published in this journal are irrelevant to Australia, the trends in growth noted are important in providing some way of predicting the direction of future demand. For the period 2002 to 2012, the publication does not predict faster than average job growth in any of the science or mathematics professions. For mathematicians, there is a predicted decline, because ‘this work is becoming more integrated with other fields’ (p. 12). Modest growth is predicted in most other science-related jobs, with a note that for doctoral students there is likely to be increasing competition for research positions as the number of completions in the sciences grows. In Australia, physicist John Prescott (1993, 1995, 2000, 2004) has monitored the extent of demand for physics-related jobs over the past 25 years. His research has shown that for professional jobs in physics a PhD is a stated or preferred requirement in the majority of cases. Prescott’s collection of job advertisement data reveals that demand for physicists declined between 1984 and 1993 and has been relatively steady since. His most recent data show that about 460 positions for physicists in Australia were advertised in 2003 (Prescott, 2004). As simple as this analysis is, it is one of the few studies that attempt to quantify demand for higher degree qualified persons in the sciences. Despite these collections and predictions, the task for universities and policy makers to effectively tailor supply to demand is extremely difficult.

The two main reasons for the difficulty in predicting demand in order to regulate future supply relate to quality of graduates and destinations of graduates (Braddock, 1992; Haas, 2005; Leggon, 2001; Lowell & Salzman, 2007; Mackenzie, 2002; Mason, 1999; National Science Board, 2008; Paldy, 1994; Patel, 1996; Pearson et al., 2001; Reys, 2006; Royal Australian Chemical Institute, 2006). If employers perceive graduate quality to be low, they are likely to argue that there are shortfalls with supply. Likewise, if graduates perceive science and mathematics employment prospects to be poor, and instead choose to find employment outside their field of expertise, then demand within their fields for graduates will increase. The difficulties in predicting these two elements of demand are the reason why there is so little literature that pinpoints the dimensions of demand. The issue of quality is outlined immediately below, while graduate perceptions and workplace destinations are discussed in the following section.

Quality

Throughout the existing evaluations of the employment market for science and mathematics occupations, the quality of graduates appears as a central theme in determinations of demand. It appears from the current research that ‘work readiness’, and ‘soft’ skills are viewed by employers to be as important as technical and cognitive skills and qualifications (Precision Consulting, 2007). This is a key reason why international and Australian research suggests that the growing workforce demand in these fields has much to do with the fact that employers do not believe that the supply in these areas is of ‘employable’ quality. While employer perceptions of shortages can be misguided (Lowell & Salzman, 2007), they are nonetheless an extremely important element in the supply and demand chain. Therefore, concerns about quality voiced by industries and employers are hard to dismiss.

As shown above, worldwide, the supply side of the science and mathematics higher degree equation appears to be relatively healthy in numeric terms. However, given there are still concerns about the demand for science and mathematics skills, the quality issue is one that appears to be of crucial importance. The Federation of Australian Scientific and Technological Societies (FASTS) has clearly articulated its views in relation to balancing these issues in a recent submission to the House of Representatives Inquiry into research training and workforce issues in Australia: ‘while there are good reasons to increase capacity in research training … the primary focus needs to be on improving the quality of research training’ (2008, p. 1).

This emphasis would be strongly supported by Mason, who in assessing such issues in the UK notes ‘the great majority of mismatches between supply and demand … are attributable to quality problems rather than any overall shortfall of quantity’ (1999, p. 1). In his study of employer experiences in hiring science graduates, Mason found that work experience, commercial understanding and communication skills were of vital importance to employers.

The technical and cognitive skills (‘hard’ skills) of graduates are focused on in their studies, but according to Mason (1999) and Coll and Zegwaard (2006, pp. 29-31), employers are increasingly keen to find graduates with behavioural skills (‘soft’ skills). ‘Hard’ skills include technical, analytical and appreciative skills. Technical skills relate to the specific ability to apply learned expertise to a task, analytical skills relate to problem identification and problem solving, while appreciative skills relate to the ability to evaluate and make appropriate judgements about complex situations.

These are skills that are found to be prevalent in postgraduates as a direct result of their training.

'Soft' skills are a combination of personal, interpersonal and organisational skills. As noted above, these skills are highly sought after by employers, but appear to be lacking in many postgraduates in the science and mathematics fields. Coll and Zegwaard (2006, p. 31) define personal skills as relating to the way an individual handles various situations, interpersonal skills as being about securing outcomes through interaction with others, and organisational skills as understanding workplace dynamics and being able to solve problems by utilising organisational networks. These skills are 'primarily affective in nature and are associated with the related emotional quotient, comprising a blend of innate characteristics and human, personal and interpersonal skills.' Among these skills, according to Coll and Zegwaard (p. 29), 'the single most desirable skill is *ability and willingness to learn*.'

In the workforce, these 'soft' skills translate into greater ability to communicate and work in a team, something that within the sciences is becoming more important due to an increasing need to interact with clients and a growing need for collaboration within the industry (Mason, 1999). They also contribute to the ability to recognise the adaptability of technical skills, so that organisational and commercial opportunities can be more readily recognised.

However, according to Mason, employers generally perceived a lack of such qualities among the majority of graduates who were applying for jobs. These themes were also common in literature from the US (Lowell & Salzman, 2007) and Australia (Wood & Reid, 2006; Wood & Smith, 2007).

As noted above in Mason's research, one of the key concerns raised by employers regarding quality and employability of graduates in the science and mathematics fields is the apparent lack of 'work-readiness' of these graduates. US research by Greene, Hardy and Smith (1995) has given further weight to the complexities of employability and desired skills within the science and mathematics fields. These researchers voiced concern regarding graduate destinations given the changes in the job market, noting that 'the work activities of scientists are increasingly diverse and increasingly removed from the basic skills that earn a doctorate' (p. 59). A French research project also reached similar conclusions (Dany & Mangematin, 2004). New Zealand based researchers Coll and Zegwaard (2006) argue that the work-readiness facet of graduate attributes in the mathematics and sciences is but one of a suite of expectations required by employers:

> Graduates contemplating a career in science … require a wide variety of skills both cognitive and behavioural. Moreover, they require such skills to a high level. They must be technically competent, computer literate and able to interact with people, and in the future will need to become more computer literate and customer-oriented (p. 51).

Coll and Zegwaard note that the role of educational institutions in preparing graduates with such skills is becoming more difficult. This is a theme that is common throughout related research in this area (Gott, Duggan, & Johnson, 1999).

Such concerns are also present in Australia. A submission to an inquiry into research training and research workforce issues in Australian universities by the Australian Academy of Technological Sciences and Engineering (2008, p. 3) recently noted that 'research training … must equip postgraduates not only with research skills but also with a range of attributes that include business and innovation skills, Intellectual Property (IP) management and entrepreneurship'. In addition, a detailed study of mathematics graduates in Australia concluded that in this field there are 'serious areas of underpreparedness for the workforce' (Wood & Reid, 2006).

The key concerns relating to work readiness generally revolve around the 'soft' skill capabilities described above, but also include some other specific competencies. In particular, commercial understanding appears to have an increasing importance. Greene et al. (1995) found that employers of recently graduated scientists and mathematicians were particularly interested in those who showed some business knowledge because of the increasing need to drive innovation in areas with commercial and financial viability. These researchers argue that much of the training undertaken by science postgraduates does not transfer well from the laboratory into other work environments where scientists are required. Those graduates with multidisciplinary (rather than specialised) knowledge and an ability to adapt to commercial needs are most sought after (Greene et al., 1995).

It is possible that many employers are unrealistic in their expectations of postgraduates, especially in regards to experience (Lowell & Salzman, 2007); however, with a labour market for these graduates generally balanced towards oversupply, only those graduates who possess all of these skills will be able to successfully negotiate a career in their fields (Coll & Zegwaard, 2006).

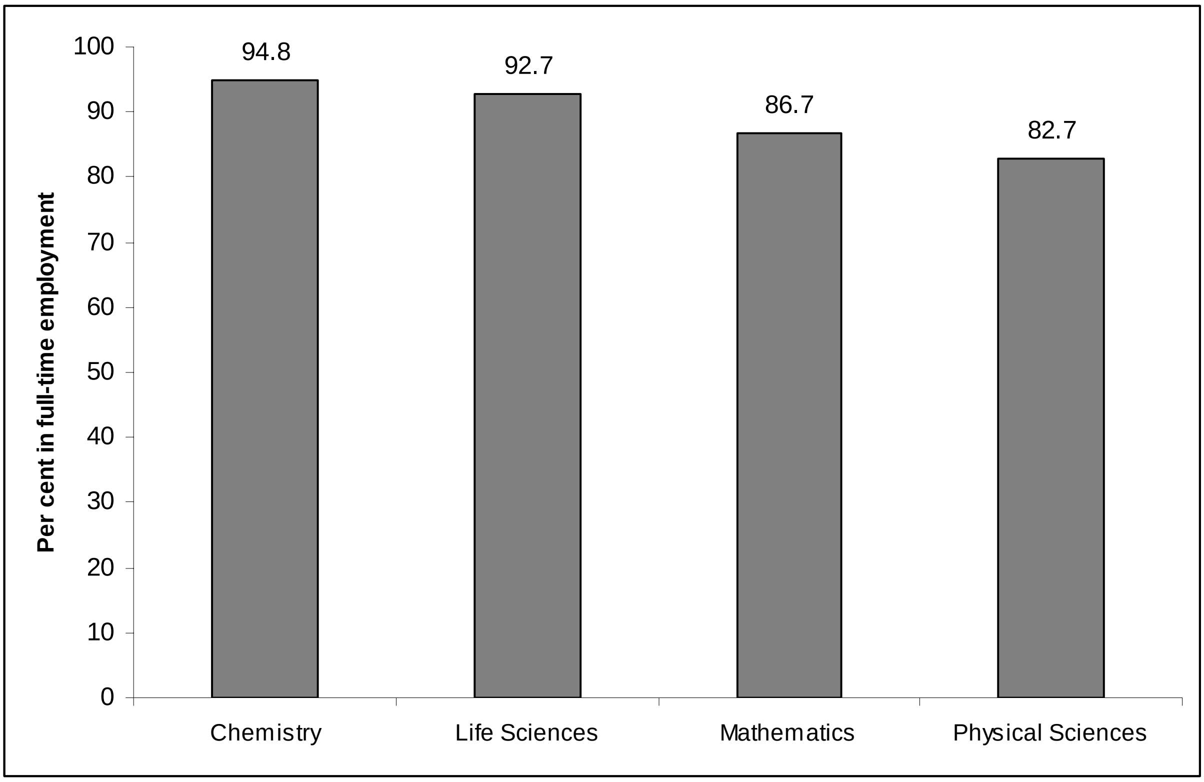
Where do science and mathematics postgraduates go?

In general, the literature on the workforce destinations of postgraduates in the science and mathematics fields indicates that degree holders have relatively good employment outcomes. Numerous studies show that the higher the level of degree in the sciences, the more likely a graduate is to be employed and working in their field (Kannankutty, 2008; Lavoie & Finnie, 1999; Mark Regets, 2006). However, within the lower qualifications, the extent of mismatch between field of education and industry of occupation grows (Kannankutty, 2003; Lavoie & Finnie, 1999).

Analysis of postgraduate destinations data from the US has shown that unemployment rates of science postgraduates have been at near record lows over the past few years. Figures for 2006 show that 2.3 per cent of residents with a doctorate in the physical sciences were unemployed, down from 2.7 per cent in 2003 (Kannankutty, 2008). The unemployment rate for bachelor graduates in this field was also low, but at 3.9 per cent was higher than that for doctoral graduates (Kannankutty, 2008).

In Australia, the postgraduate destination employment figures in science and mathematics fields are also relatively robust. However, details from an annual survey undertaken by Graduate Careers Australia of graduate destinations in the six months following completion of a degree show that, within the sciences, there are some differences in employment outcomes. For higher degree postgraduates from 2006 in Australia, the Graduate Destinations Survey shows that 94.8 per cent of chemistry graduates were in full-time work in the period immediately after graduation, with similar high figures achieved by life sciences postgraduate completers (Figure 2). The figures for mathematics graduates were slightly lower, with 86.7 per cent in full-time work. In the physical science fields the outcomes were lower again at 82.7 per cent (Graduate Careers Australia, 2008). In all cases, the employment outcomes of those with higher degrees were superior to the bachelor degree cohort in the same discipline.

Figure 2: Proportion of recently completed PhD and Masters by Research postgraduates in full-time employment by discipline, 2006 completions, Australia



Source: GCA, Graduate Destinations Survey, 2007

While the unemployment figures of postgraduates in Australia are not as readily available, a study by McInnis, Hartley and Anderson (2001) found that 3 per cent of science graduates with a bachelor degree (who completed their degrees between 1990 and 1999) were unemployed. Assuming that employment prospects are even more positive for higher degree qualified science and mathematics graduates, it is likely that the employment rates of this group in Australia are equal to or lower than corresponding rates in the US.

Across international research, it appears that most graduates in science and mathematics follow an employment pathway that is closely related to their qualification. Using large-scale graduate destination data from Canada, Lavoie and Finne (1999) show that 'job-education' matches among the pure and applied science cohort are strongest for PhD holders, and like unemployment rates, become worse for lower degrees such as a masters or bachelors. Claudy, Henly and Migdalski (2002), who analysed the class of 2001 doctoral graduates in the earth and space sciences in the US, found that 78 per cent were working in their specific field and 98 per cent were employed in some form of science or engineering.

At the postgraduate level in Australia, the link between employment pathway and field of qualification is relatively strong. The Australian data is not as specific in nature about asking graduates the exact relevance of their qualification to their work as is the Canadian data used by Lavoie and Finnie. However, using the Graduate Destinations Survey (GDS), it is possible to make some assumptions about the relevance of qualifications to the employment of postgraduates by examining information about the industries of employment entered by this group.

The GDS data shows that completing higher degree graduates in Australia in 2006 were spread across a range of broad industries. Chemistry postgraduates were mainly situated in the ‘science professions’ (64.8 per cent), but some (7.6 per cent) were working in the ‘business and computing professions’ (Table 2). Mathematics postgraduates were employed in ‘education professions’ (42.3 per cent), ‘business and computing professions’ (30.8 per cent) and ‘science professions’ (11.5 per cent). The survey found that 41.9 per cent of physical science postgraduates were employed in ‘science professions’, 9.7 per cent in ‘business and computing professions’ and 9.7 per cent in ‘education professions’ (Graduate Careers Australia, 2008). Other Australian research into the destinations of science graduates (both bachelor and postgraduate) has found that the majority find employment in the sciences, but that about one-third of employed graduates were working in a non-science based occupation following graduation (McInnis et al., 2001).

Table 2: Occupations of recently completed natural and physical science higher degree graduates, selected occupations and disciplines, 2007, Australia (per cent)

Field of Education	*Science Professionals*	*Education Professionals*	*Business and Computing Professionals*
Chemistry	64.8	n/a	7.6
Life Sciences	62	11.6	n/a
Mathematics	11.5	42.3	30.8
Physical Sciences	41.9	9.7	9.7

Note: Only a limited number of disciplines and occupations have been used here due to limitations in the data available at www.gradsonline.edu.au.

Source: GCA, Graduate Destinations Survey, 2007

While these figures tend to illustrate a relatively successful articulation into their fields for science and mathematics graduates, there is still concern about the number of graduates in these fields that are not taking up a position in a related occupation. In a US analysis of the 'leaks in the pipeline from school to work', Lowell and Salzman show that a sizeable proportion of science graduates do not articulate into science occupations. They claim that by two years after graduation, 20 per cent of science bachelor graduates are back in study but not studying in a science field, and a further 45 per cent are working but in non-science employment (Lowell & Salzman, 2007). Their data shows that these levels of attrition are lower among masters graduates (7 per cent in non-science study and 31 per cent in non-science work), but they do not display data for doctoral graduates. Given the trends in other destinations data from US and Canadian sources (Kannankutty, 2008; Lavoie & Finnie, 1999), the figures for doctoral graduates are likely to be much lower than bachelor and masters graduates.

In addition to Lowell and Salzman's concerns, Greene, Hardy and Smith (1995) argue that current employment prospects for doctoral graduates in the sciences are not as rosy as they are sometimes painted. They express concern that the rapidly changing pace of the job market means that there are a number of new challenges being faced by young doctoral graduates in the sciences. In particular, they note that there is a distinctive move away from the academic sphere for graduates in these fields, but that their education is based almost entirely on preparation for an academic job. Greene et al. believe that the employment outcomes for PhD graduates in the sciences in particular are bleak and claim that ‘the crux of the problem is that there is little relationship between the supply of doctoral scientists and the demand for them’ (p. 59). In relation to the mismatch between measures of supply and demand, the authors claim that the data from the National Science Foundation in the US, as used by Kannankutty (Kannankutty, 2003, 2008; Kannankutty & Burrelli, 2007; Kannankutty & Kang, 2001; Kannankutty & Wilkinson, 1999), Johnson (Johnson & Regets, 1998) and Regets (M. Regets, 1997; Mark Regets, 2006; M. C. Regets, 1995) among others, and used widely in this literature review, is lacking in quality and analysis – which is widely used by higher education institutions and industry – and has misinterpreted the nuances of the science and mathematics fields.

Concern relating to the employment prospects of science and mathematics graduates has also been expressed in the European context. In a cross-country study of European nations, Pearson et al. (2001, p. 4) found that ‘in a number of countries, unemployment among newly qualified scientists and technologists has remained relatively high’. They also found a notable under-utilisation of skills among these graduates, whereby many were gaining employment, but not in jobs suitable to their qualification. Pearson claims this is a relatively recent phenomenon in the science fields, noting that this is ‘a situation relatively unknown in previous decades’. Within the doctoral degree qualified graduate cohort, the research found there were particular employment problems in France and that modelling of future supply and demand suggested excess aggregate supply over the next few decades, which is likely to affect employment prospects for graduates in the natural and life sciences in particular.

Another element of the destination analyses of science and mathematics postgraduates appears to be related to the quality issues voiced by employers and outlined in the earlier discussion. Within some literature, there is concern noted that many of the best and brightest young scientists and mathematicians are not actually following a traditional science employment pathway, but instead are moving into other, potentially more lucrative industries, where their skills need to be adapted but their qualification can still be utilised. This issue is raised specifically by Lowell and Salzman (2007) who use Grade Point Average (GPA) data of US science and engineering (S&E) graduates to show that ‘a greater proportion of low-GPA graduates find S&E employment than do high-GPA students’ (p. 32). The authors note that this is in part because many high-GPA students go on to further study, but they also believe there is a trend towards high-GPA students entering non-science careers. In the Australian context, Anderson et al. (2003, p. 75) hint at the emergence of this issue by pointing out that there are ‘declining numbers of high performing students interested in science’.

UK research by Kidd and Green (2006) indicates that among research scientists, there was a notable presence of the intention to leave the profession and seek other work. They identified that career identity (or lack of it), career resilience and salary were ‘predictors of intention to leave science’ (p. 229). In Australia, Dobson and Calderon (1999) and McInnis et al. (2001) noted a trend among graduates in the sciences to move into employment in information technology, where in the early 2000s at least, job prospects were more attractive. The graduate destinations data discussed above shows that, in more recent times, this has continued to be the case (Graduate Careers Australia, 2008). Canadian research also suggests such a trend. Lavoie and Finnie (1999) note that Canadian science graduates have low satisfaction levels with their earnings, and while it is suggested that this could be a driver in such postgraduates moving away from science and mathematics jobs, they do not present any specific data to prove this.

Outcomes and participation of women

Women are a traditionally under-represented group in science and mathematics professions. While their overall representation among PhD students and professional workers in these fields is growing (Hill, 2006), participation is still low. Barber (1995) notes that while women are slowly becoming more visible, they continue to face considerable hurdles in progressing up the academic ladder. In addition, Glover and Fielding (1999) note that while there is growth in women’s representation in the science and mathematics fields, this growth has been nowhere near as rapid as in other fields of education, such as law and medicine.

Huisman, de Weert and Bartelse (2002) show that in the UK women make up 37 per cent of PhDs in science and 10 per cent of scientific academic positions; in Sweden women comprise 42 per cent of PhD students and 10 per cent of the academic positions; and in the Netherlands women represent only 7 per cent of science academics (the lowest in Europe). In Australia, research by McInnis et al. (2001) found a rise in the proportion of women studying science, from 36 per cent in 1987 to 42 per cent in 1997, but noted that there were substantial gender differences within individual science disciplines. For example, McInnis et al. (2001, p. 4) cite research from the Office of Status for Women, which showed in 1996 that 41 per cent of chemistry students were women, but that in the physics discipline women made up only 19 per cent of students. Dobson and Calderon (1999) show that while labour market prospects for women in science are relatively good in Australia, they were more likely to be unemployed or not in the labour force than men. In addition, a study by the European Parliament found that while women account for 43 per cent of all PhDs in science in Europe, they fill only 15 per cent of senior positions within universities (Thomsen, 2008).

The main reasons identified in the literature for the lower participation of females in the science and mathematics fields, especially in the PhD and early career research stage, relate to fertility issues (Bhattacharjee, 2004; Leggon, 2001; Lord, 2007). Lord (2007, p. 16) notes research by Ginther and Kahn that found ‘the academic world’s gender gap is entirely influenced by fertility decisions’. Similarly, Bhattacharjee (2004, p. 2) uses statistics from the US National Science Foundation to conclude that ‘the pressures of marriage and child rearing affect women more adversely than they affect men, which could be a significant reason behind the gender disparities in academic science and engineering disciplines’.

These pressures lead to women having more trouble being able to translate their science qualifications into professional work (Palermo, Guiffra, Arzenton, & Bucchi, 2008). Glover and Fielding (1999, p. 57) reveal that women ‘show higher levels of over-qualification in the labour market’ than men and suggest that both labour market and education policies require attention to address this issue. Such policies are in development, but remain relatively scarce. Of those that do exist, one example is a project recently announced in the US designed to improve participation of minorities in science, which will have a particular emphasis on attracting women (Brainard, 2008).

The academic workforce

The academe is a key destination point for substantial numbers of science and mathematics higher degree research graduates. The training provided to most science and mathematics doctoral students is inherently focused towards this sort of employment pathway (Coll & Zegwaard, 2006; Dany & Mangematin, 2004; Gott et al., 1999; Greene et al., 1995; Wood & Reid, 2006). It is therefore pertinent to examine the particular nuances within this employment field. The key issues emerging from the literature on the academic profession in mathematics and science relate to the ageing of the academic workforce and changes in employment opportunities for young researchers – in particular, a decline in tenured positions and increase in contract and post doctorate positions.

The research conducted for the Australian Council of Deans of Science (Anderson et al., 2003; McInnis et al., 2001) is the main source of Australian research currently available that specifically identifies issues within the science and mathematics fields. The trend in Australia is similar to that occurring in other parts of the world, whereby 'there has been a significant contraction of academic positions available to PhDs and increases in contract and grant-based employment' (McInnis et al., 2001, p. 5). This situation means that higher degree graduates are spending increasingly long periods of time on temporary or short-term contracts linked to specific research projects and do not have the opportunity to build their profiles through engagement in long-running research and teaching. Similar findings are also present in recent Australian research undertaken by Laudel and Glaser (2008). In the 2008 Australian Budget, there was some recognition of this problem (and its implications on fields other than the sciences) with the doubling of postgraduate awards and funding of a 'Future Fellowships' scheme, which will increase the number of mid-career fellowships offered to academics in Australian universities (Carr, 2008; Healy, 2008). Similar incentives have also been implemented in the UK and Ireland (Dawson, 2007).

The issues relating to problems of articulation into tenured academic postings are well documented in the US, UK, European and Canadian literature. Overall, these problems in early and mid-careers for science and mathematics academics have failed to keep talented researchers and teachers in the academe (Dawson, 2007; Glanz, 1998; Kidd & Green, 2006). Halyard notes that the lack of genuine long-term employment opportunities in the sciences at universities in the US is leading to more graduates exploring their options outside the university sphere (1995).

Internationally, the boom times for scientists and mathematicians that were present in the late 1960s and 1970s have passed; in the 1990s the aftershocks of the boom times were continuing in terms of graduate supply, but funding for tenured positions had depleted and therefore opportunities in the sciences became severely limited (Huisman et al., 2002; Leggon, 2001; Paldy, 1994). As a result, the research focus in universities has more recently become fixated on short-term results, and in employment terms, ‘temporary’ is becoming the norm (Huisman et al., 2002; Nolch, 2001).

Within the US, Leggon (2001) notes that ‘new generation’ academic scientists are increasingly becoming divided into two groups: a large group comprising those undertaking post doctoral research and temporary faculty positions because they cannot find tenured jobs; and a smaller group of those who do find a good tenured position, but struggle to fund their research because of their junior status.

Leggon (2001) and numerous others (Dawson, 2007; Glanz, 1998; Huisman et al., 2002; McGinnis, Allison, & Long, 1982; Monastersky, 2007) highlight the substantial increases in post doctoral positions in the US and Europe over the past two decades. Leggon (2001) shows that in the US, post doctoral positions offered to graduate scientists increased by 63 per cent between 1982 and 1992; while more recently, Monastersky (2007) showed that in physics nearly 70 per cent of PhD graduates go into temporary post doctoral positions compared with 43 per cent in 2000.

In the Australian context, a substantial number of new post doctoral positions have become available since the introduction of the Collaborative Research Centres (CRCs) program. While this growth in post doctoral opportunities appears to have been important to the scientific community, Prescott (2004) notes that the majority of jobs created are condensed in the field of biological sciences.

It is argued that although these increases provide some opportunities for graduates with higher degrees, in reality they are no longer serving their intended purpose, which is to provide a stepping-stone to a tenured position. Increasingly, evidence is mounting that shows early and mid-career researchers in these fields are scraping from one post doctorate to the next and never having time to properly advance their skills and expertise in core areas of research and teaching (Dawson, 2007; Monastersky, 2007; M. Regets, 1997).

Thus, while graduate destinations data may show that a large number of doctoral students in the sciences are employed in their fields, the interpretation of this result needs to be made with the issues of short-term and temporary contracts and reduced career opportunities in mind.

While much of the above research was undertaken looking at the sciences in general (including mathematics), it appears that within the mathematics field, in the US at least, the academic job prospects of PhD graduates appear to be slightly different than for those in the natural and physical sciences. Research by Reys (2006) in particular has been widely cited in reference to the fact that higher education institutions are struggling to fill faculty positions for mathematicians. Similar findings in the mathematics field have also been shown by Barrow and Germann (2006), who found that the success rates for filling academic positions in these fields are not particularly high.

The issues outlined above regarding lack of career trajectory and limited tenured opportunities to higher degree graduates in the mathematics and science fields is somewhat in contrast to the demographic reality facing the academe over the coming years. In all fields, there are large swathes of retirements within academic ranks anticipated in the near future. Demographer Graeme Hugo has shown that the proportion of people aged 50 and over within the academic workforce in Australia increased from 26 per cent in 1991 to almost 40 per cent in 2006 (Healy, 2008). Put another way, Hugo's results show an 80 per cent increase in the number of academics aged over 50 in just 15 years. Similar figures are present in the US (Barrow & Germann, 2006; Dubowsky & Simons, 2000), UK and Europe (Huisman et al., 2002).

It is apparent that while there is widespread acknowledgement of these issues, there is little change in funding or recruitment strategies to ensure that the impending retirements of senior academics are countered by the introduction of young researchers to the academe. In the Netherlands, a predicted shortfall of 12 per cent in the university science faculties is unlikely to be met because early and mid-career researchers are not being retained in the university system (Huisman et al., 2002). In the US a definite trend away from faculty positions among science PhD graduates is similarly unlikely to adequately prepare young academics for tenured positions over the next decade (Paldy, 1994; M. Regets, 1997). Russian science faculties are facing similar issues (Sudas & Iurasova, 2006). Likewise, Germany and the UK are faced with similar problems, with increasing numbers of PhD students shunning university positions and German research showing that the majority of doctoral students in the sciences do not intend to enter an academic career (Huisman et al., 2002).

Given these issues, the challenge for the science academe is substantial. In the present climate, impending workforce shortages are unlikely to be filled by young academics waiting for tenured positions to open up. Numerous international sources emphasise the fact that the academic route is fast becoming a second option for science PhDs, as industry jobs increase in prestige and in salary (Borthwick & Murphy, 1998; Cabral-Cardoso, 2001; Halyard, 1995; Leggon, 2001).

What are the solutions to ensuring supply matches demand?

The issues for higher degree graduates in science and mathematics in Australia and the rest of the world are relatively uniform. As the analysis above has shown there are problems with oversupply, but lack of quality; importance of research, but lack of career pathways and remuneration; and increasing demand, but seemingly decreasing incentives for students to follow a science career. There are a number of solutions put forward in the literature to the perceived problems that research has raised. These solutions are generally focused on the two destinations that graduates in this area follow – the science and technology industry, and higher education institutions.

Given that an ever growing proportion of doctoral degree graduates in the science and mathematics fields are entering private industry, both large and small scale (Cabral-Cardoso, 2001), the majority of the solutions that are discussed in the literature relate to the implementation of greater links between universities and industry.

A common theme in the literature is that imbalances of supply and demand would be minimised if there was better contact between universities and industry (Gott et al., 1999; Greene et al., 1995; Hay, 1992; King, 2007; Mason, 1999; McInnis et al., 2001; Pearson et al., 2001). Dany and Magematin (2004, p. 201) argue that not only does such communication make sense given the workforce trends of the science graduate population, ‘it would also facilitate the diffusion of scientific knowledge into the economic sphere’.

The role of industry in any relationship with higher education institutions is seen to be in advising universities about specific areas of demand as well as in providing work integrated learning for existing students. The importance of an advisory role in curriculum and specialisations is highlighted by Pearson et al. (2001), who note that employers need to build-in systems that are able to adequately assess their long-term skill needs and establish a dialogue with universities to ‘improve the flow of potential scientists … into and out of higher education’ (p. 4). In this regard, the authors propose establishing a Science and Technology Skills Observatory for Europe.

Greater employer and industry involvement during the training phase is emphasised in particular by Mason (1999), Coll and Zegwaard (2006), and Greene et al. (1995). Mason’s UK research revealed that almost no small- to medium-sized science and technology employers were engaged with university science faculties, yet a large number had articulated problems in recruiting both higher degree research graduates and bachelor graduates. He found that larger firms were more likely to have been in contact with local universities, but those that did make this connection were still in the minority. Greene’s conclusions suggest that for the sciences, PhD students should be required to spend some time during their research period outside the university. Coll and Zegwaard’s (2006) strong emphasis on work integrated learning would seem to fit well with the conclusions of this other research.

However, there is a note of caution in this kind of interaction in some of the literature in the field. Some researchers warn that individual employers are likely to over-emphasise skills shortages, or have unrealistically high expectations of graduates, and are therefore not helpful to the development process of training courses (Lowell & Salzman, 2007). Others, such as Anderson et al. (2003) and McInnis et al. (2001) in

Australia, warn that there is a fine balance between generalisation and specialisation within universities. They acknowledge the important role of industry in shaping employment pathways for young graduates but warn that universities should not specialise their science programs to cater to the whim of industry needs at one particular point in time. Anderson et al. (p. 75) note: ‘over-systematising, controlling and monitoring student options in science degrees has the potential to reduce the capacity for long-term adaptability in the world of work’.

Within the university sector the literature highlights substantial problems facing new and mid-career PhD recipients. For most, opportunities are limited to living from one post doctorate position to the next, with no definite career pathway to follow. This is despite the fact that a large chunk of the current cohort of senior academic staff in science faculties around the world is close to retirement. Providing fellowships that are geared towards helping mid-career researchers establish themselves within the academe, such as those recently announced in Australia, are one way of helping to address this issue (Healy, 2008). However, the key to solving career trajectory issues in the academe is to open up tenured academic positions in the sciences (Leggon, 2001). While this may be easier in the coming years, as tenured positions become available, unless there are clear options made available to young scientists, Glanz (1998) warns that universities will find there are few young motivated academics left in the system – a fate that seems to have reached the mathematics field already (Reys, 2006).

Raising the profile of scientists and mathematicians is also a core issue raised throughout the literature. It is argued that increasing awareness of the kinds of jobs that are available through a science degree is an important step in increasing the quality and enthusiasm of science candidates (Duberley, Cohen, & Leeson, 2007; Tytler et al., 2008; Walters, 2007). While research by Nolch (2001) shows that Australian scientists rank in the top 20 per cent in terms of income, there is also a perceived need among the research that increasing salaries further would help to lift the quality of candidates in these areas (Mason, 1999). Mason’s work in the UK with science industry employers revealed that employers would be willing to increase salaries for science graduates if this resulted in improvements in quality.

Conclusion

A review of the Australian and international literature on the supply, demand and employment prospects of higher degree qualified people in the science and mathematics fields has revealed a number of key issues facing employers, universities and graduates. While there is far from homogeneity among the individual science and mathematics disciplines, there are central themes apparent that can be generalised across the broad spectrum. There is a clear sense from existing evidence that supply and demand do not match particularly well within these areas. This disconnect is particularly interesting because although there appears to be adequate supply (and according to some, over-supply) of postgraduates in the science and mathematics areas, outside the university employment market there are notable concerns voiced by employers about lack of skills and shortages in talent. Within the university employment market, the issue is different in that there appear to be plenty of postgraduates available (except, according to some, in the mathematics areas) and openings in tenured staff positions to workforce ageing, yet the career options offered to PhD holders are un-enticing and therefore shortage issues will become more acute.

Establishing a better balance between supply and demand in these fields is seen by most who have conducted research in this area to revolve around creating effective links between universities and industry, both in the adaptation of curricula that increase the work readiness of graduates and the facilitation of work integrated learning placements within small, medium and large sized businesses that employ scientists and mathematicians. Within the university sector, there is evidence to suggest that career pathways need to be more clearly articulated for new postgraduates, and that quality researchers be offered tenured positions rather than moved from one post doctoral position or short-term contract to the next.

2. Data Analysis

Introduction

The literature review revealed a number of key themes related to the supply, demand and employment situations faced by postgraduates with qualifications in the science and mathematics fields. In particular, international evidence suggested there is a healthy supply of postgraduates in these fields – seemingly large enough to satisfy demand. However, paradoxically, demand does not appear to be satisfied through this supply, because of employer expectations and perceptions of lack of quality among the ranks of postgraduates, and because postgraduates are choosing to seek employment in higher-paying fields than what they were specifically trained for. Both these issues are of concern across the science and mathematics disciplines. However, within the academic profession, the second issue is of particular concern among those studying transition into the academic professions for young scientists and mathematicians.

The international data, especially that from the US (Bhattacharjee, 2003; Corley & Sabharwal, 2007; Hill, 2006; Johnson & Regets, 1998; Kannankutty, 2008; National Science Board, 2008) and Canada (Lavoie & Finnie, 1999), provide detailed insight into postgraduate completions, destinations and other factors of supply such as migration. European and UK literature also contained evidence relating to some of these issues, although the dissemination of statistical evidence did not appear to be as detailed as that for the US. However, the literature exploring such data for Australian postgraduates is much sparser, particularly in relation to the science and mathematics fields specifically. In terms of using available data to explore supply in Australia, Dobson's work for the Australian Council of Deans of Science (Dobson, 2003, 2007; Dobson & Calderon, 1999) appears the most detailed of the few accounts. In addition, McInnis, Hartley and Anderson's (2001) Australian Council of Deans of Science study, which involved a survey of graduates, provides some insights into these issues.

This data analysis builds on the findings of these previous studies by utilising a wide range of data sets to explore the supply and demand dynamics of science and mathematics postgraduates. This is the first such study in Australia to combine these sources to examine this group. The findings presented below are discussed in the context of the key themes that emerged from the literature review. They show that many of the issues exposed in the international data are also being experienced in Australia.

The data analysis below is structured in the following way: it begins by utilising course completion, migration and Census data to examine the supply of postgraduates with science and mathematics qualifications in Australia; this is followed by data detailing the employment outcomes of the postgraduate cohort as a whole, as well as a specific investigation of recently qualified postgraduates and a comparison with recently completed honours graduates; it then examines data that can help to quantify demand, utilising Census data, skilled vacancies data and graduate destinations statistics; the report finishes with a detailed analysis of the academic profession in the natural and physical sciences in Australia. Appendix B of this report contains an outline of the data sources used here, their limitations and the methodology used for disseminating them.

Throughout the discussion below the strict definition of ‘natural and physical sciences’ is used interchangeably with the term ‘science and mathematics’; in this report, these two terms refer to the same groups. In addition, where the term postgraduate is used below, unless otherwise specified it refers to a person who has *obtained* a postgraduate qualification, rather than a person who is *studying* for a postgraduate qualification.

Supply

Higher education

The data from the Higher Education Collection held by DEEWR have been used in this analysis of supply to monitor the numbers of higher degree postgraduate completions in the natural and physical sciences. As the time series data in Table 3 show, there were 1,328 doctorate completions and 179 masters by research completions in these fields in 2006. This indicates, within the higher degree research completions in the natural and physical sciences, doctorate degrees are by far the most commonly studied qualification. The trend data also show a decline in masters completions, indicating a movement away from this award type in these fields.

Doctorate completions in the natural and physical sciences increased 25 per cent overall between 2001 and 2006 (Table 3). Compared to growth in all other fields of education (53 per cent), growth in the natural and physical sciences is relatively small, indicating that the output of postgraduates in the sciences is not keeping pace with output in other areas.

There was variation across the science disciplines in the number of completions during the 2001 to 2006 period, with the data showing small increases in mathematics and physics, declines in chemical sciences and earth sciences, and a doubling of completions in the other natural sciences category (this category includes sub-groups of medical science, forensic science, pharmacology, food science and biotechnology, and laboratory technology; see Appendix B for more detail). However, as noted in the methodology section, careful interpretation of figures at the individual discipline level is required due to the different faculty structures and coding practices used across Australian institutions.

Table 3: Higher degree course completions at Australian higher education institutions by field of education and course type, 2001 to 2006

	2001	*2002*	*2003*	*2004*	*2005*	*2006*	*Change (no.) 2001–2006*	*Change (%) 2001–2006*
			Doctorate by Research/Higher Doctorate					
Math sciences	75	66	85	73	77	79	4	5
Physics, astronomy	118	111	140	122	122	124	6	5
Chemical sciences	186	170	164	153	154	176	–10	–5
Earth sciences	95	77	82	105	100	88	–7	–7
Biological sciences	431	456	529	494	436	549	118	27
Other natural sciences	148	162	180	251	393	297	149	101
Natural and Physical Sciences, nfd	12	13	11	14	16	15	3	25
Total Natural and Physical Sciences	*1,065*	*1,055*	*1,191*	*1,212*	*1,298*	*1,328*	*263*	*25*
Non-Nat Phys Science fields	2,890	3,257	3,572	3,919	4,165	4,415	1,525	53
			Masters by Research					
Math sciences	17	21	22	17	17	19	2	12
Physics, astronomy	30	21	31	27	29	24	–6	–20
Chemical sciences	39	36	37	25	18	18	–21	–54
Earth sciences	19	23	24	32	16	18	–1	–5
Biological sciences	71	56	70	61	74	57	–14	–20
Other natural sciences	46	46	42	35	45	43	–3	–7
Natural and Physical Sciences, nfd	4	3	6	1	6	0	–4	–100
Total Natural and Physical Sciences	*226*	*206*	*232*	*198*	*205*	*179*	*–47*	*–21*
Non-Nat Phys Science fields	1,368	1,345	1,361	1,400	1,387	1,426	58	4

nfd: Not further defined

Source: DEST Course Completions files, 2002 to 2007

As noted in the literature, growth in higher degree completions in the science and mathematics fields in the US over the past few years has been exclusively the result of increasing international student numbers (National Science Board, 2008). Previously undertaken Australian research has also shown this (Birrell et al., 2005; McInnis et al., 2001), although not exclusively for higher degree completions in the science and mathematics fields.

Table 4 shows that in this specific cohort, there has been growth in both domestic and overseas student completions between 2001 and 2006, but international student growth (34 per cent) was substantially larger than the growth in domestic student completions (13 per cent). Again, growth in this field is smaller for both domestic and international student completions when compared with other fields of education; this is graphically illustrated in Figure 3.

The data also show that international student completions in the natural and physical sciences make up only a small proportion of all completions, with 298 completions in 2006 compared with 1,209 domestic student completions.

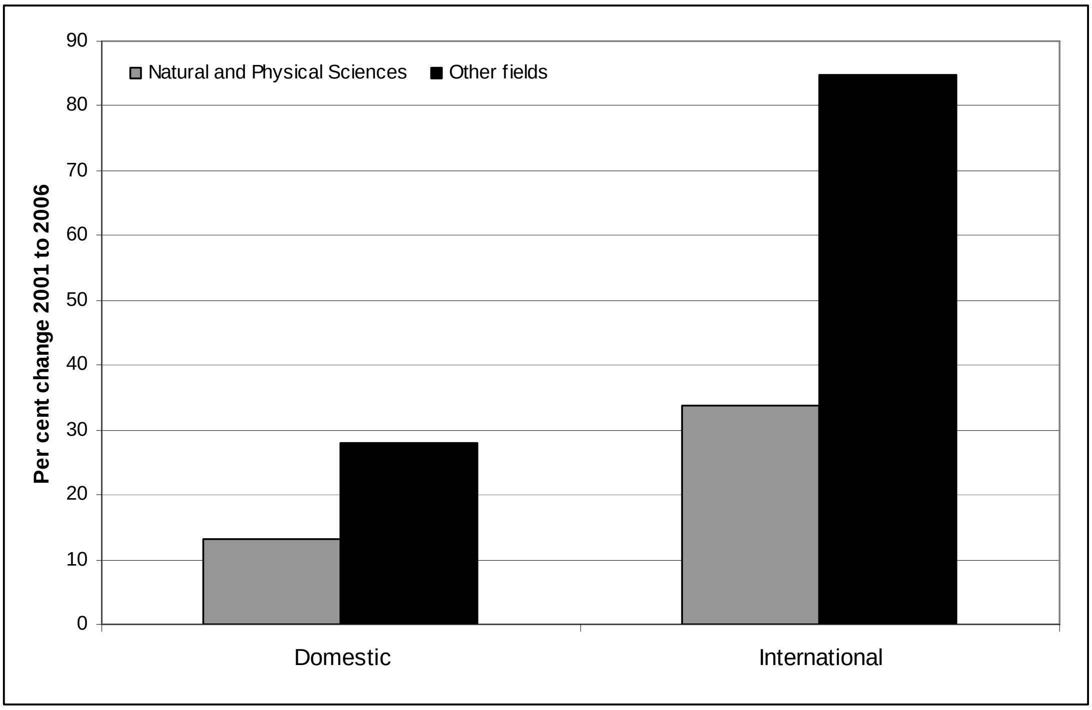
Table 4: Higher degree course completions at Australian higher education institutions by field of education and student type, 2001 to 2006

	2001	*2002*	*2003*	*2004*	*2005*	*2006*	*Change (no.) 2001–2006*	*Change (%) 2001–2006*
				Domestic Students				
Math sciences	68	71	88	64	78	82	14	21
Physics, astronomy	125	108	144	121	130	111	–14	–11
Chemical sciences	199	179	171	151	136	153	–46	–23
Earth sciences	85	79	86	114	92	82	–3	–4
Biological sciences	404	426	495	448	417	497	93	23
Other natural sciences	172	171	175	227	366	271	99	58
Natural and Physical Sciences, nfd	15	15	13	13	18	13	–2	–13
Total Natural and Physical Sciences	*1,068*	*1,049*	*1,172*	*1,138*	*1,237*	*1,209*	*141*	*13*
Non-Nat Phys Science fields	3,570	3,890	4,133	4,320	4,481	4,569	999	28
				International Students				
Math sciences	24	16	19	26	16	16	–8	–33
Physics, astronomy	23	24	27	28	21	37	14	61
Chemical sciences	26	27	30	27	36	41	15	58
Earth sciences	29	21	20	23	24	24	–5	–17
Biological sciences	98	86	104	107	93	109	11	11
Other natural sciences	22	37	47	59	72	69	47	214
Natural and Physical Sciences, nfd	1	1	4	2	4	2	1	100
Total Natural and Physical Sciences	*223*	*212*	*251*	*272*	*266*	*298*	*75*	*34*
Non-Nat Phys Science fields	688	712	800	999	1,071	1,272	584	85

nfd: Not further defined

Source: DEST Course Completions files, 2002 to 2007

Figure 3: Change in number of higher degree completions for domestic and international students by broad field, 2001 to 2006 (percent)

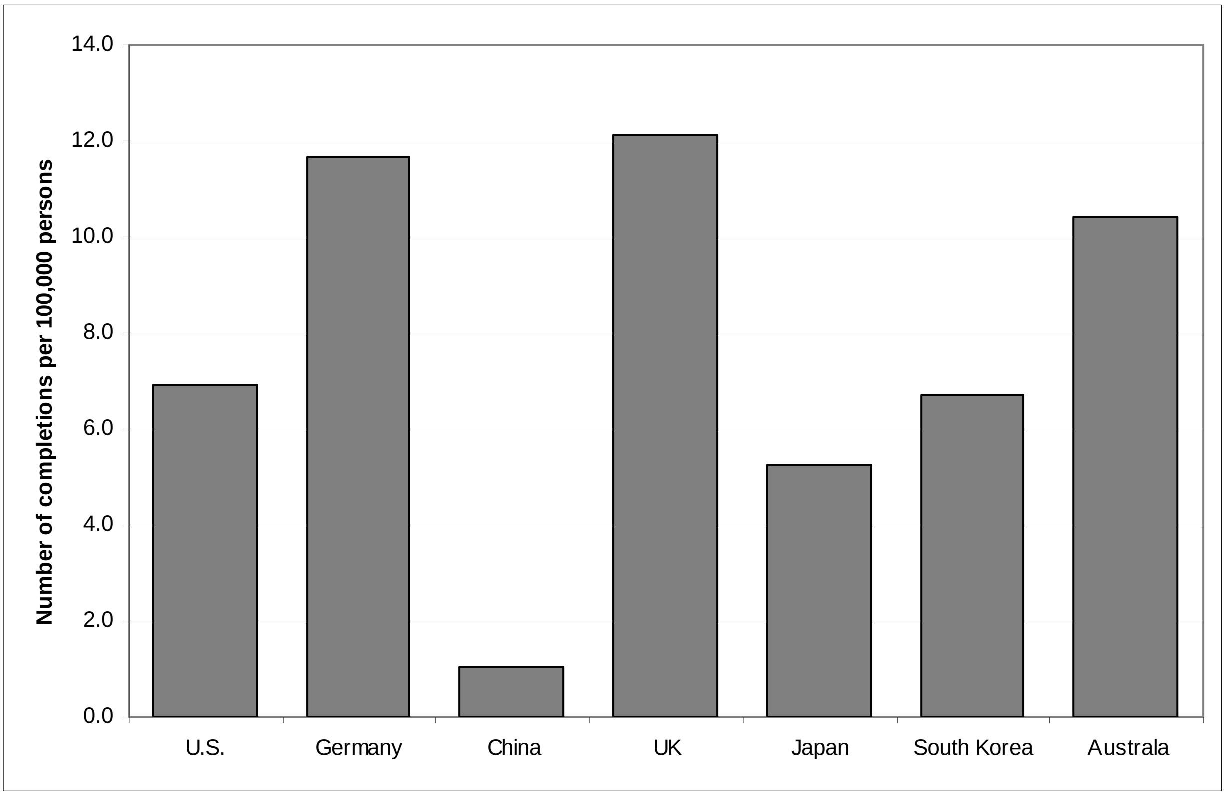


Source: DEST Course Completions files, 2002 to 2007

Figure 4 and Figure 5 provide an international comparison for higher education supply of doctorates in the mathematics and sciences. This comparison builds on the basic figures compiled from the research in the literature review. Figures from the US National Science Board, the US Census Bureau and DEST course completions files have been integrated in order to display the output of doctorate completions in these fields across seven countries. In order to be as accurate as possible in comparison with the available international data, the Australian numbers in Figure 4 and Figure 5 also include engineering and computer science doctorate completions (these are the only instances within this report where this occurs).

Figure 4 displays the number of doctorate completions in the mathematics and science fields for each country per 100,000 persons in the population. It shows that Australia’s output is robust when compared to the listed Asian countries and the US. The UK and Germany are the only countries in this list with a higher rate of output in these areas than Australia. In this regard, Figure 5 shows that between 2001 and 2004 the output in the UK and Germany of doctorates in these areas was in decline, while the Australian increase outstripped all other countries except the booming China. The indications from these data are that Australia's comparative position in the international supply of science and mathematics doctorates is strong when population size is taken into account. However, in terms of total world output, the Australian figures are relatively small. In comparison to the US alone, Australia in 2005 was producing one postgraduate for every 10 postgraduate completions in the US.

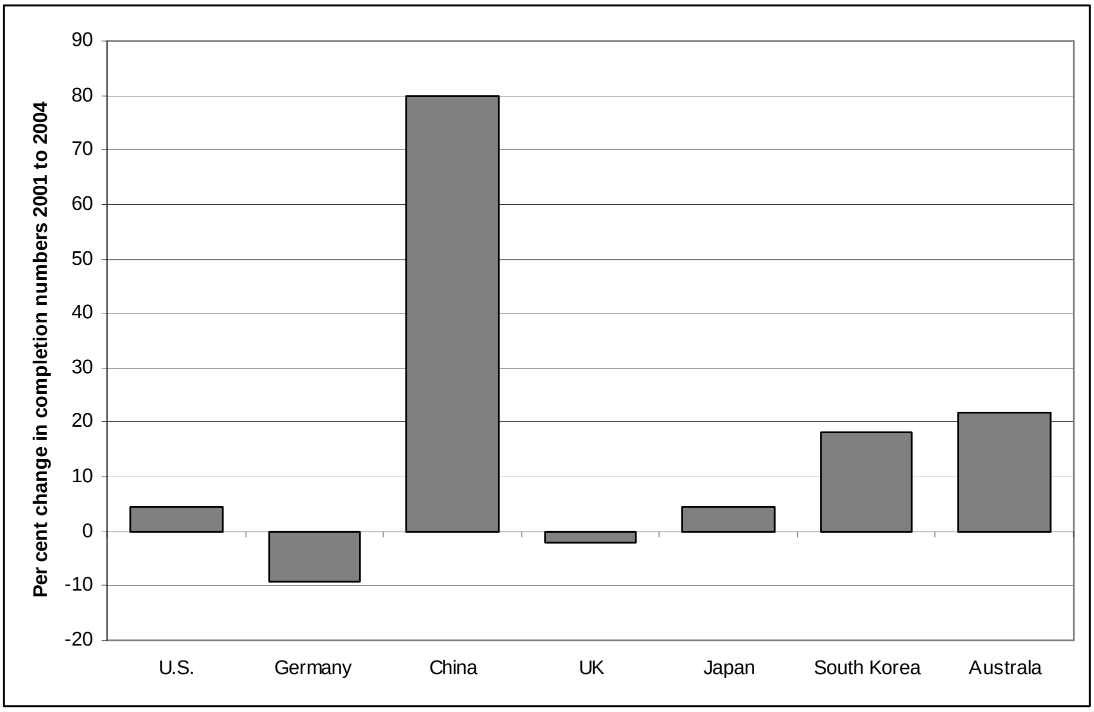
Figure 4: Science, mathematics, engineering and computer science doctorate completions for selected countries by 100,000 persons in population, 2005



Note: The calculation for this figure includes Australian engineering, computer science and agricultural science doctorate completions as well as natural and physical sciences completions. This is done so as to provide comparative numbers with international figures, which are aggregated by broader field of education dimensions.

Source**:** DEST Course Completions files, 2002 to 2007; US National Science Board, *Science and Engineering Indicators 2008*; and US Census Bureau, International Data Base, http://www.census.gov/cgi-bin/ipc/agggen

Figure 5: Percentage change in science, mathematics, engineering and computer science doctorate completions for selected countries, 2001 to 2004



Note: The calculation for this figure includes Australian engineering, computer science and agricultural science doctorate completions, as well as natural and physical sciences completions. This is done so as to provide comparative numbers with international figures, which are aggregated by broader field of education dimensions.

Source**:** DEST Course Completions files, 2002 to 2005; US National Science Board, *Science and Engineering Indicators 2008*.

Migration

As the literature on the supply of skilled persons showed, migration is an important component of the supply equation. Australian Overseas Arrivals and Departures data have been used here to track the 'brain drain' and 'brain gain' of science professionals between 2002 and 2007. As noted in Appendix B, this data is not detailed to the level of qualification held by those arriving and departing. Therefore, an indication of the exact number of PhD or masters qualified persons in these occupations is not available. However, focusing purely on professional occupations within the science and mathematics fields provides an indication of the movement of highly skilled persons moving in and out of Australia.

Table 5 shows the flow of permanent and long-term arrivals and departures to Australia by individual professional science occupations. It reveals that there has been a steady growth in the numbers of both those arriving in and those departing from

Australia in these occupations between 2002 and 2007. Overall, Australia has maintained its ‘brain gain’ position during this period. In the 2002/2003 financial year, the DIAC data shows that 2,596 scientists and mathematicians arrived in Australia, while 1,892 people in these occupations departed – a net gain of 704 science and mathematics professionals to Australia. By 2006/07, the inflow and outflow figures had increased, with 4,025 entrants and 2,639 exits. While these numbers had increased in both the in- and out-flow, Australia’s gain of scientists and mathematicians through migration had grown to 1,386 by 2006/07. This growth in both arrivals and departures of professional scientists and mathematicians is illustrated further in Figure 6, which graphs the upward trajectory of these two categories and shows how the gap between the two has increased in recent years.

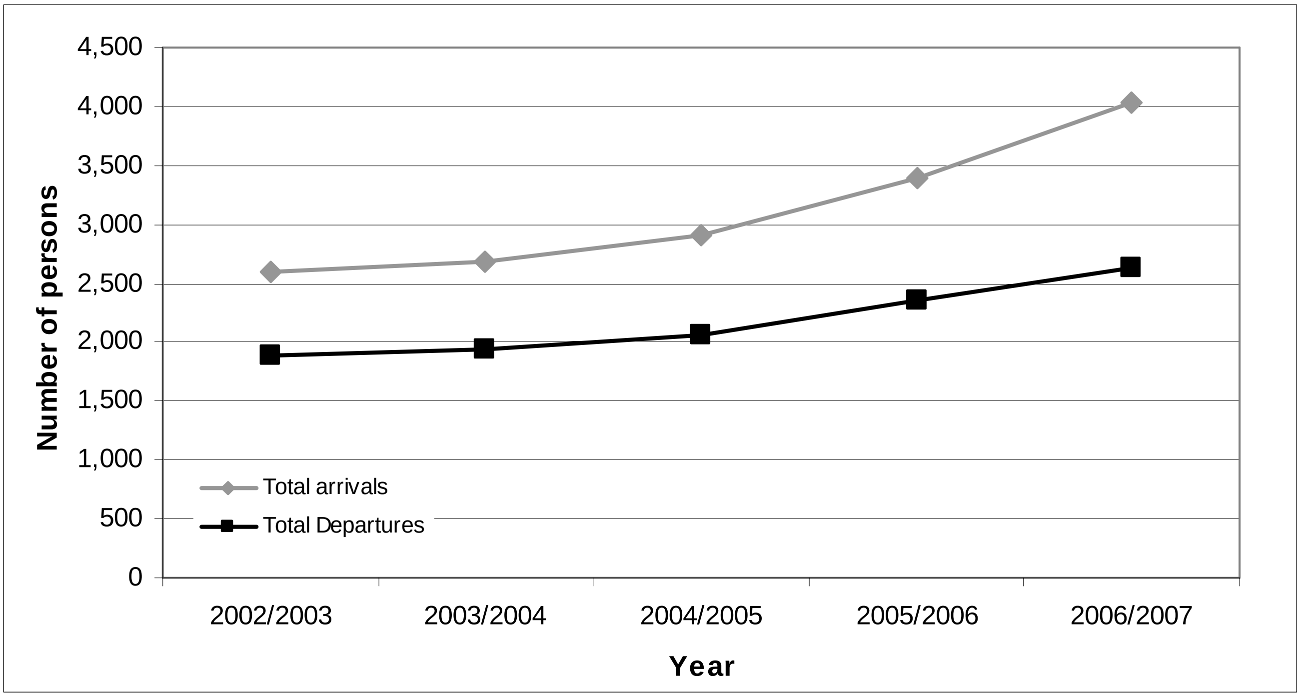
As can be seen in Table 5, one of the key reasons for this ‘brain gain’ position being maintained is the growth in the number of ‘long term visitor’ arrivals to Australia during this period. As can be seen in the table, the visitor arrivals group grew from 862 to 2,341 between 2002 and 2007. This increase is mainly due to a substantial growth in the long term visitor visa sub-class 457 – the business long-stay visa. By 2007, the majority of people in these occupations who are classified as long term visitors, enter Australia on a 457 visa.

Table 5: Arrivals and departures of science professionals, Australia, 2002–03 to 2006–07

Year	Occupation - Science Professionals (ASCO)	*Arrivals* Settler Arrival	Long Term Resident Return	Long Term Visitor Arrival	*Total arrivals*	*Departures* Resident Permanent Departure	Long Term Resident Departure	Long Term Visitor Departure	*Total Departures*	***Net change***
2002 to 2003	Chemists	96	103	113	*312*	43	104	63	*210*	**102**
	Geologists & Geophysicists	80	176	233	*489*	110	187	56	*353*	**136**
	Life Scientists	118	48	128	*294*	14	41	18	*73*	**221**
	Envrnmntl & Agrcltrl Scientists	34	45	91	*170*	16	46	33	*95*	**75**
	Medical Scientists	182	22	41	*245*	6	24	10	*40*	**205**
	Oth Natural & Physical Scientists	119	581	203	*903*	190	666	143	*999*	**-96**
	Mathmtcns, Statistcns & Actuaries	63	67	53	*183*	32	69	21	*122*	**61**
	All science professionals	692	1,042	862	*2,596*	411	1,137	344	*1,892*	**704**
2003 to 2004	Chemists	110	101	89	*300*	58	97	75	*230*	**70**
	Geologists & Geophysicists	58	175	220	*453*	116	175	59	*350*	**103**
	Life Scientists	143	40	140	*323*	17	38	38	*93*	**230**
	Envrnmntl & Agrcltrl Scientists	39	46	81	*166*	23	63	29	*115*	**51**
	Medical Scientists	178	45	78	*301*	17	39	12	*68*	**233**
	Oth Natural & Physical Scientists	135	568	228	*931*	185	630	142	*957*	**-26**
	Mathmtcns, Statistcns & Actuaries	68	42	94	*204*	28	74	26	*128*	**76**
	All science professionals	731	1,017	930	*2,678*	444	1,116	381	*1,941*	**737**
2004 to 2005	Chemists	112	94	101	*307*	37	95	50	*182*	**125**
	Geologists & Geophysicists	90	200	347	*637*	153	180	70	*403*	**234**
	Life Scientists	160	29	85	*274*	20	29	36	*85*	**189**
	Envrnmntl & Agrcltrl Scientists	29	50	66	*145*	24	63	33	*120*	**25**
	Medical Scientists	200	41	52	*293*	11	25	11	*47*	**246**
	Oth Natural & Physical Scientists	135	582	362	*1,079*	271	691	152	*1,114*	**-35**
	Mathmtcns, Statistcns & Actuaries	53	58	70	*181*	29	67	20	*116*	**65**
	All science professionals	779	1,054	1,083	*2,916*	545	1,150	372	*2,067*	**849**
2005 to 2006	Chemists	118	84	134	*336*	30	81	60	*171*	**165**
	Geologists & Geophysicists	88	175	474	*737*	156	227	88	*471*	**266**
	Life Scientists	78	42	173	*293*	17	27	39	*83*	**210**
	Envrnmntl & Agrcltrl Scientists	29	52	215	*296*	21	61	42	*124*	**172**
	Medical Scientists	101	38	160	*299*	12	24	25	*61*	**238**
	Oth Natural & Physical Scientists	185	601	431	*1,217*	300	829	183	*1,312*	**-95**
	Mathmtcns, Statistcns & Actuaries	48	60	104	*212*	31	80	21	*132*	**80**
	All science professionals	647	1,052	1,691	*3,390*	567	1,329	458	*2,354*	**1,036**
2006 to 2007	Chemists	121	90	157	*368*	37	87	61	*185*	**183**
	Geologists & Geophysicists	106	161	680	*947*	179	234	125	*538*	**409**
	Life Scientists	46	39	334	*419*	19	31	83	*133*	**286**
	Envrnmntl & Agrcltrl Scientists	46	50	365	*461*	29	78	68	*175*	**286**
	Medical Scientists	29	40	231	*300*	5	15	55	*75*	**225**
	Oth Natural & Physical Scientists	225	596	445	*1,266*	336	858	152	*1,346*	**-80**
	Mathmtcns, Statistcns & Actuaries	30	105	129	*264*	52	107	28	*187*	**77**
	All science professionals	603	1,081	2,341	*4,025*	657	1,410	572	*2,639*	**1,386**

Source: DIAC unpublished, 2008

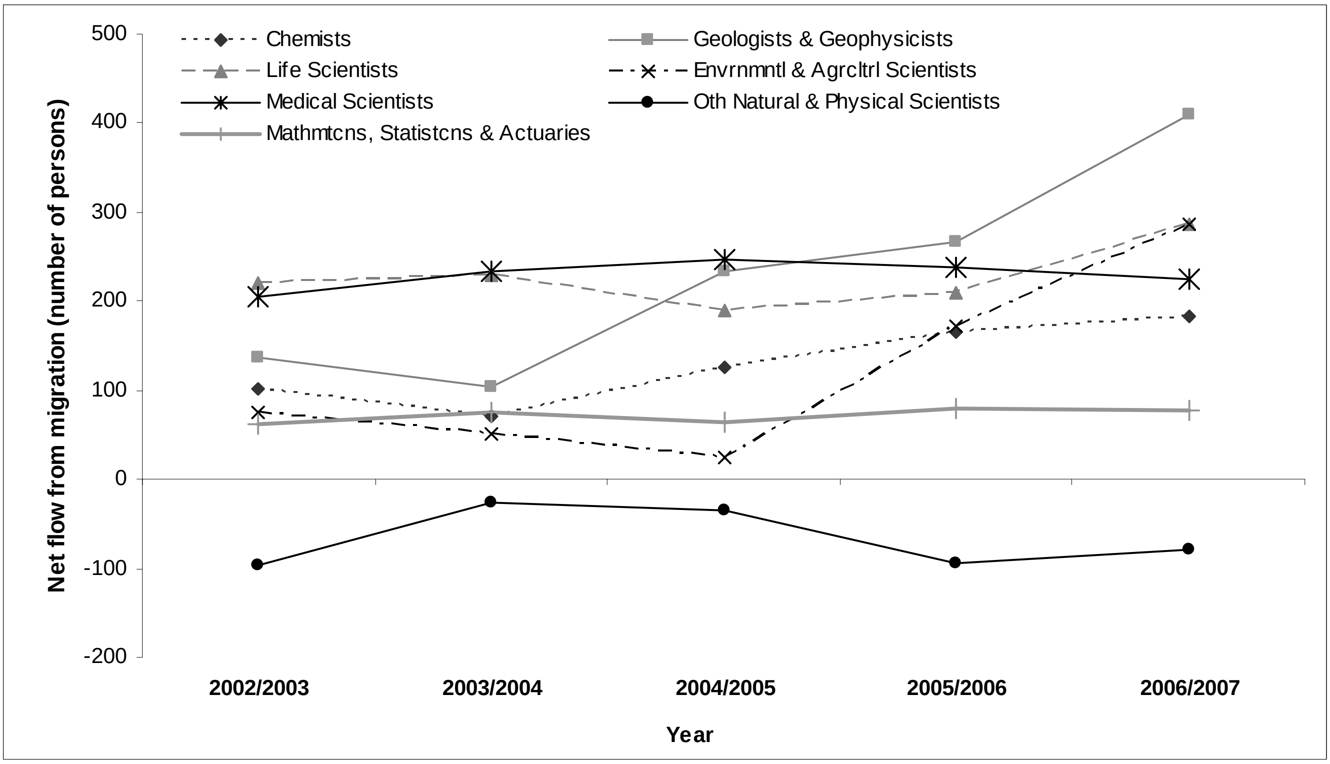
Figure 6: Arrivals and departures of science and mathematics professionals, 2002–03 to 2006–07, Australia



Source: DIAC unpublished, 2008

Within individual professional science occupations, Table 5 indicates notable variation in arrivals and departures. Some of the data from Table 5 are displayed in Figure 7, which shows the net flow from migration for each of the specific professional science occupations. It shows that within the 2002 to 2007 period, almost all professional science occupational categories remained in a ‘brain gain’ position. Some occupations, particularly geologists and geophysicists, and environmental and agricultural scientists have seen notable increases in ‘gains’. The net growth in other occupations, such as mathematicians and medical scientists has remained fairly steady during this period. Only the ‘other natural and physical scientist’ category (of which one of the main occupations is physicist) experienced a ‘brain drain’ during this time, with Australia losing between 10 and 100 people in such occupations during the time series.

Figure 7: Net flow from migration for individual professional science and mathematics occupations (ASCO), 2002–03 to 2006–07



Source: DIAC unpublished, 2008

Table 6 outlines this net flow aggregated across the whole time series and put in the context of the overall size of each of the aforementioned occupations in Australia ('stock').[1] The middle part of the table shows the net flow for each occupation between 2002–03 and 2006–07, while the second last column shows the total net flow across this period. Overall, there was robust growth in the professional science occupations (4,712 persons) over this time. Among the occupations listed here, the largest net growth during this period was in geologists and geophysicists, life scientists and medical scientists. There was smaller net growth in mathematicians, and as Figure 7 revealed, there was a decline in the other natural and physical science occupations.

In Table 6, the '% of 2001 stock' (far right) column provides a perspective of the size of the net flow of migration to each occupation across the time series. The total stock

[1] This method of analysis has been adapted from Birrell, Rapson, Dobson and Smith (2004).

figure used as the benchmark is for employed persons in August 2001 (as collected in the 2001 Census), slightly before the first migration figures used here. Overall the net gain from migration between 2002–03 and 2006–07 was equivalent to 8.6 per cent of science professionals in Australia in 2001. As a proportion of ‘stock’, the largest gain among these occupations was again in geologists and geophysicists. In this field the inflow of 1,148 persons was equivalent to 22.6 per cent growth in the stock of professionals in this occupation in 2001. Gains through migration in life scientists was of a similar high proportion during this time. Despite a net growth of more than 600 environmental and agricultural scientists between 2002 and 2007, the large size of this occupational group meant that in relative terms the growth from migration in this field was only equivalent to a 3.7 per cent increase on the 2001 numbers. In contrast, mathematicians had a more modest net gain in terms of numbers (359 persons), but a relative gain of 10.5 per cent on the size of the 2001 figures for this occupation.

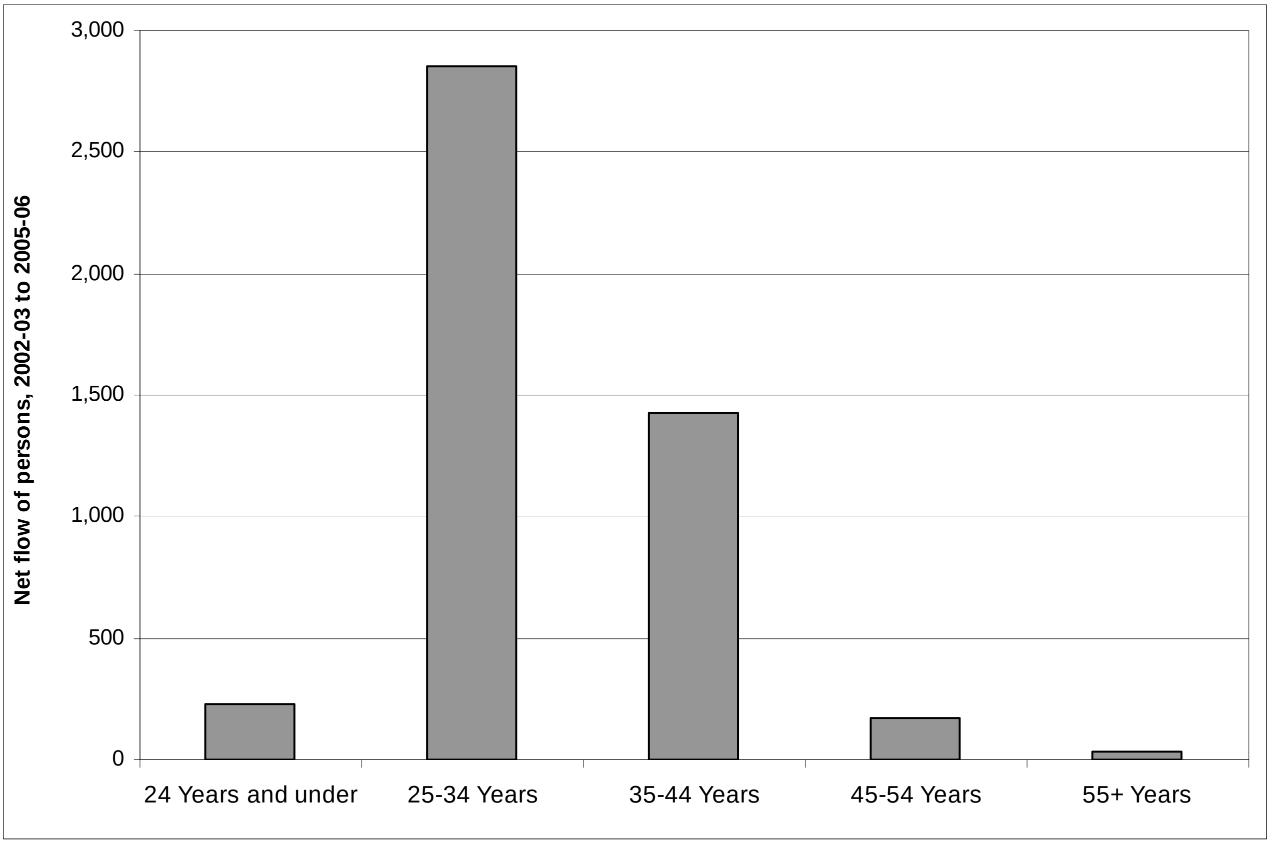
Table 6: Net flow from migration of selected occupations, 2002–03 to 2006–07, in relation to total stock in 2001, Australia

Occupation (ASCO)	*Total Stock (employed persons Aug 2001)*	*Net flow (arrivals minus departures)*					*Total net flow 2002/03 to 2006/07*	*% of 2001 stock*
		2002–2003	*2003–2004*	*2004–2005*	*2005–2006*	*2006–2007*		
Chemists	5,367	102	70	125	165	183	645	12.0
Geologists & Geophysicists	5,090	136	103	234	266	409	1,148	22.6
Life Scientists	5,227	221	230	189	210	286	1,136	21.7
Envrnmntl & Agrcltrl Scientists	16,613	75	51	25	172	286	609	3.7
Medical Scientists	11,112	205	233	246	238	225	1,147	10.3
Oth Natural & Physical Scientists	7,883	-96	-26	-35	-95	-80	-332	-4.2
Mathmtcns, Statistcns & Actuaries	3,422	61	76	65	80	77	359	10.5
All science professionals	54,714	704	737	849	1,036	1,386	4,712	8.6

Source: DIAC unpublished, 2008 and ABS Census of Population and Households, 2001

The age of professionals in the sciences entering and exiting Australia is also an important indicator of supply dimensions. The arrivals and departures data show that the main ages in which gains of persons in these occupations occurred during the 2002 to 2007 period was in the 25 to 34 and 35 to 44 year age groups (Figure 8). Australia’s gains in the youngest age group (below 24 years) and the older age groups (45–55 years and over 55 years) were considerably smaller. The small gains in these three age groups are not as important to the overall supply of postgraduates in the mathematics and sciences. This is because among the below 24 years old group, only a small proportion would be qualified with a PhD, and the older cohorts are closer to retirement and therefore not as important to long-term supply in these occupations. The fact that Australia has experienced substantial growth in the numbers of professional scientists aged between 25 and 44 years is a positive finding emanating from this data.

Figure 8: Net flow to Australia of science and mathematics professionals, by age 2002–03 to 2006–07



Source: DIAC unpublished, 2008

Supply of migrants to Australia can also be monitored via Census data. Table 7 shows the country of birth for all people in Australia with a postgraduate qualification in mathematics and science. Overall, migrants comprise more than half of this group in Australia. Nearly one-third of all people living in Australia with these qualifications are from non-English speaking countries.

The arrival year information shows that 6,194 people with such qualifications arrived in Australia between 2001 and 2006. Of this group, 4,201 were from non-English speaking countries. It is clear that these countries are a growing source of science and mathematics qualified people for Australia.

Table 7: Country of birth and year of arrival of persons with postgraduate qualifications in the natural and physical sciences, Australia, 2006

	Country of Birth				
Year of arrival	Australia	Main English speaking countries	Non-English speaking countries	Not stated	*Total*
Before 2001		7,636	10,765	122	18,523
2001–2006		1,968	4,201	25	6,194
Not stated		222	345	459	1,026
Not applicable	22,944				22,944
Total	22,944	9,826	15,311	606	48,687
Share by country	47.1	20.2	31.4	1.2	100.0

Source: ABS, Customised 2006 Census matrix

Total supply

The current levels of supply of postgraduates in the natural and physical sciences can be quantified using Census data. The recently released data from the 2006 Census of Population and Households has been used here to examine the size and characteristics of this group.

Table 8 shows that the Census recorded nearly 50,000 persons in Australia with postgraduate degrees in the natural and physical sciences. The largest individual discipline within this field was the biological sciences, comprising nearly 30 per cent of all science degree holders.

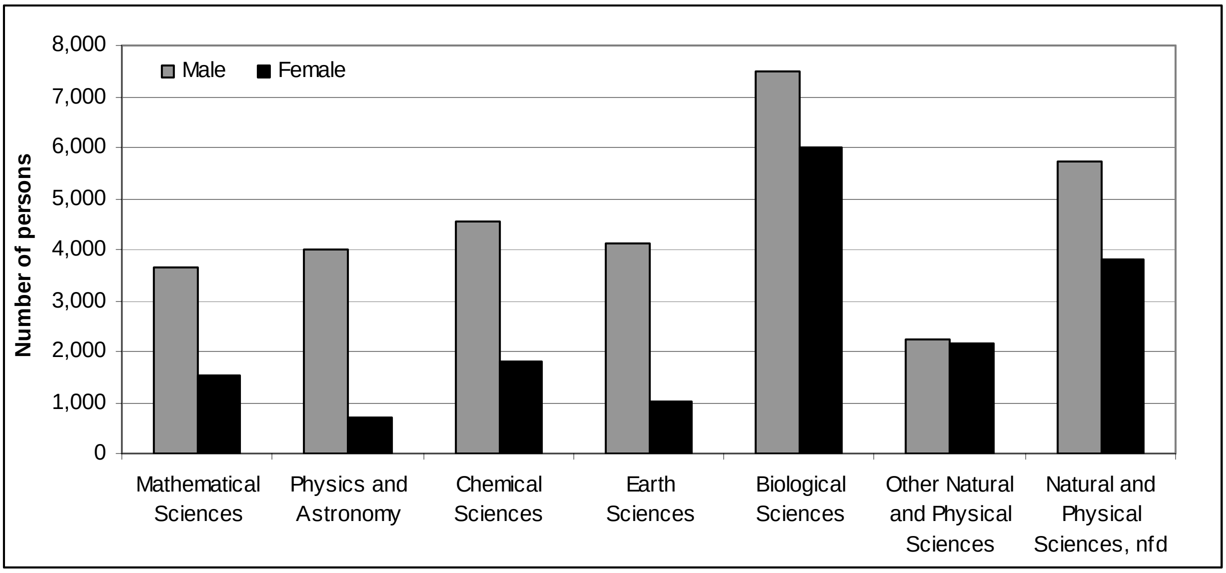
Table 8: Persons with a postgraduate qualification in the natural and physical sciences, by discipline, Australia, 2006

Field of education	*Persons*	*Share across disciplines*
Mathematical Sciences	5,164	10.6
Physics and Astronomy	4,694	9.6
Chemical Sciences	6,351	13.0
Earth Sciences	5,107	10.5
Biological Sciences	13,468	27.7
Other Natural and Physical Sciences	4,379	9.0
Natural and Physical Sciences, nfd	9,524	19.6
Total	48,687	100.0

Source: ABS, Customised 2006 Census matrix

As outlined in the literature review, there is evidence that suggests a worldwide gender imbalance within the mathematics and science fields (Glover & Fielding, 1999; Hill, 2006; Huisman et al., 2002; Leggon, 2001). In addition, previous Australian studies have noted the over-representation of males in these fields (Dobson & Calderon, 1999; McInnis et al., 2001). The 2006 Census data also shows that in Australia, males far out-number females in most science disciplines when postgraduates are examined (Figure 9). In disciplines such as physics the ratio of men to women is almost six to one, in the earth sciences it is four to one. There is a closer match between gender numbers in the biological sciences and other natural and physical science disciplines, but the numbers for males remain greater.

Figure 9: Persons with a postgraduate qualification in the natural and physical sciences, by discipline and sex, Australia, 2006



Source: ABS, Customised 2006 Census matrix

Postgraduates with qualifications in the mathematics and sciences are spread right across Australia. Table 9 shows particular concentrations in the large population centres of Sydney and Melbourne. Perth has particularly large numbers of earth science postgraduates relative to other capital cities – largely an indication of the strength of the mining boom in Western Australia and the present demand for such qualifications.

Figure 10 shows the share of persons with postgraduate qualifications in the mathematics and sciences across the states of Australia. The data indicate a spread that is relatively proportional to overall population distribution in Australia.

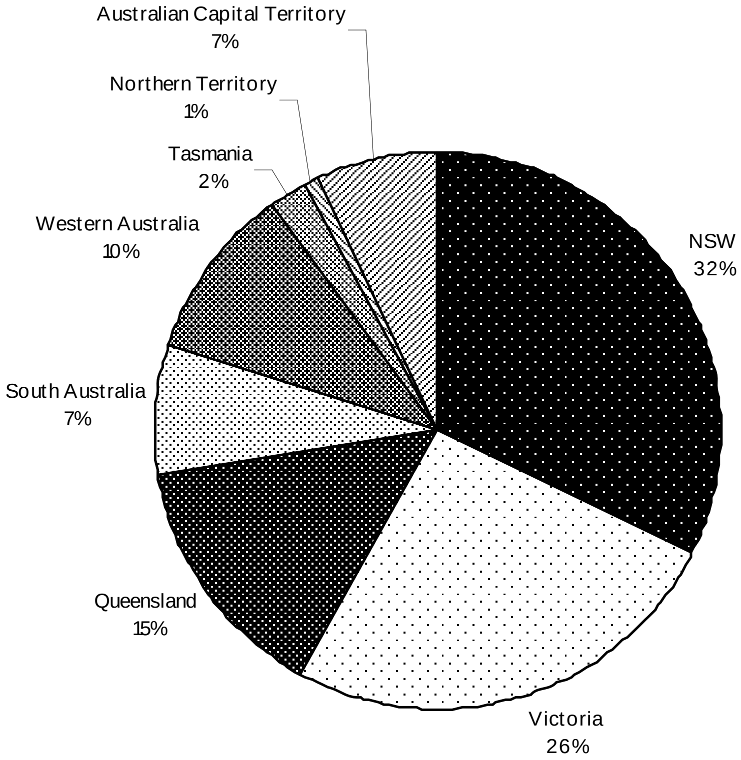
Table 9: Residential location of postgraduate qualified persons in the natural and physical sciences, by discipline, 2006

Place of usual residence Census night 2006	Mathe-matical Sciences	Physics and Astron-omy	Chemi-cal Sciences	Earth Sciences	Bio-logical Sciences	Other Natural and Physical Sciences	Natural and Physical Sciences nfd	*Total*
	Field of Education of Qualification							
Sydney	1,785	1,339	1,733	871	2,845	1,284	2,615	12,472
Newcastle	101	55	94	81	165	69	1284	684
Wollongong	74	64	106	45	97	27	125	538
Balance of NSW	185	153	201	274	737	105	364	2,019
Total NSW	2,145	1,611	2,134	1,271	3,844	1,485	3223	15,713
Melbourne	1,225	1,132	1,829	675	2,823	1,196	0	11,157
Greater Geelong City	19	18	63	9	78	11	1196	268
Balance of Victoria	80	84	142	97	347	90	235	1,075
Total Victoria	1,324	1,234	2,034	781	3,248	1,297	2582	12,500
Brisbane	407	334	549	445	1,571	517	0	4,918
Gold Coast	32	25	49	19	129	70	82	406
Sunshine Coast	24	25	26	32	97	18	51	273
Balance of Queensland	113	77	129	176	635	64	297	1,491
Total Queensland	576	461	753	672	2,432	669	1525	7,088
Adelaide	338	419	370	330	918	334	0	3,298
Balance of South Australia	24	31	39	21	131	27	49	322
Total South Australia	362	450	409	351	1,049	361	638	3,620
Perth	321	323	451	1,302	1,179	320	0	4,474
Balance of West Australia	9	25	39	122	141	12	55	403
Total Western Australia	330	348	490	1,424	1,320	332	633	4,877
Tasmania	53	88	111	195	444	45	0	1,146
Northern Territory	20	18	12	60	134	15	83	342
Australian Capital Territory	354	484	408	353	997	175	630	3,401
Total	5,164	4,694	6,351	5,107	13,468	4,379	9524	48,687

nfd = not further defined

Source: ABS, Customised 2006 Census matrix

Figure 10: Share of postgraduate degree qualified persons in the natural and physical sciences, by state, Australia 2006



Source: ABS, Customised 2006 Census matrix

Employment

It is important to quantify supply, but, as noted in the literature review, while quantity of postgraduates is important in assessing skill demand, understanding the quality and extent to which they are engaged in the workforce is perhaps even more crucial.

Census data allow a detailed picture of the employment outcomes of people with postgraduate degrees in the maths and sciences to be examined. As shown in Table 10, the proportion of this cohort that were employed in 2006 was relatively high (78.6 per cent), especially given that 18.9 per cent were not in the labour force. This meant that the unemployment rate for this cohort was only 2.8 per cent in 2006.[2]

[2] The proportion of persons unemployed and the unemployment rate displayed in Table 10 are different measurements. The unemployed figure is the percentage of the whole cohort who were not working but

The figure of 18.9 per cent ‘not in the labour force’ (Table 10) is made up mainly of older persons – 63 per cent of all those in the table who were not in the labour force were aged over 55. This is primarily due to a large number of this age group being near to retirement. There is much greater labour force participation among younger age groups, where the not in the labour force figures are between 9 and 15 per cent.

Table 10: Labour force status of persons with postgraduate qualifications in the natural and physical sciences by sex, Australia, 2006

	Number			*Percentage*		
Labour force status	*Male*	*Female*	*Total*	*Male*	*Female*	*Total*
Employed	25,139	13,146	38,285	79.2	77.6	78.6
Unemployed	600	493	1,093	1.9	2.9	2.2
Not in the labour force	5,938	3,251	9,189	18.7	19.2	18.9
Not stated	66	54	120	0.2	0.3	0.2
Total	31,743	16,944	48,687	100.0	100.0	100.0
Unemployment rate				2.3	3.6	2.8

Source: ABS, Customised 2006 Census matrix

As a result of lower participation rates for the over-55 group, the data in Table 11 and Figure 11 comprise only those who are aged less than 55 years old. Table 11 shows the employment numbers and percentages for individual disciplines within the natural and physical sciences. It shows high levels of employment across all the disciplines for this cohort. Among the disciplines, the highest employment rate is 91 per cent for earth science postgraduates; the lowest (although not substantially lower) is for those with mathematical science qualifications (86 per cent employed). These figures are graphically displayed in Figure 11.

Table 11: Labour force status of persons under 55 years of age with postgraduate qualifications in the natural and physical sciences by detailed field of education, Australia, 2006

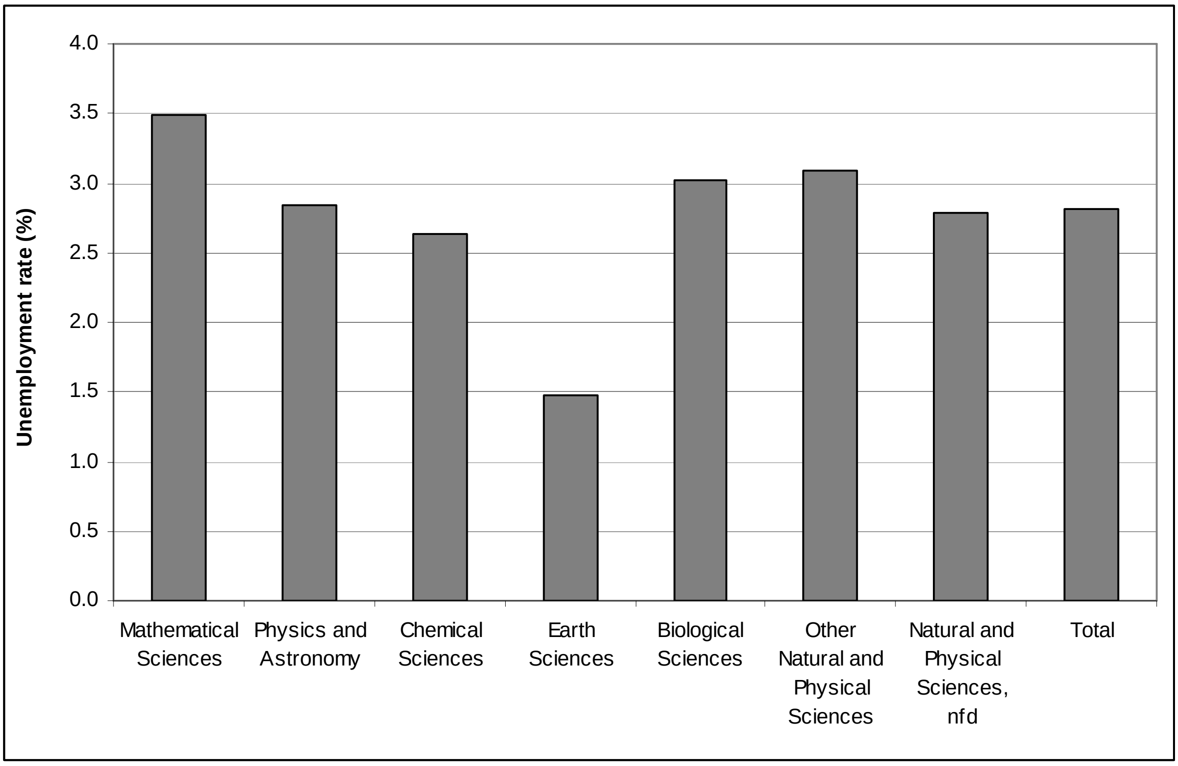
Field of education	*Employed*	*Un-employed*	*Not in the labour force*	*Not stated*	*Total*

seeking work. The unemployment rate is the proportion of people in the labour force who were not working and were looking for work. The unemployment rate is the measure used most commonly in reports of unemployment.

	Number of persons (under 55)				
Mathematical Sciences	3,009	109	374	6	3,498
Physics and Astronomy	2,634	77	253	3	2,967
Chemical Sciences	3,614	98	369	15	4,096
Earth Sciences	3,141	47	259	6	3,453
Biological Sciences	8,525	266	1,087	9	9,887
Other Natural and Physical Sciences	3,172	101	377	9	3,659
Natural and Physical Sciences, nfd	6,379	183	627	36	7,225
Total	30,474	881	3,346	84	34,785
	Percentage				
Mathematical Sciences	86.0	3.1	10.7	0.2	100.0
Physics and Astronomy	88.8	2.6	8.5	0.1	100.0
Chemical Sciences	88.2	2.4	9.0	0.4	100.0
Earth Sciences	91.0	1.4	7.5	0.2	100.0
Biological Sciences	86.2	2.7	11.0	0.1	100.0
Other Natural and Physical Sciences	86.7	2.8	10.3	0.2	100.0
Natural and Physical Sciences, nfd	88.3	2.5	8.7	0.5	100.0
Total	87.6	2.5	9.6	0.2	100.0

Source: ABS, Customised 2006 Census matrix

Figure 11: Unemployment rate of postgraduate qualified persons under 55, by detailed field of education, Australia, 2006



Source: ABS, Customised 2006 Census matrix

Among those with postgraduate qualifications in the natural and physical sciences who were employed in 2006, the majority were working in professional occupations (Table 12). Across all fields, 72.2 per cent of this group were in professional occupations, 15 per cent were in managerial occupations, and the small remainder were employed in other occupation types. In comparison to the whole Australian workforce, the proportion of workers in professional occupations among the science and mathematics postgraduate group is very high.

Within the individual disciplines, there is some variation on these general figures. For example, mathematical science postgraduates are the most likely of all the disciplines to be in a professional occupation (77.1 per cent), while chemical science postgraduates were least likely (66.3 per cent) and subsequently most likely to be employed as managers (20.3 per cent).

Table 12: Broad occupation types of employed postgraduates with qualifications in the natural and physical sciences, Australia, 2006, selected occupations (percent)

Occupation type	*Mathe-matical Science*	*Physics and Astro-nomy*	*Chemical Sciences*	*Earth Science*	*Bio-logical Science*	*Other Natural and Physical Science*	*Natural and Physical Science nfd*	*All Natural and Phys Science PGs*	*Whole Australian workforce*
Managers	11.4	13.7	20.3	13.7	13.5	14.2	17.2	15.0	13.2
Professionals	77.1	75.7	66.3	76.4	73.0	73.4	67.7	72.2	19.8
Technicians and Trades Workers	1.4	2.7	3.6	2.2	3.1	3.1	3.1	2.9	14.4
Community and Personal Service Workers	0.8	1.0	0.8	0.8	1.8	1.5	1.7	1.3	8.8
Clerical and Administrative Workers	5.2	3.1	4.0	3.5	5.0	3.6	5.5	4.5	15.0
Sales Workers	1.0	1.0	1.5	0.7	1.1	1.6	1.8	1.2	9.8
Machinery Operators and Drivers	0.6	0.6	0.9	1.2	0.4	0.4	0.6	0.6	6.6
Labourers	1.2	1.0	1.4	0.9	1.2	1.4	1.2	1.2	10.5
Inadequately described or Not stated	1.4	1.1	1.3	0.6	1.0	0.8	1.3	1.0	1.8
Total employed	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total employed (number)	3,976	3,542	4,753	4,134	10,512	3,630	7,740	38,287	9,104,187

Source: ABS, Customised 2006 Census matrix

The figures in Table 12 provide insight into the broad occupational types among those with postgraduate qualifications in the science and mathematics fields. Taking this analysis further, the following tables explore the job types and industries of employment for this group in more detail.

Job–skills matches are an important facet of monitoring supply and demand (Lavoie & Finnie, 1999). The Census data displayed in Table 13 and Table 14 help to match postgraduate science qualifications with occupations and industries of employment among this cohort. These are supplemented by tables in Appendix A, which provide additional detail about the types of jobs undertaken by postgraduates in each of the natural and physical science disciplines.

Table 13 shows the proportion of employed postgraduates, by discipline, who are employed in each of the occupations listed. It shows that the most common specific occupation for these postgraduates is as a university lecturer or tutor; across the cohort, 10.9 per cent were employed in these jobs in 2006. However, there is notable differentiation within individual disciplines in the propensity of postgraduates to be in this occupation. More than 20 per cent of mathematical science postgraduates were employed as university lecturers or tutors in 2006 compared to only 6.5 per cent of earth science postgraduates.

Among the other specific occupations listed in Table 13, there is an indication of a relatively large degree of job–skill matches. The most notable job–skills match in Table 13 appears in the high proportion of earth sciences postgraduates who are employed as geologists or geophysicists (37.5 per cent). In other notable job–skill matches, almost 15 per cent of chemical science postgraduates work specifically as Chemists, or Food and Wine Scientists, while another 20 per cent are managers. Table 28 in Appendix A reveals that a number of these managers work as research and development managers and as ‘other specialist managers’ – a category that includes laboratory managers.

For mathematical science postgraduates, 12.1 per cent were working as actuaries, mathematicians or statisticians in 2006 – a close match to the skills they acquired in their study. A further 13.8 per cent of these postgraduates were working in Information and Communication Technology (ICT) professions. In particular, Table 26 (Appendix A) shows that 8.3 per cent of all mathematical science postgraduates were working as Software and Applications Programmers, while smaller proportions were employed as ICT Business Systems Analysts, Database Systems Administrators and ICT Security Specialists. The ICT professions also attract 12 per cent of employed physics postgraduates, the majority of whom are Software and Applications Programmers (Table 27). These occupations do not necessarily require the exact skills obtained by these postgraduates, but often some skills can be adapted to suit the industry; an adaptation that generally results in more generous employment incentives (Dobson, 2003; McInnis et al., 2001).

The Appendix A tables also allow some further detail to be gained in relation to the types of employment of those classified as ‘Other Professionals’ in Table 13. This Other Professionals category makes up 15 to 31 per cent of the workforce across the individual disciplines in the Table. The occupational breakdowns in the Appendix A tables show that many of these occupations are equally ambiguously categorised in the detailed analysis, with many categorised as ‘Professionals, nfd’ (not further defined). However, of the more detailed categories that provide more meaning, the largest occupational group is Secondary School Teachers. Among mathematical science postgraduates, this occupation makes up 6.4 per cent of all those employed (Table 26). The proportion of those employed among the physics cohort (3.2 per cent) and chemical sciences group (3.6 per cent) are lower, but worth noting, while the figures for the other disciplines are below 2 per cent.

Table 13: Occupation by field of qualification for employed postgraduate qualified persons in the natural and physical sciences, Australia, 2006 (percent)

Occupation (ANZSCO)	*Mathe-matical Sciences*	*Physics and Astrono-my*	*Chemic-al Sciences*	*Earth Scien -ces*	*Bio-logical Scien -ces*	*Other Natural and Physical Sciences*	*Natural and Physical Sciences nfd*	*Total*	*Total (no.)*
Actuaries, Mathematicians and Statisticians	12.1	1.0	0.1	0.1	0.3	0.2	0.4	1.6	597
Agricultural and Forestry Scientists	0.1	0.0	0.5	0.9	2.2	0.4	1.2	1.1	408
Chemists, and Food and Wine Scientists	0.2	0.0	14.7	0.4	0.5	2.4	1.4	2.5	970
Environmental Scientists	0.2	0.7	1.8	4.6	5.1	0.4	3.2	2.9	1,099
Geologists and Geophysicists	0.6	0.8	0.3	37.5	0.4	0.4	1.0	4.6	1,756
Life Scientists	0.3	0.3	1.1	0.9	11.1	3.7	4.1	4.5	1,732
Medical Laboratory Scientists	0.4	0.8	2.0	0.1	10.1	26.1	10.0	7.6	2,927
Other Natural and Physical Science Professionals*	1.6	14.2	2.0	2.5	0.7	2.5	1.6	2.7	1,051
University Lecturers and Tutors	20.7	12.7	10.1	6.5	12.5	8.6	6.8	10.9	4,181
Engineering Professionals	0.9	3.2	1.4	4.6	0.2	0.7	1.2	1.4	545
Health Diagnostic and Promotion Professionals	0.0	0.2	2.3	0.3	1.0	2.9	2.3	1.3	511
ICT Professionals	13.8	12.0	2.7	2.8	1.4	1.1	3.1	4.3	1,644
Other Professionals	26.7	29.7	27.3	15.1	27.5	23.9	31.4	26.7	10,222
Managers	11.4	13.7	20.3	13.7	13.5	14.2	17.2	15.0	5,742
Technicians & Trades Workers	1.4	2.7	3.6	2.2	3.1	3.1	3.1	2.9	1,098
Other occupations^	9.7	7.9	9.8	7.7	10.2	9.4	12.0	9.9	3,804
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	38,287
Total (no.)	3,976	3,542	4,753	4,134	10,512	3,630	7,740	38,287	

*This category is made up of 'Other Nat and Phys Sciences' (code 2349) and 'Veterinarians' (code 2347)

^ includes occupations not in the categories listed, inadequately described and not stated

nfd = not further defined

Source: ABS, Customised 2006 Census matrix

The industry to qualification matches for the natural and physical science postgraduates are displayed in Table 14. These figures show that apart from earth science postgraduates, a large proportion of this cohort is employed in the education and training industry – an expected outcome given the findings from the occupation details in Table 13, which indicates that a relatively large proportion of this group are employed as university lecturers or tutors. Among employed earth science postgraduates, 23.7 per cent were employed in the mining industry – evidence of the importance of this industry (and the current boom) to postgraduates in this discipline. Large proportions of postgraduates from most disciplines were employed in the professional, scientific and technical services industry, indicating there are relatively good job–skills matches for postgraduates from the natural and physical sciences.

Table 14: Industry by field of qualification for employed postgraduate qualified persons in the natural and physical sciences, Australia, 2006 (percent)

Industry of Employment	*Mathematical Sciences*	*Physics and Astronomy*	*Chemical Sciences*	*Earth Sciences*	*Biological Sciences*	*Other Natural and Physical Sciences*	*Natural and Physical Sciences nfd*	*Total*	*Total (no.)*
Agriculture, Forestry and Fishing	0.5	0.8	0.7	1.3	2.1	0.6	1.3	1.3	479
Mining	0.4	0.8	0.9	23.7	0.4	0.2	0.8	3.1	1,175
Information Media and Telecommunications	1.5	1.6	0.8	0.6	0.7	0.7	1.1	0.9	362
Financial and Insurance Services	10.3	4.3	1.8	1.9	1.2	1.0	2.1	2.7	1,051
Professional, Scientific and Technical Services	19.9	23.7	21.8	29.1	21.7	19.1	22.9	22.5	8,608
Public Administration and Safety	9.0	11.5	8.6	13.4	12.9	5.0	12.9	11.1	4,267
Education and Training	40.9	36.2	30.6	17.2	35.9	28.5	26.0	31.1	11,895
Health Care and Social Assistance	3.1	4.7	3.6	0.8	10.3	25.0	12.9	9.1	3,490
Other industry of employment*	14.4	16.4	31.3	12.1	14.7	20.0	20.0	18.2	6,960
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	38,287
Total (no.)	3,976	3,542	4,753	4,134	10,512	3,630	7,740	38,287	

* includes not stated

nfd = not further defined

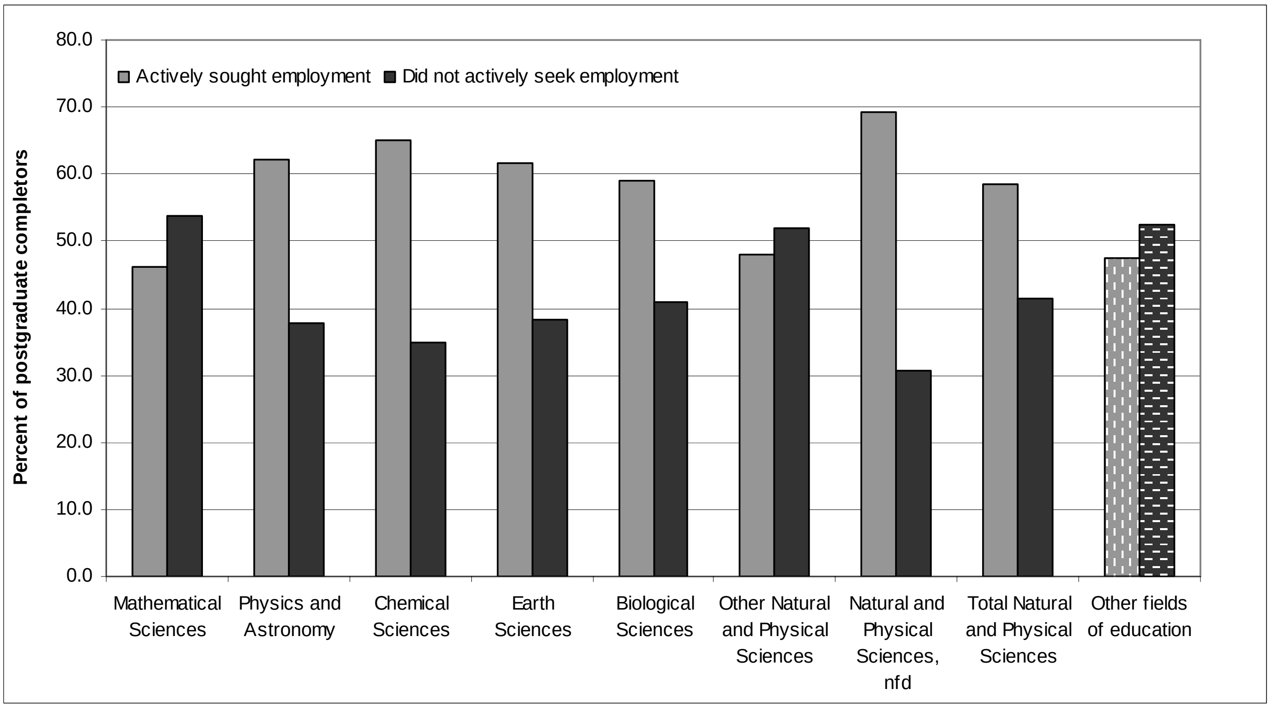
Source: ABS, Customised 2006 Census matrix

Recently qualified postgraduates

The Census data has provided a good basis for investigating skill-matches and employment characteristics of the whole postgraduate cohort in the natural and physical sciences. However, it is also pertinent to specifically examine the early career experiences of recently qualified postgraduates. Such examination helps to understand university-to-work transitions and assess the extent to which graduates from the higher education sector are articulating into occupations and industries relevant to their fields of expertise. The Graduate Destinations Survey (GDS), administered by Graduate Careers Australia (GCA), which is an annual survey of recently completed graduates from all universities and across all qualifications, is a useful tool to use for these purposes. The most recent data set (2007), which details the outcomes of persons graduating in 2006, has been used for this analysis.

The GDS survey shows that higher degree postgraduates in the mathematics and sciences were generally more likely to actively seek employment in the final year of their study than were students in other fields of education (Figure 12). The exception was among mathematics postgraduates, where it was more common for this group to not actively seek employment during the last year of their study.

Figure 12: Recently qualified postgraduates by job seeking status in their final year of study, selected fields of education, Australia, 2007



Source: GCA, Graduate Destinations Survey, 2007, unpublished

Among the recently qualified higher degree postgraduates in the natural and physical sciences, the rate of transition to full-time work is relatively high. Overall for this group, 76.8 per cent were in full-time employment in the months following completion of their qualification, as shown in Table 15. This is a more positive result than the average across all other fields of education for higher degree research completions (67.7 per cent).

Within the science disciplines, mathematical sciences and the 'not further defined' (nfd) groups had the largest proportion of completers who were not in the labour force following graduation. The nfd group is very small (14 respondents) but the mathematical science group is larger and therefore the proportion who are not in the labour force in the months following graduation is of note.

The largest proportions of completers still seeking work in the months following graduation are found among physics and astronomy postgraduates. The lowest rates are in the mathematical sciences and nfd group – but this is not particularly illuminating given that so many are not engaged in the labour force at all.

Table 15: Employment status of recently qualified postgraduates by selected field of education, Australia, 2007 (percent)

	Employed					
Field of qualification	*Full time*	*Part time*	*Seeking work*	*Not in the labour force*	*Total*	*Total (no.)*
Mathematical Sciences	75.5	9.4	1.9	13.2	100.0	53
Physics and Astronomy	72.6	11.0	8.2	8.2	100.0	73
Chemical Sciences	75.3	14.0	4.3	6.5	100.0	93
Earth Sciences	76.2	11.9	2.4	9.5	100.0	84
Biological Sciences	77.4	12.5	3.6	6.4	100.0	359
Other Natural and Physical Sciences	81.1	14.7	2.1	2.1	100.0	95
Natural and Physical Sciences, nfd	71.4	14.3	0.0	14.3	100.0	14
Total Natural and Physical sciences	76.8	12.6	3.6	7.0	100.0	771
Total Natural and Physical sciences (no.)	592	97	28	54	771	
Other fields of education	67.7	19.6	3.6	9.1	100.0	2,889

Source: GCA, Graduate Destinations Survey, 2007, unpublished

Table 16 shows that recently qualified, employed postgraduates in the natural and physical sciences are most likely to have contracts spanning a period greater than 12 months. One-third of natural and physical science postgraduates were permanently employed, while another third held fixed-term contracts of longer than 12 months. Among the disciplines, mathematics and earth science postgraduates faired best in terms of securing permanent contracts. Only 8.9 per cent of all science and mathematics postgraduates employed were working in temporary or casual jobs.

Table 16: Employment terms for employed, recently completed postgraduates in the natural and physical sciences, Australia, 2007 (percent)

Field of qualification	*Permanent or open-ended contract*	*Fixed-term contract more than 12 months*	*Fixed-term contract up to 12 months*	*Temporary or casual*	*Total*	*Total (no.)**
Mathematical Sciences	48.7	25.6	20.5	5.1	100.0	39
Physics and Astronomy	21.2	40.4	26.9	11.5	100.0	52
Chemical Sciences	39.0	22.1	31.2	7.8	100.0	77
Earth Sciences	48.4	33.9	11.3	6.5	100.0	62
Biological Sciences	27.5	35.2	28.2	9.1	100.0	298
Other Natural and Physical Sciences	38.2	28.9	23.7	9.2	100.0	76
Natural and Physical Sciences, nfd	45.5	18.2	9.1	27.3	100.0	11
Total Natural and Physical sciences	33.5	32.2	25.4	8.9	100.0	615

* Numbers of employed may be different to previous tables due to differing response numbers to individual GDS questions

Source: GCA, Graduate Destinations Survey, 2007, unpublished

Of the large proportion of recently completed science and mathematics postgraduates who were employed, the range of occupations they were engaged in is vast. Table 17 lists the ten occupations with the largest number of postgraduates employed among the 2006 completion group. It shows the proportion of employed postgraduates from each discipline who were employed in each of the occupations listed. This table provides another opportunity to evaluate the job–skill matches of postgraduates in the natural and physical sciences. Over one-quarter of all employed mathematical and science graduates were working as university lecturers or tutors, and almost a further quarter as actuaries, mathematicians or statisticians, indicating a relatively good job–skills match for this group. Another clear indication of good job–skill matches was among the earth science postgraduates. Almost 50 per cent of employed earth science postgraduates were working as geologists, geophysicists or environmental scientists and a further 9.8 per cent were university lecturers or tutors. In addition, in the biological sciences, 44.6 per cent of employed postgraduates were life scientists and a further 10.5 per cent were environmental scientists.

Table 17: Ten most common occupations among recently completed postgraduates in the natural and physical sciences, Australia, 2007, occupations ranked by number of employed new postgraduates (percent)

Occupation (GCA classified)	*Mathe-matical Sciences*	*Physics and Astro-nomy*	*Chemical Sciences*	*Earth Sciences*	*Biological Sciences*	*Other Natural and Physical Sciences*	*Natural and Physical Sciences, nfd*	*Total Natural and Physical sciences*
Life Scientists	2.6	19.2	11.7	6.6	44.6	28.4	18.2	29.3
University Lecturers and Tutors	25.6	15.4	13.0	9.8	5.7	9.5	27.3	10.0
Environmental Scientists	0.0	1.9	1.3	14.8	10.5	2.7	9.1	7.4
Medical Laboratory Scientists	5.1	0.0	9.1	0.0	8.4	8.1	9.1	6.7
Other Natural and Physical Science Professionals	0.0	28.8	5.2	11.5	2.0	2.7	0.0	5.6
Chemists, and Food and Wine Scientists	0.0	0.0	32.5	0.0	0.0	5.4	0.0	4.8
Geologists and Geophysicists	0.0	0.0	0.0	34.4	0.0	0.0	0.0	3.4
Actuaries, Mathematicians and Statisticians	23.1	3.8	0.0	0.0	0.3	1.4	0.0	2.1
Other Specialist Managers	0.0	0.0	2.6	1.6	2.0	1.4	0.0	1.6
Research and Development Managers	5.1	0.0	1.3	1.6	1.4	2.7	0.0	1.6
Other occupations	38.5	30.8	23.4	19.7	25.0	37.8	36.4	27.4
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total (no.)	39	52	77	61	296	74	11	610

* Numbers of employed may be different to previous tables due to differing response numbers to individual GDS questions

Source: GCA, Graduate Destinations Survey, 2007, unpublished

As with Table 17, Table 18 also provides an indication of job–skills matches, by examining industry of employment among recently qualified postgraduates in the natural and physical sciences. The table shows a large proportion of the 2006 completers were employed in the higher education sector and in scientific research services. For employed physics postgraduates, these two industries accounted for more than three-quarters of all employment destinations.

Table 18: Ten most common types of enterprises worked in among recently completed postgraduates in the natural and physical sciences, Australia, 2007 (percent)

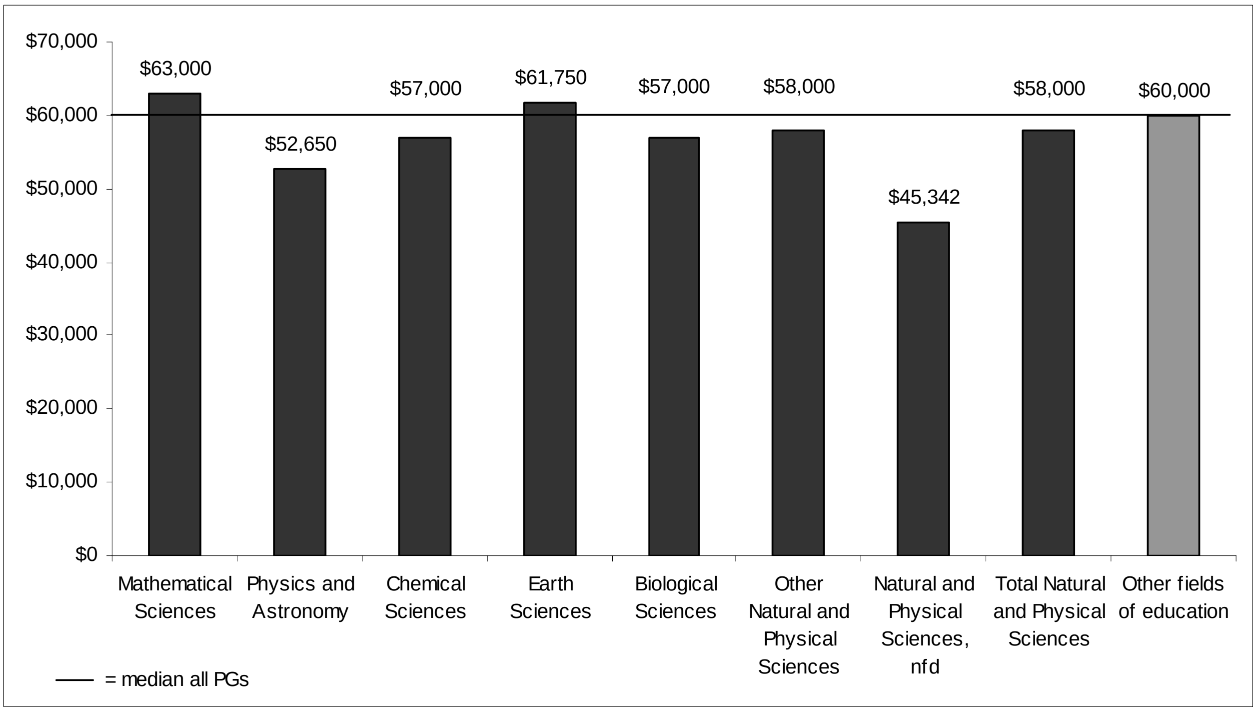
Employer's main business	*Mathe-matical Sciences*	*Physics and Astro-nomy*	*Chemical Sciences*	*Earth Sciences*	*Biological Sciences*	*Other Natural and Physical Sciences*	*Natural and Physical Sciences, nfd*	*Total Natural and Physical sciences*
Higher Education	50.0	57.4	46.1	35.5	44.4	31.1	63.6	43.9
Scientific Research Services	7.9	24.1	10.5	22.6	21.2	16.2	0.0	18.5
State Government Administration	2.6	1.9	2.6	6.5	4.6	2.7	9.1	4.1
Hospitals	2.6	0.0	1.3	0.0	3.3	8.1	9.1	3.1
Federal Government Administration	2.6	1.9	1.3	3.2	2.3	1.4	9.1	2.3
Management & Related Consulting Services	5.3	0.0	0.0	3.2	2.0	1.4	0.0	1.8
Pharmaceutical & Medicinal Product Manufacturing	0.0	0.0	2.6	0.0	0.7	8.1	0.0	1.6
Other Professional, Scientific & Technical Services	0.0	1.9	1.3	0.0	1.7	4.1	0.0	1.6
Other Health Care Services	0.0	0.0	1.3	0.0	2.0	2.7	0.0	1.5
Secondary Education	5.3	1.9	1.3	1.6	1.0	0.0	0.0	1.3
Other types of business	23.7	11.1	31.6	27.4	16.9	24.3	9.1	20.4
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total (no.)	38	54	76	62	302	74	11	617

* Numbers of employed may be different to previous tables due to differing response numbers to individual GDS questions

Source: GCA, Graduate Destinations Survey, 2007, unpublished

Salary is an important factor in attracting and retaining people in all types of industries and occupations (Mason, 1999), and the science and mathematics fields are no exception. The GDS data for recently qualified postgraduates in the science and mathematics fields shows there was a range of salary outcomes across disciplines among the 2006 completers (Figure 13). The data for median reported salary show that mathematical science postgraduates attracted the highest salaries ($63,000 per annum), while the 'nfd' group (a very small cohort) was the lowest paid ($45,342). Overall, salaries across the disciplines generally match the median salary for postgraduates for all other fields of education ($60,000), although most are slightly below this figure.

Figure 13: Median annual salary of employed, recently completed postgraduates by selected fields of education, Australia, 2007



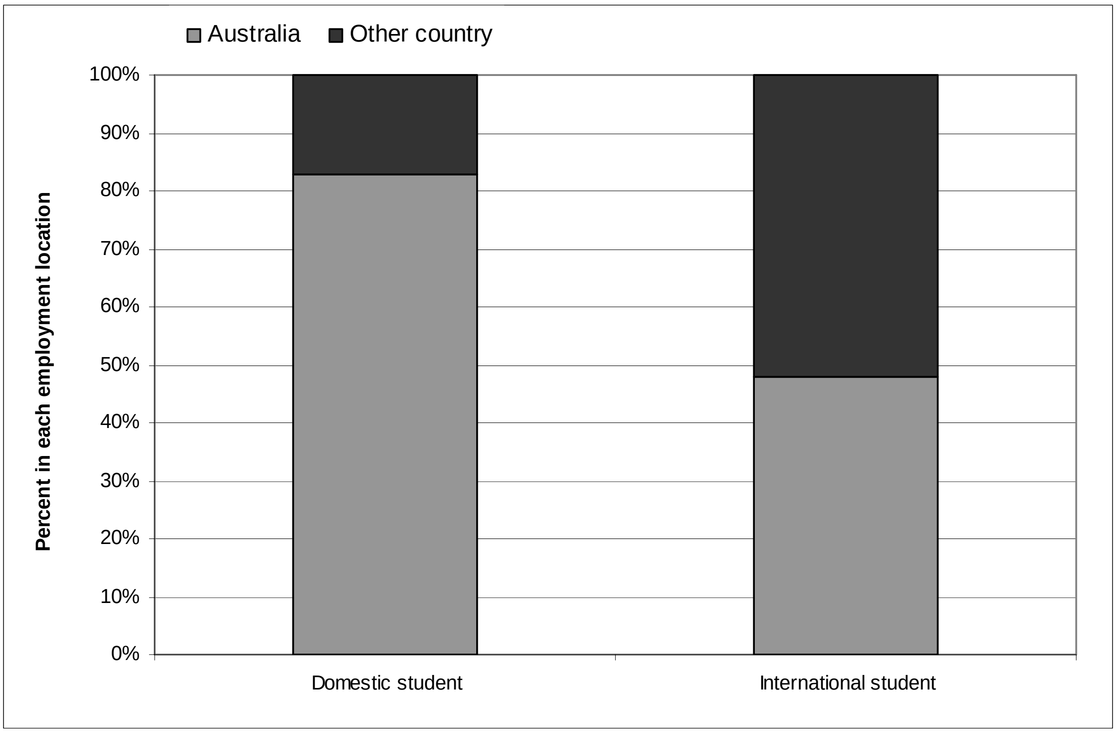
Source: GCA, Graduate Destinations Survey, 2007, unpublished

As noted earlier, the supply of postgraduates from Australian higher education institutions is important in addressing workforce demand for skilled scientists and mathematicians. However, this supply needs to be monitored to understand the extent to which it is satisfying demand. The results above from the GDS and the Census indicate that employment levels of postgraduates in the science and mathematics fields are relatively high and that overall the job–skills match among this group is relatively good. It is also important to monitor the extent to which qualified postgraduates leave Australia following completion in order to undertake work overseas. Among higher degree research postgraduates, it is inevitable that a number will seek to broaden their skills outside Australia. Using the GDS data, the extent to which this is happening can be tracked.

The GDS data indicate that of the science and mathematics postgraduate completers in 2006 who were employed in 2007, 21 per cent were working outside of Australia. Further analysis of this issue has found (as might be expected) that this is much more common among former international students than among former domestic students. As Figure 14 shows, more than half of all international higher degree research completers who were employed following graduation found employment outside of Australia.

While the international postgraduate group in the science and mathematics fields is relatively small (298 completers in 2006 [Table 4]), and the response rates to the GDS among this cohort are likely to be lower than the overall rate of about 50 per cent, these figures still have potentially serious implications for measuring the supply-side of the science and mathematics equation for the Australian workforce. It appears that the market should not rely on growth in international student numbers in these higher research degrees to satisfy domestic workplace demand.

Figure 14: Employment location by student status of recently completed postgraduate research students in the natural and physical sciences from Australian higher education institutions, 2007



Source: GCA, Graduate Destinations Survey, 2007, unpublished

Honours versus Postgraduate destinations

Another element of supply to the highly qualified science and mathematics domain is the articulation of students from bachelor to postgraduate degrees. To a certain extent, the GDS data allow this process to be monitored. Firstly, however, it is important to examine the extent to which employment outcomes for honours graduates in the natural and physical sciences differ from those of higher degree research postgraduates. If their job prospects are not as fruitful as their postgraduate superiors, perhaps there is scope to encourage more to stay in education and complete a higher degree.

Figure 15 shows that the unemployment rate for honours graduates in the natural and physical sciences was twice as high as that for higher degree postgraduates from the same field in 2007. It also shows that labour force participation rates of recent postgraduate completers are much higher than those for honours graduates. In addition, Figure 16 shows that median salary for honours graduates was $20,000 lower than for postgraduates in the natural and physical sciences.

Figure 15: Employment and participation rates of recent honours and higher degree research completers in the natural and physical sciences, Australia, 2007

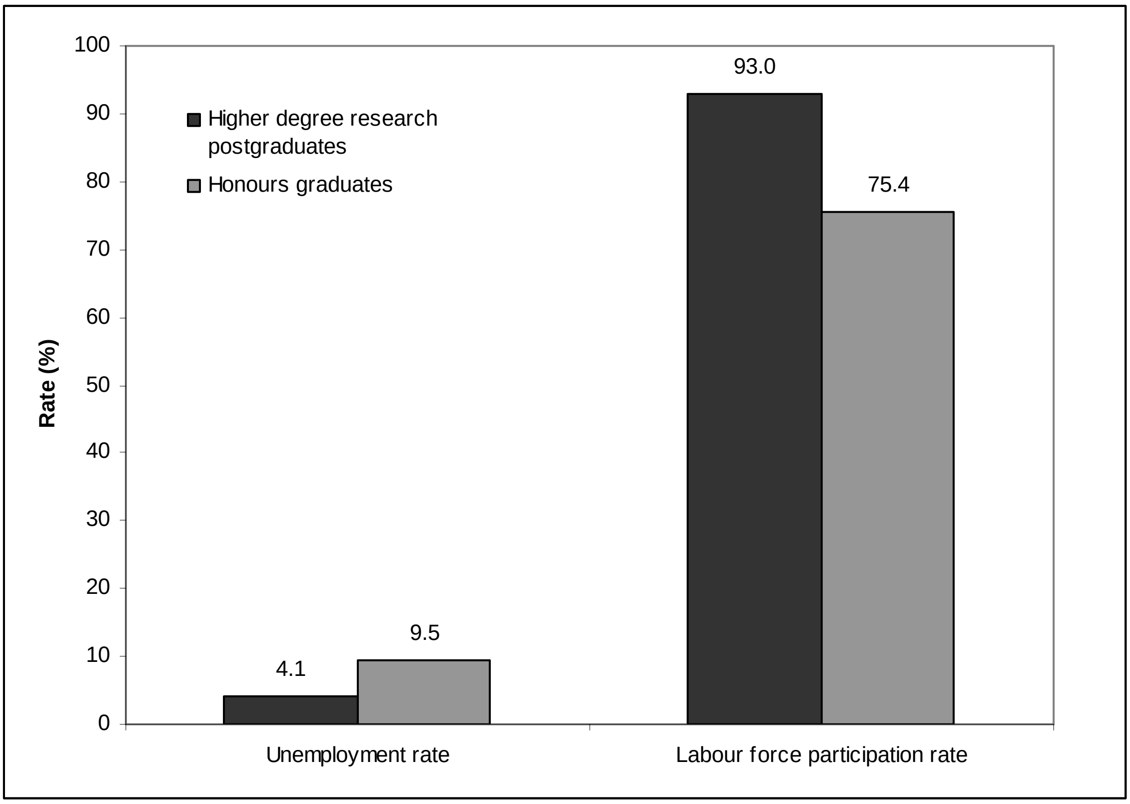


Figure 16: Median annual salaries of employed recent honours and higher degree research completers in the natural and physical sciences, Australia, 2007

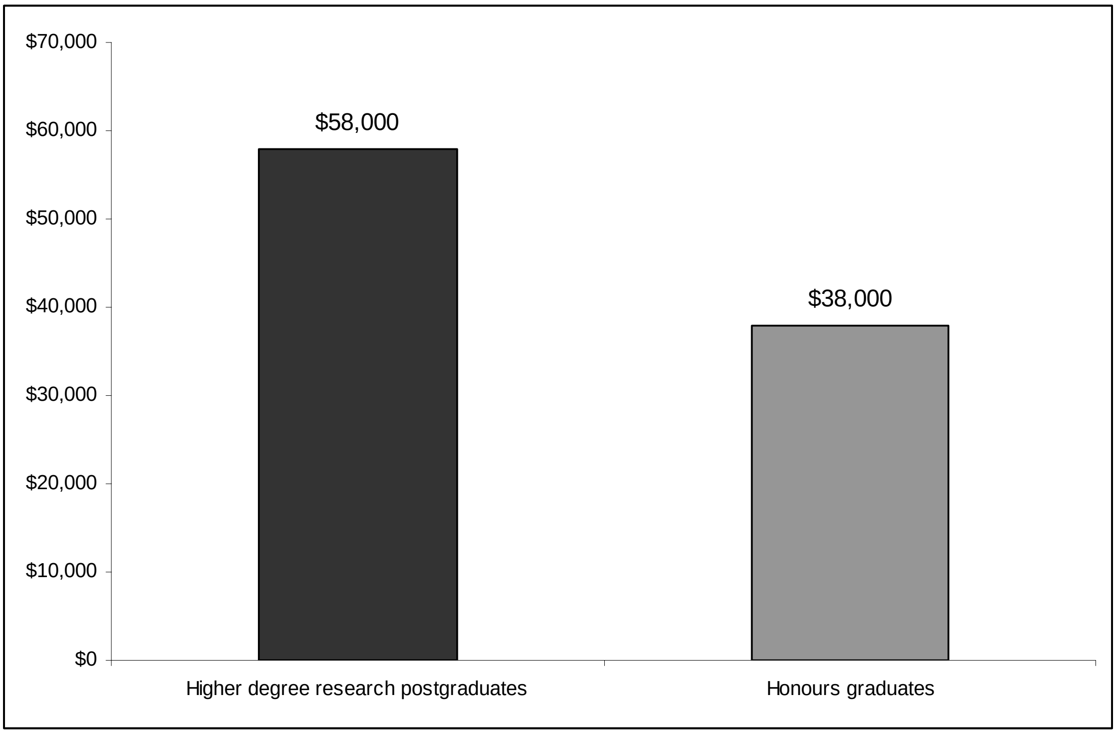


Table 19 shows that a notable proportion of honours graduates in the science and mathematics fields are articulating into further education following completion of their honours degree. In total, 44.3 per cent were in further study in the year following graduation. However, only 28.8 per cent of honours graduates in the natural and physical sciences were studying a natural and physical science course. In total, 23.3 per cent of all honours graduates in this field in 2006 went on to begin a doctorate in the natural and physical sciences in 2007. This appears to be a relatively good articulation rate.

Table 19: Further study transition, type and field of recent honours graduates in the natural and physical sciences, destination matrix, Australia, 2007 (per cent)

	All honours graduates	*Honours graduates continuing study*	*Honours graduates studying doctorate*
Studying	44.3	100.0	100.0
Studying in Natural and Physical Sciences	28.8	64.6	82.1
Studying doctorate	28.6	64.5	100.0
Studying doctorate in Natural and Physical Sciences	23.3	52.5	82.1
Totals	1,740	771	497

Source: GCA, Graduate Destinations Survey, 2007, unpublished

Demand

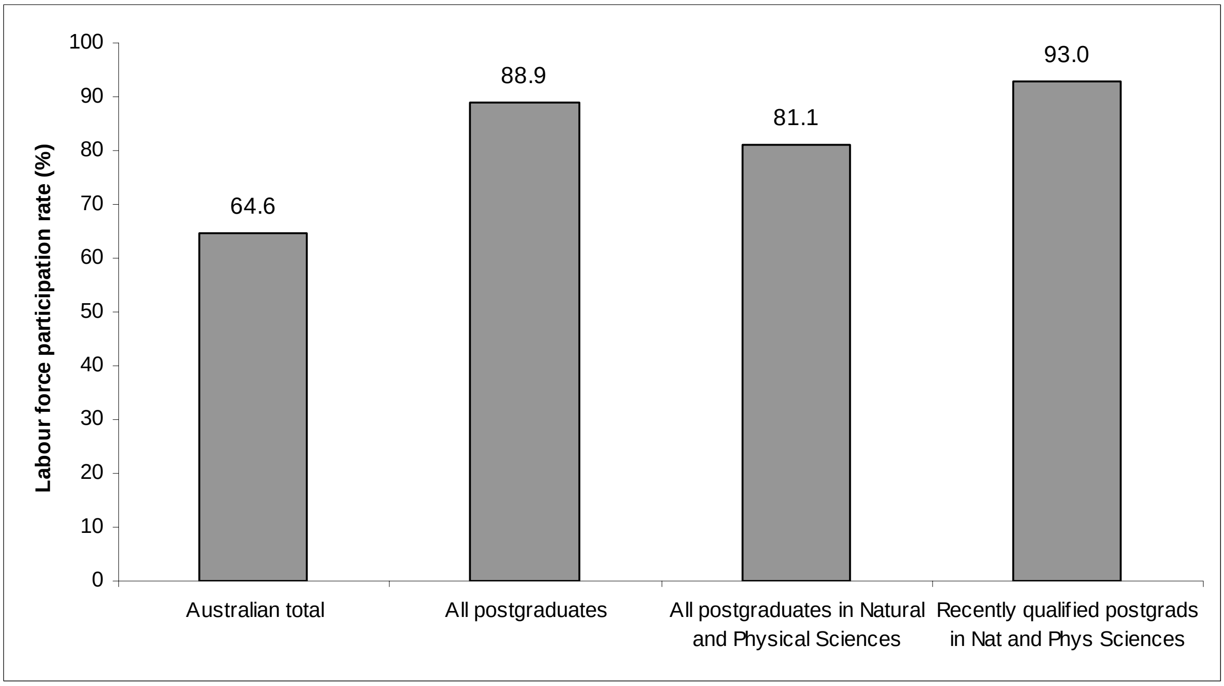
Monitoring demand is a complex and difficult task. Over the whole of this project, a number of different methods of assessing demand for postgraduates in the mathematics and sciences will be examined. This section uses some existing data sources to explore the demand for this group in the Australian employment market. It examines demand from the perspective of the extent of unemployment within the cohort, in order to understand the level of these postgraduates who are not able to find employment. If, for example, unemployment was high compared to other groups, this might suggest that there was little demand for such skills in the market. This analysis also explores the age profile of the current cohort of postgraduates in the mathematics and sciences to identify whether future shortfalls are likely. It finally investigates current and trend data relating to job vacancies in professional science and mathematics occupations to gain an understanding of the recent demand trends for skills in these areas.

Employment and participation

As shown in the analyses earlier, the employment rates of postgraduates in the natural and physical sciences are relatively high. These figures suggest there is a healthy demand for such skills in the labour force. Of those that are employed, the Census and GDS data show that a large proportion are working professionally and many are employed within science-specific industries and occupations.

Figure 17 and Figure 18 compare the labour force participation rates and the unemployment rates of the science and mathematics postgraduate groups (both all and recently qualified) with the Australian workforce as a whole, and all postgraduates in Australia regardless of qualification. Figure 17 shows that recently qualified science and mathematics postgraduates had the highest labour force participation rate of all these groups. Science and mathematics postgraduates as a whole are shown to have a slightly lower participation rate than the overall for postgraduates in general, but participation is much higher than that for the general population.

Figure 17: Labour force participation rates of selected groups, Australia, 2006/2007

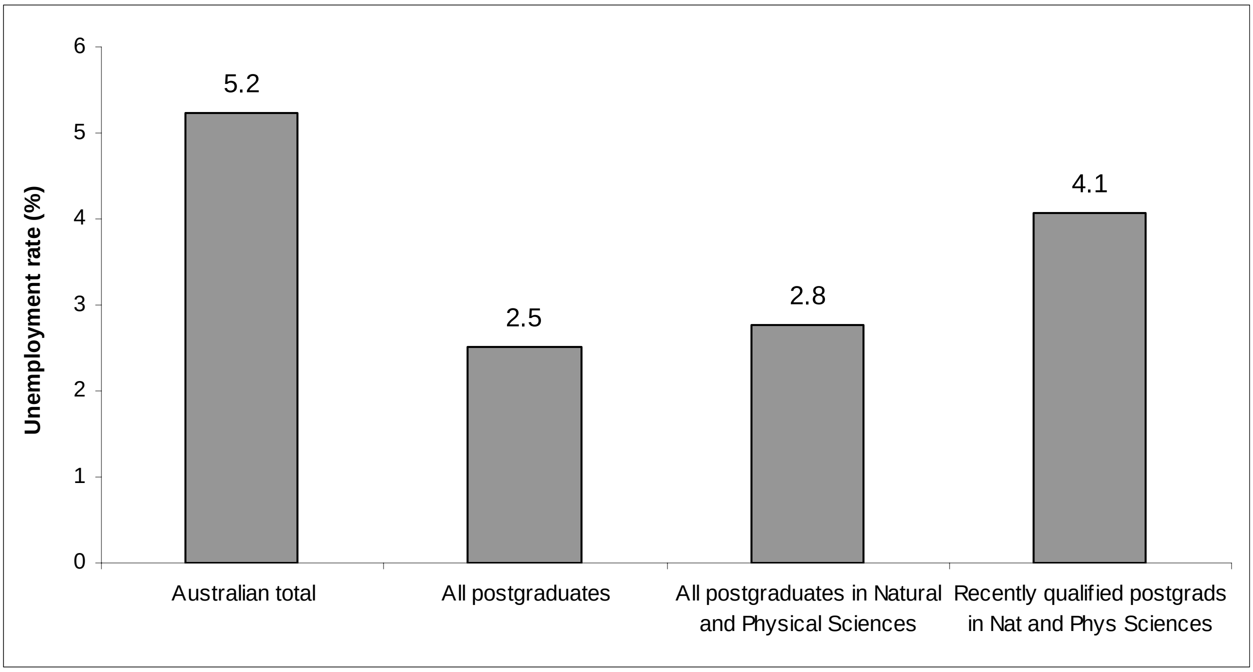


NB. The figures for All Postgraduates are for May 2007 and the Recently qualified postgraduates figures are for April 2007, the other two groups are for August 2006

Sources: ABS, *Basic Community Profile*, Census 2006; ABS, *Education and Work*, 2007; ABS, Customised 2006 Census matrix; GCA, Graduate Destinations Survey, 2007

More important to monitoring demand, Figure 18 shows that the unemployment levels of all and recent postgraduates in the natural and physical sciences were lower than the overall Australian rate in 2006. The rate for all postgraduates regardless of qualification was the lowest of all four groups displayed here. The recently qualified natural and physical science postgraduates unemployment rate, while being low, is a few percentage points higher than that of the overall natural and physical science postgraduates group. This may indicate early career issues in gaining employment in these fields – which may be related to employer needs for experienced workers. As articulated in the literature, there is some evidence of employer scepticism about hiring people fresh out of university (Mason, 1999).

Figure 18: Unemployment rates of selected groups, Australia 2006/2007



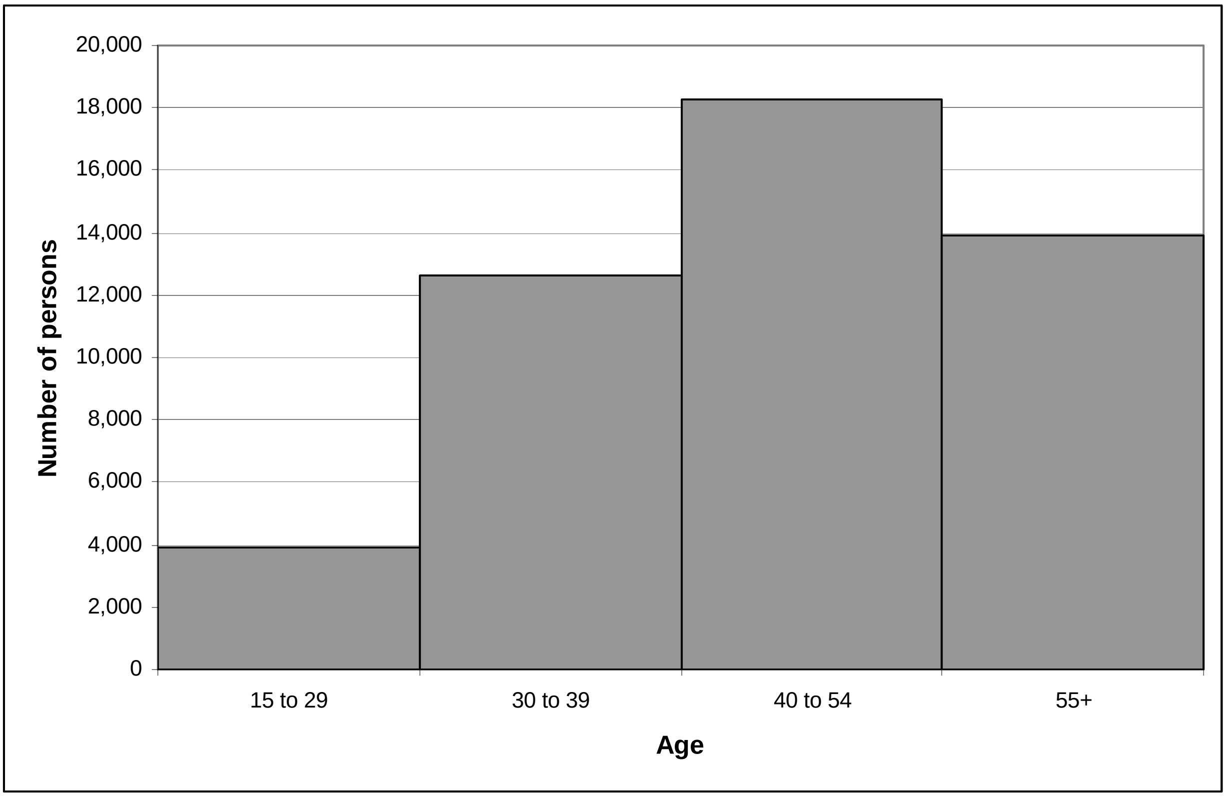
NB. The figures for All Postgraduates are for May 2007 and the Recently qualified postgraduates figures are for April 2007, the other two groups are for August 2006

Sources: ABS, *Basic Community Profile*, Census 2006, ABS, *Education and Work*, 2007, ABS, customised 2006 Census matrix, GCA, Graduate Destinations Survey, 2007

Age distribution

Nearly one-third of all postgraduates in the science and mathematics disciplines are aged over 55. This group is at, or will reach, retirement age over the next decade. Behind this group are a large number of 40 to 55 year olds, who as a group are currently assuming leadership positions in their respective fields. This cohort will remain in the labour force for the next 15 to 25 years and will fill many of the high level positions left by the older age cohort as retirement approaches. Figure 19 suggests that when considering age, there are a relatively healthy proportion of 30 to 39 year olds among the stock of persons with postgraduate qualifications in these fields, that are in the early to mid-career stages and who will help replace the older cohorts over the coming decades. In the younger age group, the share of postgraduates is lower. It is likely this is due to the fact that few have an opportunity to complete these qualifications by 29. Given that domestic supply of postgraduate completions in these fields increased 25 per cent over the 2001 to 2006 period (Table 3), there does seem to be an indication that present levels of supply can be maintained over the longer term. Whether this is enough to satisfy demand will be explored in the next section.

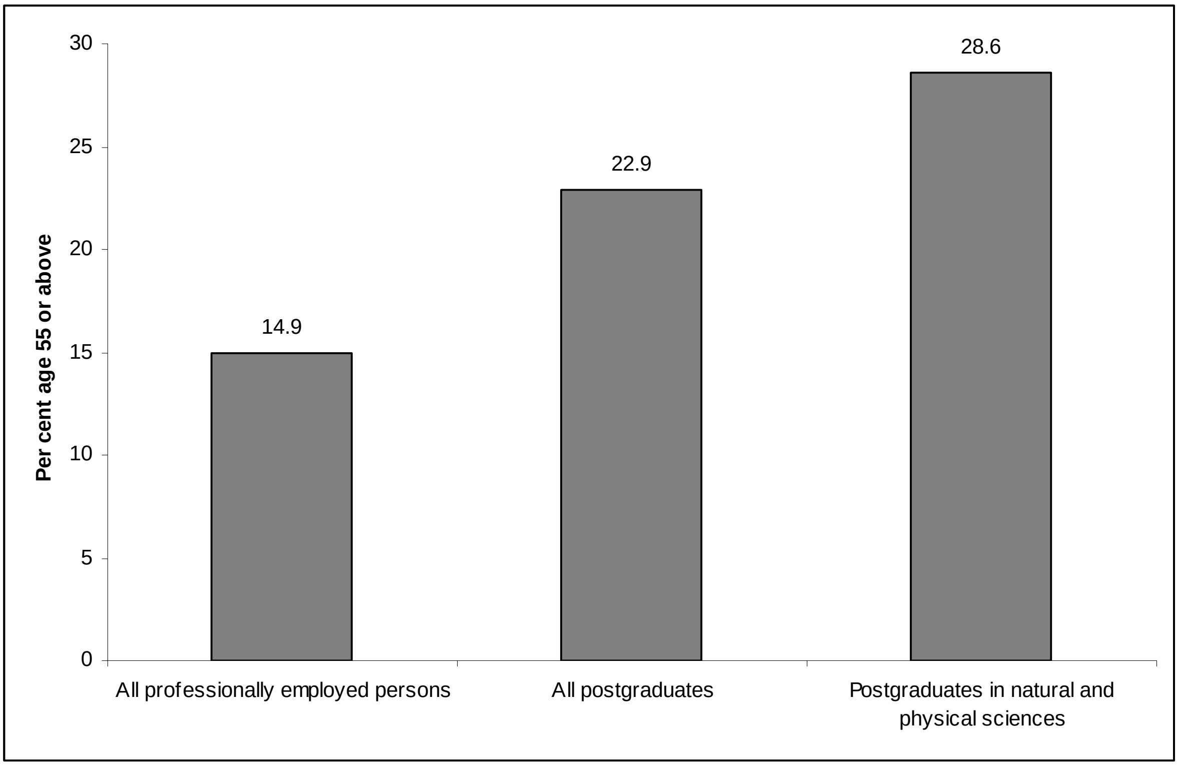
Figure 19: Age distribution of persons with postgraduate qualifications in the natural and physical sciences, Australia, 2006



Source: ABS, Customised 2006 Census matrix

While these figures appear to be relatively good, it is worth noting that the science and mathematics fields might have a harder job in the short term in dealing with impending retirements than other areas of the labour market. As Figure 20 shows, the proportion of postgraduates in the natural and physical sciences who are over 55 years old is larger than the share of this age group among all postgraduates and much larger than the share of these people in the professional labour force. As was discussed in the literature review and will be explored below, this will have particular consequences for demand in the higher education sector.

Figure 20: Proportion of persons in selected groups who are aged 55 or above, Australia, 2006

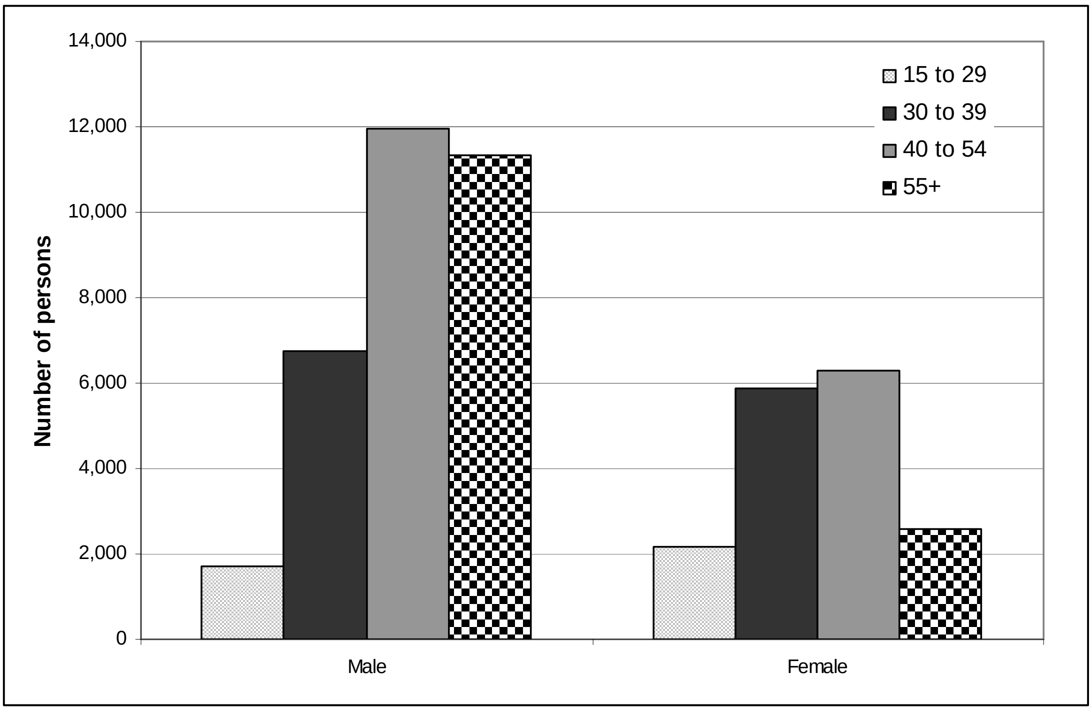


Source: ABS, Customised 2006 Census matrix and ABS *Basic Community Profile* 2006

Another factor of interest in exploring the age distribution of people in Australia with postgraduate qualifications in the science and mathematics fields is the gender difference within the age profile of these people. Figure 21 shows that the number of males in the 40 to 54 and 55-plus age groups is far larger than the number of females in these age brackets. However, in the younger age groups, 30 to 39 and 15 to 29, the ratio of females to males is much more even; in fact, females outnumber males in the youngest age group.

This finding is interesting, suggesting that the traditional dominance of males within the science and mathematics fields is likely to wane considerably over the next 20 to 30 years.

Figure 21: Age distribution of males and females with postgraduate qualifications in the natural and physical sciences, Australia, 2006



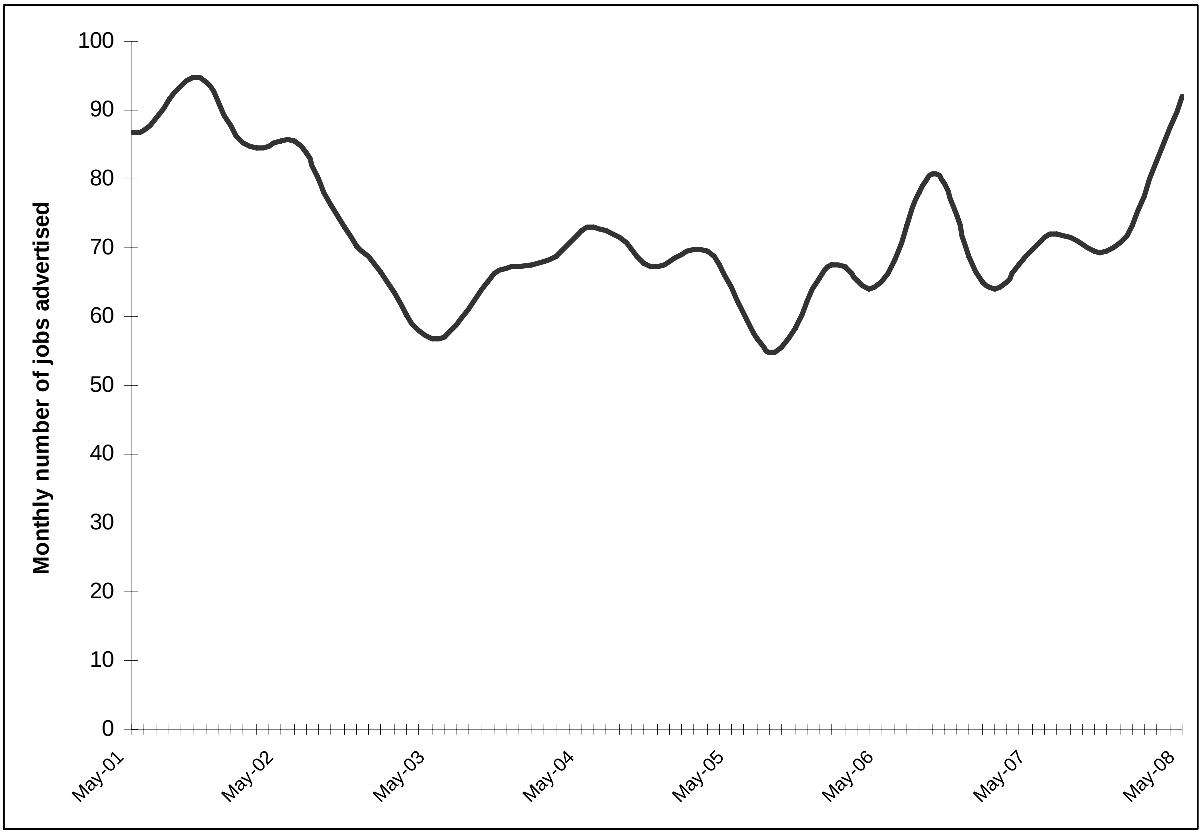
Source: ABS, Customised 2006 Census matrix

Job demand

The Skilled Vacancies Index (SVI), compiled by DEEWR provides an indication of the demand trends for jobs in the science professions over time and across the states of Australia. As detailed in the methodology section of this report (Appendix B), caution should be taken in interpreting the numbers in the SVI data as a literal indication of demand – these data are compiled from newspaper advertisements in major metropolitan areas once a week and therefore do not provide a full picture of the number of positions available in these occupations. The data are therefore used here in the form of a time series. Using the SVI data in this way provides a good indication of the fluctuation in the demand for these skills over time.

Using the SVI trended data to compile a time series of the number of jobs advertised for science professionals per month, Figure 22 shows that following an apparent sharp downturn in demand between May 2001 and May 2003, the number of jobs advertised has generally increased since. In particular, the last six months of data relating to job advertisements indicate that the figures for demand are currently reaching levels not experienced in more than six years.

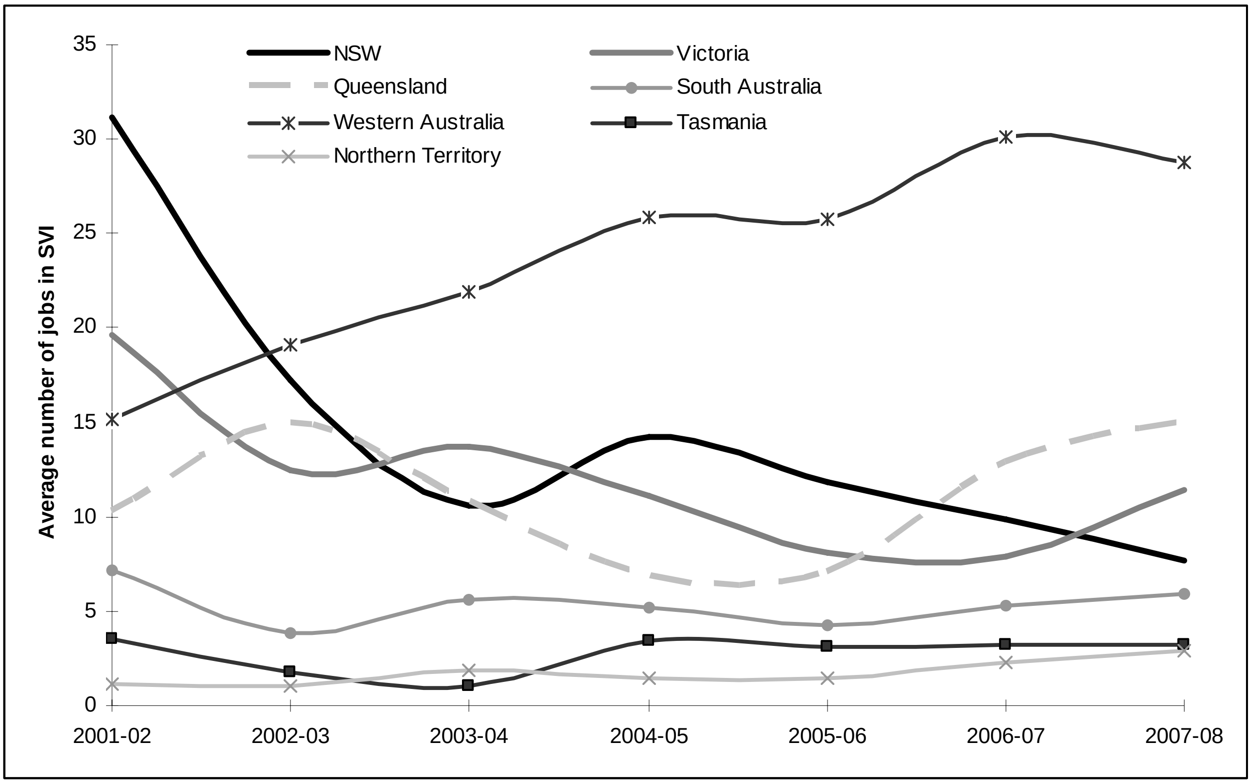
Figure 22: Number of jobs advertised for science professionals per month, May 2001 to May 2008, Australia (trended data)



Source: DEEWR, Skilled Vacancies Index, May 2008

Among the states, different levels of demand, as measured by job advertisements, are apparent (Figure 23). The trend in this figure shows that for science professions, the relative number of job vacancies does not necessarily match population size; for the past five years, Western Australia has had almost double the number of average job vacancies per month than the other states. In the past couple of years, the numbers for Queensland have also grown larger than those for the more populous states. A closer examination of this data (not displayed in the tables here) indicates that the bulk of the jobs in Western Australia are for geologists and environmental scientists and that there is a similar scenario in Queensland. These outcomes are closely linked to the current mining boom.

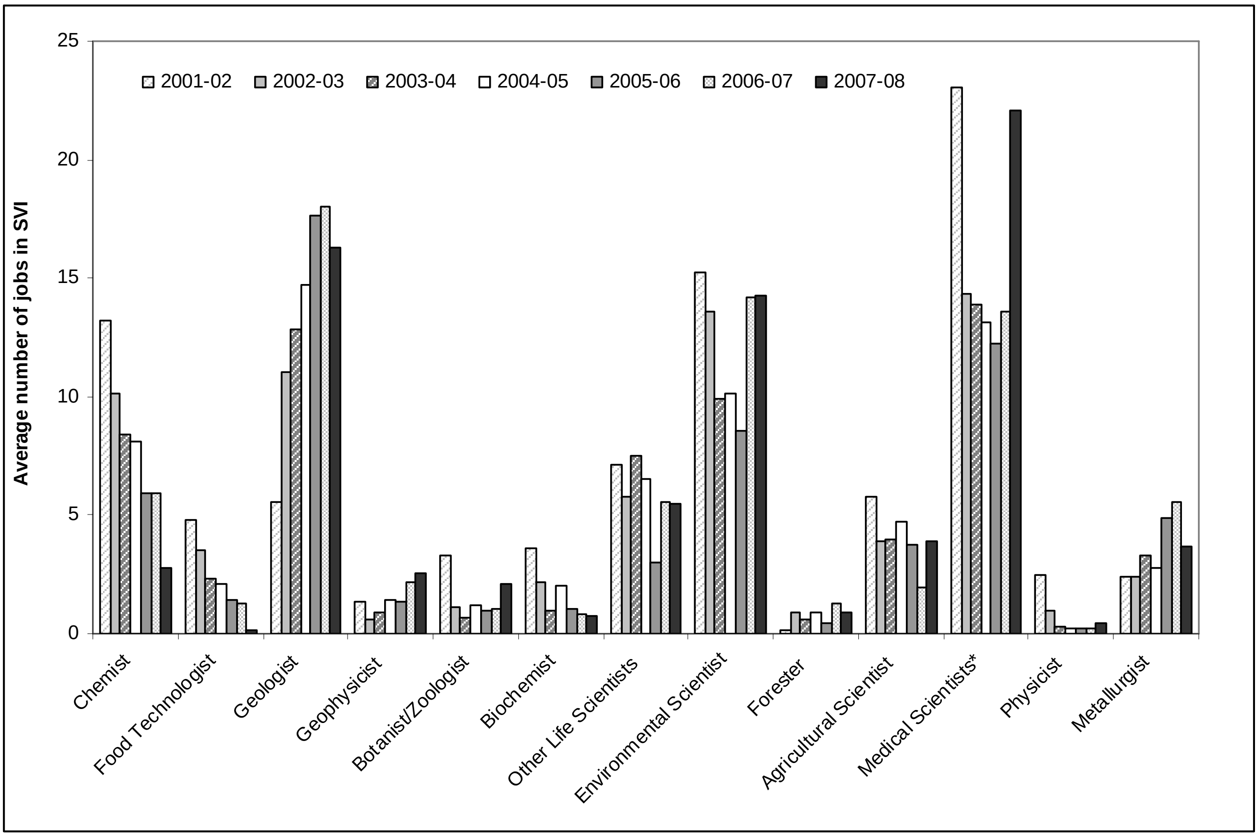
Figure 23: Average number of jobs advertised for science professionals per month by state, 2001–02 to 2007–08, Australia



Source: DEEWR, Skilled Vacancies Index, May 2008

As Figure 24 shows, job vacancies for geologists have increased substantially over the past seven years, again indicative of the mining boom. Meanwhile, advertisements for chemist positions have declined. The details in Figure 24 also provide an indication of the relative scale of the availability of jobs in the science and mathematics areas. From this data it appears that jobs in geology, environmental science and medical science are in higher demand that those in physics and biochemistry. However, as noted above, these figures only examine advertisements in newspapers, so there may be many positions advertised by other means that are not picked up in the SVI compilation.

Figure 24: Average number of jobs advertised for science professionals per month by specific occupations, 2001–02 to 2007–08, Australia



* does not include medical practitioners

Source: DEEWR, Skilled Vacancies Index, May 2008

Overall, the demand indicators reveal interesting insights into the nature of the professional science workforce and, to a certain extent, the match between supply and demand for postgraduates with science and mathematics qualifications in Australia. However, these figures do not necessarily reveal the full picture of demand. For this reason, the stakeholder consultations that form the next part of this project will be crucial in helping to interpret the data presented here and in forming a greater understanding about the nature and extent of demand for this group in the Australian workforce.

The academic profession

As noted in the earlier analyses, the academic profession is one of the key employment pathways taken by those who have higher degrees in the science and mathematics fields. It is therefore pertinent to focus on this particular occupation in assessing issues of supply and demand for people with these qualifications. As the literature review showed, the issue of an ageing workforce and impending retirement of the 'baby boomers' is of great concern among the academe and in the sciences and mathematics faculties in particular (Hughes & Rubenstien, 2006). Also revealed in the literature on this topic, is the concern that despite this impending shortage, not enough is being done in the universities across the world to nurture and maintain young academics (Huisman et al., 2002). A key issue in this regard is the lack of tenured positions being offered and the seemingly endless number of short-term contracts that early and mid-career academics are faced with, offering little incentive to remain in the academic sphere.

The analysis below investigates both the issue of ageing and the employment conditions faced by academics in the natural and physical sciences in Australia, using the most recent data available from the DEST *Higher Education Statistics Staff Collection*. The discussion also draws on the Census data used earlier in this report. It outlines some general demographic characteristics of the academic workforce in these fields, including looking at the extent to which Australia draws its academics from international institutions.

As noted in Appendix B, the data from the Staff collection is relatively accurate at the broad natural and physical sciences level, but interpretation of numbers and trends for individual disciplines within the broad field should be undertaken with caution. This is due to the different faculty structures within Australian universities. In some cases disciplines are merged together, thus causing difficulties for administrators who submit the staff data to the federal education department in allocating specific fields to some academics. Table 20 is the only instance where the individual disciplines have been identified in this analysis. The other tables and figures use the aggregated broad field of natural and physical sciences.

Table 20 displays the size of the academic workforce in the natural and physical sciences in Australia from 2002 to 2006. The total figure shows there has been a growth in the number of people employed as academics in these fields over this period. However, within individual disciplines the data suggest that there was a decline in the numbers of mathematical science, chemical science, and earth science academic positions over this period. The data indicate there were substantial increases in the biological sciences.

The bottom half of Table 20 shows the share of academic positions across the individual disciplines for each of the years in the time series. Not including the 'nfd' category, the biological sciences make up a large and growing proportion of jobs in the broad natural and physical sciences discipline. Mathematical science is the second largest individual discipline; however, like its numbers, its share of all academic positions declined between 2002 and 2006.

Table 20: Academic staff in the natural and physical sciences by discipline, Australia, 2002 to 2006

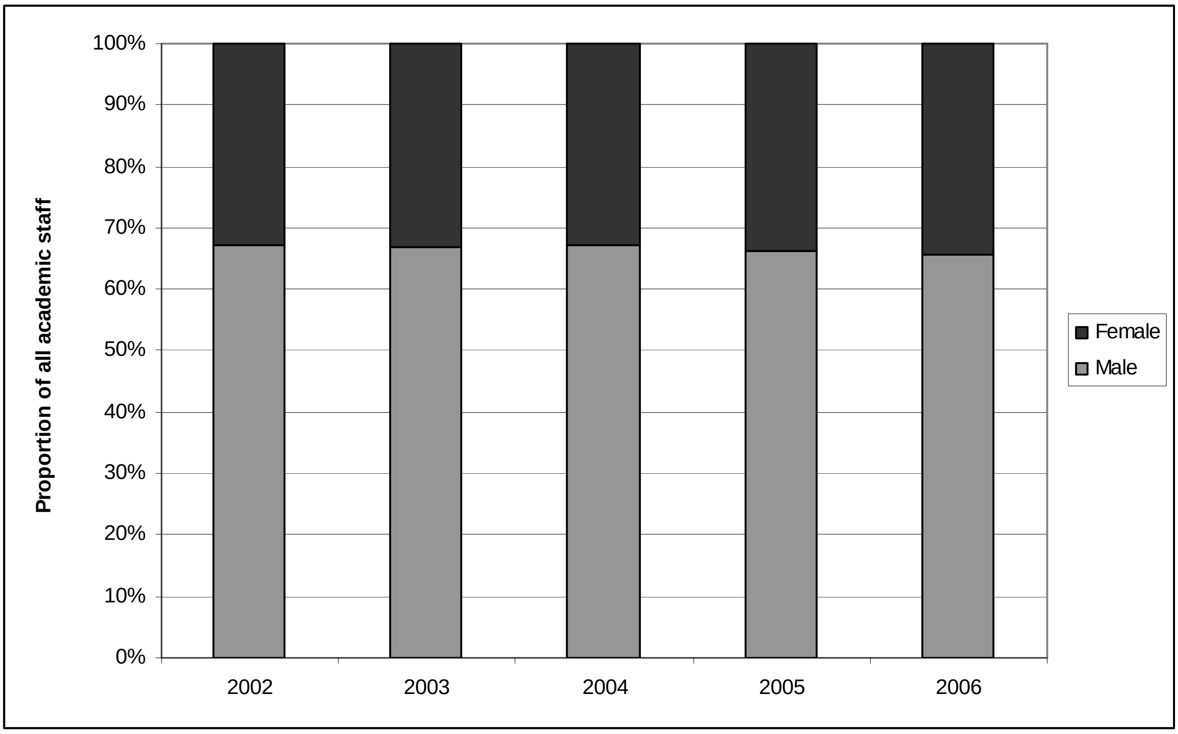
Discipline	*2002*	*2003*	*2004*	*2005*	*2006*
			Number of staff		
Mathematical Sciences	741	775	781	650	672
Physics and Astronomy	521	519	547	564	558
Chemical Sciences	502	397	488	408	497
Earth Sciences	272	244	280	262	223
Biological Sciences	1,883	1,872	2,005	2,208	2,297
Other Natural and Physical Sciences	333	370	328	309	353
Natural and Physical Sciences, nfd	2,373	2,581	2,577	2,816	3,108
Total	6,625	6,758	7,006	7,217	7,708
			Per cent		
Mathematical Sciences	11.2	11.5	11.1	9.0	8.7
Physics and Astronomy	7.9	7.7	7.8	7.8	7.2
Chemical Sciences	7.6	5.9	7.0	5.7	6.4
Earth Sciences	4.1	3.6	4.0	3.6	2.9
Biological Sciences	28.4	27.7	28.6	30.6	29.8
Other Natural and Physical Sciences	5.0	5.5	4.7	4.3	4.6
Natural and Physical Sciences, nfd	35.8	38.2	36.8	39.0	40.3
Total	100.0	100.0	100.0	100.0	100.0

NB. Care should be taken in interpreting these figures. The different disciplinary divisions between Australian universities means that some staff are classified outside their discipline or classified in the 'nfd' group. Therefore these figures are indicative only

Source: DEST Higher Education Statistical Collection, Staff, 2002–06

As the Census data for all people in Australia with a postgraduate qualification in the natural and physical sciences showed, women are under-represented in this group. Therefore, it is no surprise that the gender balance within the academics in these fields is also disproportionately weighted in favour of men. Figure 25 shows that across the time series, male academics have comprised more than 65 per cent of the workforce in the natural and physical sciences. The data does show a slight decline in this dominance, but the 2006 figure of 65.6 per cent still reveals a notable imbalance.

Figure 25: Academic staff in the natural and physical sciences by sex, Australia, 2002 to 2006



Source: DEST Higher Education Statistical Collection, Staff, 2002–06

There are a range of functions that academics are required to perform. Some are required to teach and conduct research, some only teach, while others are engaged only in research. Table 21 shows the spread of these functions across the natural and physical sciences academic workforce between 2002 and 2006. Teaching and research is the most common function, followed by research-only. The data indicate that few academics in this field perform a teaching-only function. Over the time series, the proportion of research-only staff in this field has increased, and in 2006 this function comprised 42.5 per cent of the workforce (a growth of 6.1 percentage points over five years). There were consequential declines in the share of both teaching-only and teaching and research staff during this period.

Table 21: Main 'function' of academic staff in the natural and physical sciences, Australia, 2002 to 2006 (percentage)

Main function	*2002*	*2003*	*2004*	*2005*	*2006*
Teaching only	8.3	8.4	7.5	6.7	6.5
Research only	36.4	37.1	38.3	39.7	42.5
Teaching and research	53.9	53.3	53.2	52.0	49.6
Other	1.4	1.2	1.1	1.5	1.3
Total	100.0	100.0	100.0	100.0	100.0
Total (no.)	6,625	6,758	7,006	7,217	7,708

Source: DEST Higher Education Statistical Collection, Staff, 2002–06

Table 22 outlines the extent to which Australia draws its science and mathematics academics from international institutions. In 2006, 30.6 per cent of academics employed in Australia had completed their highest qualification outside of Australia. This does not necessarily mean that these people were not Australian, but it does mean they have been drawn to Australia following completion of a higher degree. For academic ‘cross-pollination’ of knowledge and methodology, this appears to represent a healthy situation for Australia. The time series shows that the proportion of the workforce in these fields that have obtained their highest qualification overseas has been slowly increasing.

Table 22: Place in which study for highest educational qualification was undertaken, for academic staff in the natural and physical sciences, Australia, 2002 to 2006 (percent)

Place of highest qualification	*2002*	*2003*	*2004*	*2005*	*2006*
The Australian university in which they are now working	26.7	27.9	27.6	28.6	29.2
Another Australian university	42.8	41.9	41.5	38.6	37.0
Other Australian education institution	2.7	1.5	1.6	2.7	3.2
An overseas institution or entity	27.8	28.7	29.4	30.2	30.6
Total	100.0	100.0	100.0	100.0	100.0
Total (no.)*	4,923	5,178	5,745	5,877	6,251

* Total and above calculations include only cases where this element is known (data is unknown for between 18 and 25 per cent of the whole cohort)

Source: DEST Higher Education Statistical Collection, Staff, 2002–06

The levels of seniority among academic staff in the natural and physical sciences is shown in Table 23. The proportion of Australian academics in this field who were professors increased from 8.3 per cent in 2002 to 10.8 per cent in 2006. At the other end of the rankings, the share of Assistant Lecturers (or Level A positions) also increased in relation to the whole workforce.

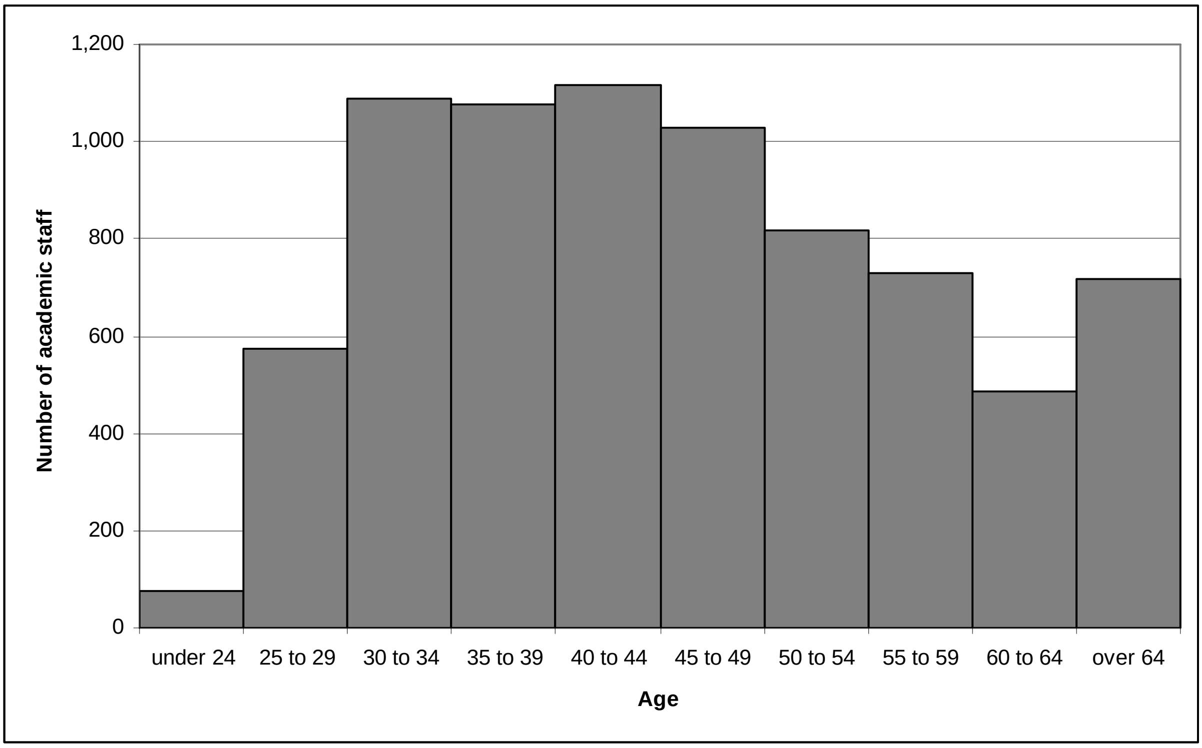
Table 23: Academic staff in the natural and physical sciences by level of employment classification, Australia, 2002 to 2006

Broad Classification	*2002*	*2003*	*2004*	*2005*	*2006*
Professor (level E)	8.3	9.7	10.1	10.7	10.8
Associate Professor (level D)	13.6	12.6	12.5	11.9	11.8
Senior Lecturer (level C)	18.6	19.3	18.6	18.1	18.1
Lecturer (level B)	25.1	25.2	25.5	25.0	24.9
Assistant Lecturer (level A)	25.0	24.9	25.5	27.0	27.5
No information	9.4	8.2	7.8	7.2	6.8
Total	100.0	100.0	100.0	100.0	100.0
Total (no.)	6,625	6,758	7,006	7,217	7,708

Source: DEST Higher Education Statistical Collection, Staff, 2002–06

Figure 26 details the age structure of the academic workforce in the mathematics and sciences in 2006. It shows a relatively large bulk of academics aged between 30 and 49, with a tapering into the older age groups. There is also a smaller number in the 25 to 29 age group, although this is chiefly because many people are still completing their higher degree qualifications at this age. The age structure displayed in this figure suggests there is a relatively healthy number of early and mid-career academics currently in these fields. The number of academics in the natural and physical sciences aged over 55 years in 2006 was 1,934; while the number of academics aged 30 to 44 was 3,281. On the basis of these numbers, it appears that if these younger academics remain in the academe, there will be sufficient numbers to replace the impending retirements over the coming decades.

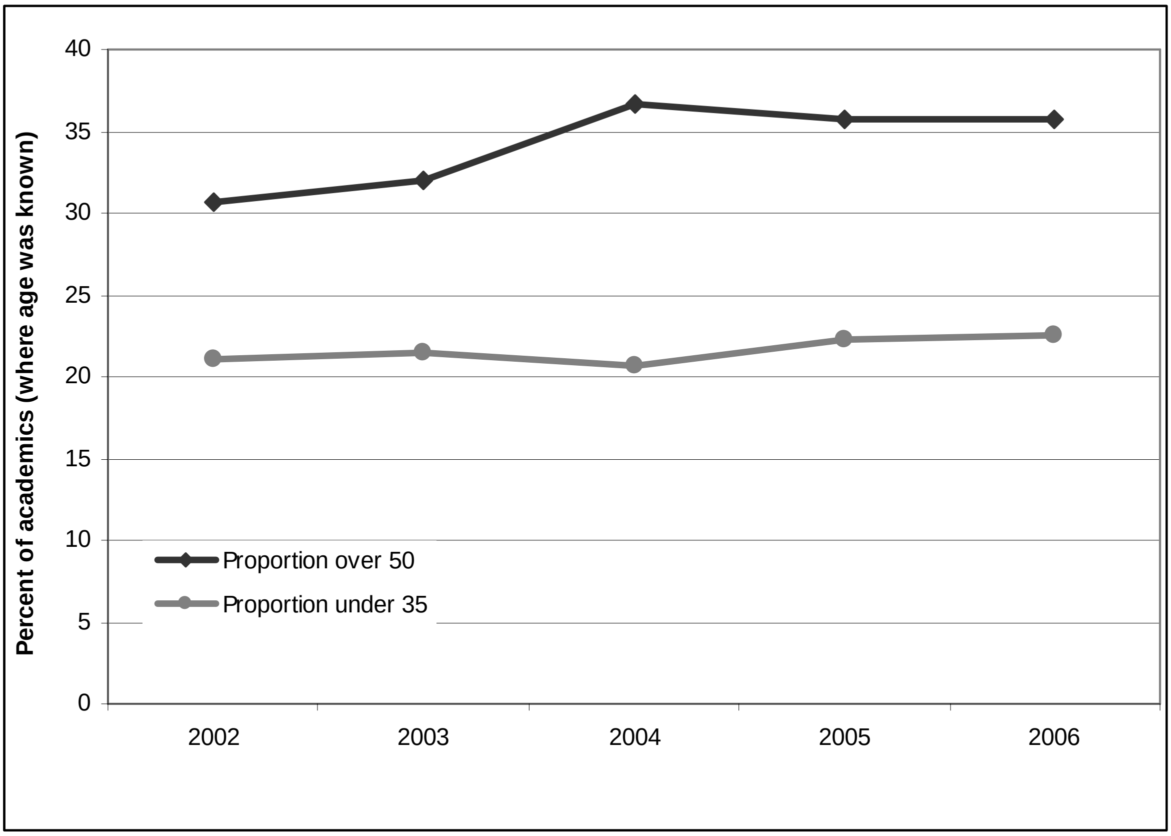
Figure 26: Age profile of academic staff in the natural and physical sciences, Australian higher education institutions, 2006



Source: DEST Higher Education Statistical Collection, Staff, 2006

This does not hide the fact that the academic workforce in the natural and physical sciences is ageing. Figure 27 shows that the proportion of all staff aged over 55 grew over the time series, particularly between 2002 and 2004, and by 2006 comprised more than one-third of the workforce. Over the same period, the proportion of academics aged under 35 remained relatively stable at just over 20 per cent.

Figure 27: Proportion of academic staff in the natural and physical sciences by selected age ranges, Australia, 2002 to 2006 (percent)



Source: DEST Higher Education Statistical Collection, Staff, 2002–06

As mentioned above, the key to ensuring that retirements in the academic workforce do not result in severe workforce shortages in the natural and physical sciences is to retain young scientists and mathematicians in academe. An important element in maintaining these young academics is to provide adequate career pathways. However, in concordance with the international literature on this subject, Table 24 shows that in Australia, the number of short- and fixed-term contracts for academics in the natural and physical sciences grew between 2002 and 2006.

The numbers in the top half of Table 24 show that, despite a small increase in the number of tenured academics, most of the growth in Australian academic positions in the natural and physical sciences field between 2002 and 2006 was in contract staff. As a percentage of all tenure types, contract staff increased from 45.7 per cent of all natural and physical science academics in 2002 to 53.7 per cent in 2006. Within this group, contracts of less than 12 months rose from 11 per cent of the whole cohort to 14.3 per cent during this period. At the same time, the proportion of tenured positions fell from 44.7 per cent to 39.3 per cent of the science and mathematics academic workforce.

Table 24: Contract terms of academic staff in the natural and physical sciences, Australia, 2002 to 2006

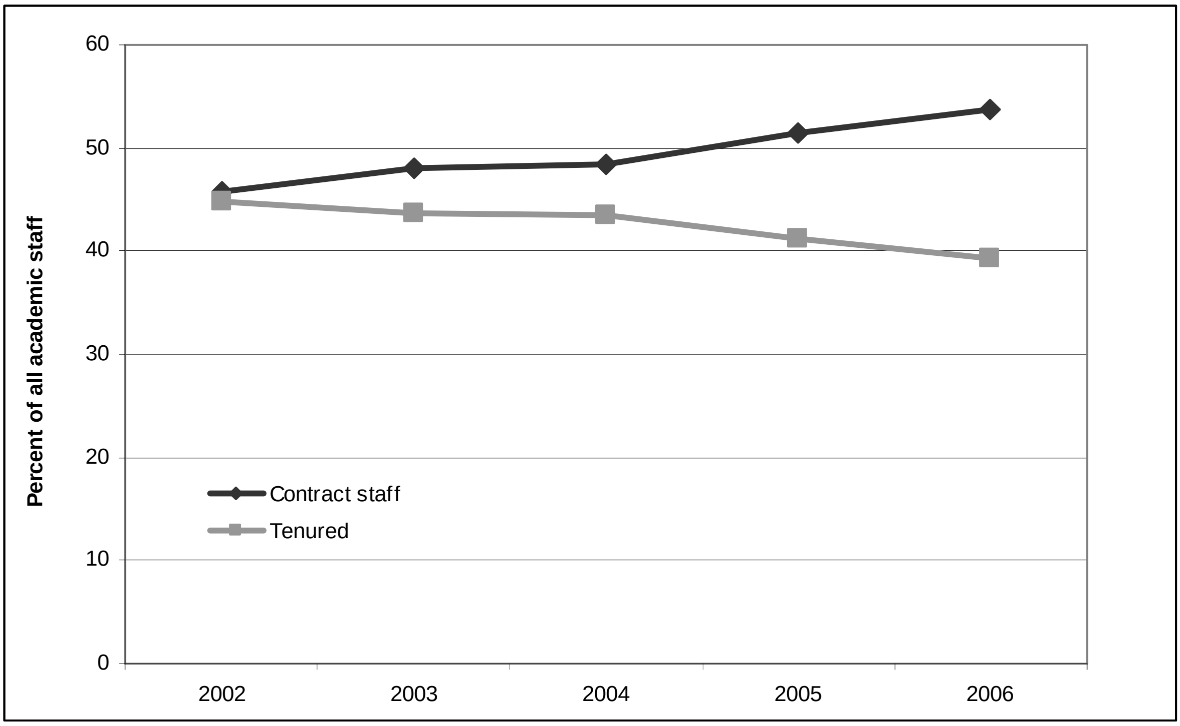
Contract term	*2002*	*2003*	*2004*	*2005*	*2006*
			Number of staff		
Contract staff					
Less than 12 months	730	797	553	914	1,104
12 months	435	483	712	500	520
13 to 24 months	580	524	545	631	653
25 months to 5 years	1,060	1,232	1,373	1,435	1,570
More than five years	223	204	214	239	294
Subtotal – Contract staff	*3,028*	*3,240*	*3,397*	*3,719*	*4,141*
Tenured	2,964	2,956	3,049	2,969	3,028
Other term	10	11	16	9	12
No information	623	551	544	520	527
Total	6,625	6,758	7,006	7,217	7,708
			Per cent		
Contract staff					
Less than 12 months	11.0	11.8	7.9	12.7	14.3
12 months	6.6	7.1	10.2	6.9	6.7
13 to 24 months	8.8	7.8	7.8	8.7	8.5
25 months to 5 years	16.0	18.2	19.6	19.9	20.4
More than five years	3.4	3.0	3.1	3.3	3.8
Subtotal – Contract staff	*45.7*	*47.9*	*48.5*	*51.5*	*53.7*
Tenured	44.7	43.7	43.5	41.1	39.3
Other term	0.2	0.2	0.2	0.1	0.2
No information	9.4	8.2	7.8	7.2	6.8
Total	100.0	100.0	100.0	100.0	100.0

Source: DEST Higher Education Statistical Collection, Staff, 2002–06

Figure 28 graphically illustrates the changing dimensions in the allocation of tenure and contract positions among academic staff in the science and mathematics fields between 2002 and 2006. The trend is stark and these figures confirm the general thrust of the international and Australian literature. According to this literature, if the increase in short-term academic positions continues, it is likely that many young researchers in science and mathematics will be discouraged from following an academic career (Dawson, 2007; Glanz, 1998; Halyard, 1995; Huisman et al., 2002;

Kidd & Green, 2006; Laudel & Glaser, 2008; Leggon, 2001; McGinnis et al., 1982; McInnis et al., 2001; Monastersky, 2007; Nolch, 2001; Paldy, 1994).

Figure 28: Percentage of academic staff in the natural and physical sciences in tenured and contract positions, Australia, 2002 to 2006



Source: DEST Higher Education Statistical Collection, Staff, 2002–06

While the international literature indicates a dire situation for young academics as regards contract terms, the data from the 2007 GDS shows that among the small sample that were employed as university lecturers or tutors, those based in Australian institutions were more likely to be on fixed-term contracts of 12 months or less (30.8 per cent) than those who had found employment in another country (13.6 per cent). The proportion of those employed in universities overseas who had permanent or open-ended contracts (72.7 per cent) was also vastly different to the terms of those new postgraduates employed in Australian higher education institutions. While these figures are based on small numbers, they do suggest that the employment terms of young academics who stay in Australia are worse than for those who gain academic positions overseas. The implications of this for sustaining a robust academic community in Australia are potentially serious.

Table 25: University lecturers and tutors: Employment terms and country of employment for recently completed higher degree postgraduates in the natural and physical sciences, graduates from Australian universities, 2007 (per cent)

Employment terms	*Australia*	*Other country*	*Total*
Permanent or open-ended contract	28.2	72.7	44.3
Fixed-term contract more than 12 months	12.8	9.1	11.5
Fixed-term contract up to 12 months	30.8	13.6	24.6
Temporary or casual	28.2	4.5	19.7
Total	100.0	100.0	100.0
Total (no.)	39	22	61

Source: GCA, Graduate Destinations Survey, 2007, unpublished

Conclusion

This report has utilised numerous national data sets to paint a picture of the supply, demand and employment dynamics of the group of postgraduates in the natural and physical sciences in Australia. The figures indicate an increasing number of postgraduates are completing studies in these fields. However, compared with other fields of education, supply in the natural and physical sciences is increasing at a slower rate. When compared to international data, the Australian higher education supply figures appear relatively robust, with growth in these fields occurring at a greater rate than a number of other countries. Figures from DIAC show that supply of professional scientists from migration has continued to grow in recent years, maintaining Australia's 'brain gain' in these areas between 2002 and 2007. Importantly, this growth from migration is also heavily balanced in Australia's favour in the key age group of 25 to 44 year olds.

Data from the 2006 Census show that in total there are nearly 50,000 postgraduates in science and mathematics in Australia. This group has generally high employment and workforce participation rates, and low unemployment rates. The employment of this group is generally in occupations and industries that broadly appear to match their fields of qualification, with university lecturers and tutors being the largest single occupation among the whole group. Among recently qualified postgraduates in these fields, employment outcomes are relatively good, although there is some evidence of difficulties in early career transitions. Among this group, the data analysis suggests that international students are likely to leave Australia following completion and therefore care should be taken in considering them as a key element of workforce supply in Australia.

The low unemployment and high participation rates for postgraduates in the mathematics and sciences in Australia tend to indicate that the current levels of provision of these skills is not surplus to the needs of employers and industry. However, job vacancies data suggest that the number of jobs being advertised monthly in the professional science fields is not particularly large. The assessment of demand dynamics is an area requiring further research and will be a particular focus of the stakeholder consultations to take place in the next stage of this research.

The final section of this report specifically examined the academic workforce in the natural and physical sciences in Australia. Figures show a slight growth in the academe between 2002 and 2006. The age structure of academics in 2006 tends to indicate that at present, the impending retirements of the over-55 age group should not be a problem due to the existence of sufficient numbers of early and mid- career academics. However, replacing senior positions within university science and mathematics departments is contingent on retaining this current crop of early and mid-career researchers. The Australian figures relating to the terms of academic employment show there is a trend towards short-term contracts and a trend away from tenured positions. International research suggests that such a situation is unlikely to continue to attract and retain academics in these areas in the future.

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Appendix A: Main occupations for each natural and physical sciences field of education

Table 26: Main occupations (4-digit level) of employment among postgraduates in mathematical sciences, 2006

Occupation (ANZSCO)	*Mathe-matical Sciences*	*% Distribution of occupation among all Maths PGs*	*Total all person employed*	*% of all employed who have PG quals in this field*
University Lecturers and Tutors	823	20.7	35,595	2.3
Actuaries, Mathematicians and Statisticians	476	12.1	4,007	11.9
Software and Applications Programmers	329	8.3	52,858	0.6
Secondary School Teachers	254	6.4	118,675	0.2
Professionals, nfd	188	4.7	24,197	0.8
ICT Managers	91	2.3	29,963	0.3
Management and Organisation Analysts	67	1.7	34,943	0.2
Other Natural and Physical Science Professionals	64	1.6	4,416	1.4
ICT Business and Systems Analysts	60	1.5	15,636	0.4
Natural and Physical Science Professionals, nfd	57	1.4	6,127	0.9
Financial Investment Advisers and Managers	54	1.4	29,937	0.2
Database and Systems Administrators, and ICT Security Specialists	53	1.3	21,100	0.3
Accountants	47	1.2	123,374	0.0
Research and Development Managers	46	1.2	8,209	0.6
ICT Professionals, nfd	45	1.1	19,334	0.2
Chief Executives and Managing Directors	43	1.1	46,432	0.1
Other occupations	1,279	32.1	8,529,384	0.0
Total employed	3,976	100.0	9,104,187	0.0

Source: ABS, Customised 2006 Census matrix

Table 27: Main occupations (4-digit level) of employment among postgraduates in physics and astronomy, 2006

Occupation (ANZSCO)	*Physics and Astronomy*	*% Distribution of occupation among all Physics PGs*	*Total all persons employed*	*% of all employed who have PG quals in this field*
Other Natural and Physical Science Professionals	504	14.2	4,416	11.4
University Lecturers and Tutors	448	12.7	35,595	1.3
Natural and Physical Science Professionals, nfd	302	8.5	6,127	4.9
Professionals, nfd	236	6.7	24,197	1.0
Software and Applications Programmers	234	6.6	52,858	0.4
Secondary School Teachers	113	3.2	118,675	0.1
Research and Development Managers	69	1.9	8,209	0.8
ICT Managers	65	1.8	29,963	0.2
Chief Executives and Managing Directors	61	1.7	46,432	0.1
Management and Organisation Analysts	50	1.4	34,943	0.1
ICT Professionals, nfd	49	1.4	19,334	0.3
Computer Network Professionals	49	1.4	16,257	0.3
Database and Systems Administrators, and ICT Security Specialists	40	1.1	21,100	0.2
Other occupations	1,322	37.3	8,686,081	0.0
Total employed	3,542	100.0	9,104,187	0.0

Source: ABS, Customised 2006 Census matrix

Table 28: Main occupations (4-digit level) of employment among postgraduates in chemical sciences, 2006

Occupation (ANZSCO)	*Chemical Sciences*	*% Distribution of occupation among all Chemical sciences PG*	*Total all persons employed*	*% of all employed who have PG quals in this field*
Chemists, and Food and Wine Scientists	697	14.7	7,421	9.4
University Lecturers and Tutors	475	10.1	35,595	1.3
Natural and Physical Science Professionals, nfd	352	7.4	6,127	5.7
Professionals, nfd	243	5.1	24,197	1.0
Other Specialist Managers	193	4.1	32,928	0.6
Secondary School Teachers	173	3.6	118,675	0.1
Research and Development Managers	130	2.7	8,209	1.6
Other Natural and Physical Science Professionals	94	2.0	4,416	2.1
Chief Executives and Managing Directors	93	2.0	46,432	0.2
Medical Laboratory Scientists	92	1.9	13,371	0.7
Pharmacists	88	1.9	15,336	0.6
Environmental Scientists	82	1.7	12,869	0.6
Advertising and Sales Managers	71	1.5	87,317	0.1
Management and Organisation Analysts	59	1.2	34,943	0.2
Software and Applications Programmers	58	1.2	52,858	0.1
Other occupations	1,853	38.9	8,603,493	0.0
Total employed	4,753	100.0	9,104,187	0.1

Source: ABS, Customised 2006 Census matrix

Table 29: Main occupations (4-digit level) of employment among postgraduates in earth sciences, 2006

Occupation (ANZSCO)	*Earth Sciences*	*% Distribution of occupation among all Earth Sciences PGs*	*Total all persons employed*	*% of all employed who have PG quals in this field*
Geologists and Geophysicists	1,553	37.5	6,096	25.5
University Lecturers and Tutors	270	6.5	35,595	0.8
Environmental Scientists	185	4.6	12,869	1.4
Natural and Physical Science Professionals, nfd	149	3.6	6,127	2.4
Professionals, nfd	127	3.1	24,197	0.5
Mining Engineers	103	2.5	4,283	2.4
Other Natural and Physical Science Professionals	101	2.4	4,416	2.3
Other Specialist Managers	96	2.3	32,928	0.3
Chief Executives and Managing Directors	83	2.0	46,432	0.2
Secondary School Teachers	58	1.4	118,675	0.0
Software and Applications Programmers	52	1.3	52,858	0.1
Civil Engineering Professionals	50	1.2	21,283	0.2
Research and Development Managers	47	1.1	8,209	0.6
General Managers	43	1.0	37,816	0.1
Other occupations	1,217	29.4	8,692,403	0.0
Total employed	4,134	100.0	9,104,187	0.0

Source: ABS, Customised 2006 Census matrix

Table 30: Main occupations (4-digit level) of employment among postgraduates in biological sciences, 2006

Occupation (ANZSCO)	*Biological Sciences*	*% Distribution of occupation among all Biological Sciences PGs*	*Total all persons employed*	*% of all employed who have PG quals in this field*
University Lecturers and Tutors	1,322	12.5	35,595	3.7
Life Scientists	1,168	11.1	5,152	22.7
Medical Laboratory Scientists	1,066	10.1	13,371	8.0
Natural and Physical Science Professionals, nfd	842	8.0	6,127	13.7
Professionals, nfd	651	6.2	24,197	2.7
Environmental Scientists	535	5.1	12,869	4.2
Research and Development Managers	234	2.2	8,209	2.9
Agricultural and Forestry Scientists	234	2.2	6,393	3.7
Other Specialist Managers	208	2.0	32,928	0.6
Secondary School Teachers	202	1.9	118,675	0.2
Chief Executives and Managing Directors	132	1.3	46,432	0.3
Policy and Planning Managers	95	0.9	15,069	0.6
Other Education Managers	94	0.9	8,205	1.1
Intelligence and Policy Analysts	92	0.9	12,204	0.8
Other occupations	3,637	34.7	8,758,761	0.0
Total employed	10,512	100.0	9,104,187	0.1

Source: ABS, Customised 2006 Census matrix

Table 31: Main occupations (4-digit level) of employment among postgraduates in other natural and physical sciences, 2006

Occupation (ANZSCO)	*Other Natural and Physical Sciences*	*% Distribution of occupation among all Other Nat Phys Science PGs*	*Total all persons employed*	*% of all employed who have PG quals in this field*
Medical Laboratory Scientists	947	26.1	13,371	7.1
University Lecturers and Tutors	310	8.6	35,595	0.9
Natural and Physical Science Professionals, nfd	185	5.1	6,127	3.0
Professionals, nfd	176	4.8	24,197	0.7
Life Scientists	135	3.7	5,152	2.6
Other Specialist Managers	119	3.3	32,928	0.4
Research and Development Managers	100	2.8	8,209	1.2
Chemists, and Food and Wine Scientists	85	2.4	7,421	1.1
Other Natural and Physical Science Professionals	80	2.2	4,416	1.8
Generalist Medical Practitioners	61	1.7	35,452	0.2
Pharmacists	61	1.7	15,336	0.4
Secondary School Teachers	46	1.3	118,675	0.0
Management and Organisation Analysts	41	1.1	34,943	0.1
Other occupations	1,284	35.2	8,762,365	0.0
Total employed	3,630	100.0	9,104,187	0.0

Source: ABS, Customised 2006 Census matrix

Appendix B: Data sources and methodology

General notes

There are a number of terms used in this report that refer to the general group being studied that require some clarification. In particular it is important to detail the specific disciplines within the broad field of education that is being examined. There are also some other terms that, if defined at the outset, will make the interpretation of the findings of this report easier.

The ‘Natural and Physical Sciences’ is the broad field of education on which the bulk of this analysis is based. This field is broken into a number of sub-fields, which for the purpose of this report are referred to collectively as ‘disciplines’. Table 32 shows the Australian Standards Classification of Education (ASCED) code and label for the disciplines that have been used throughout this report. Note that ‘nfd’ stands for ‘not further defined’. In some parts of the report this discipline is referred to as the ‘nfd group’.

While most other discipline groups listed in Table 32 are self-explanatory, there is some need for elaboration on the ‘Other Natural and Physical Sciences’ field of education group. This group includes sub-groups of Medical Science (specifically biomedical science, medical biotechnology, but not medical practitioners), Forensic Science, Pharmacology, Food Science and Biotechnology, and Laboratory Technology. See the ABS ASCED Classification manual (ABS, 2001) for more detail on the field of education codes.

Table 32: Codes and disciplines within the natural and physical sciences

ASCED Code	*Discipline label*
0100	Natural and Physical Sciences, nfd
0101	Mathematical Sciences
0103	Physics and Astronomy
0105	Chemical Sciences
0107	Earth Sciences
0109	Biological Sciences
0199	Other Natural and Physical Sciences

The Census occupation data used in this report has been coded according to the Australian New Zealand Classification of Occupations (ANZSCO). In other sources, such as the Skilled Vacancies Index, the Overseas Arrivals and Departures Data and the Graduate Destinations Survey, the older Australian Standard Classification of Occupations (ASCO) is used. These two classifications align relatively closely but are not exactly comparable. However, in the natural and physical science profession fields, the terminology for the different occupations within the classifications are almost identical.

The occupational codes as specified in the Census data for this report are listed in Table 33. The occupations listed span a number of hierarchies within the overall occupation classification. These hierarchies and their codes are organised from the broad (one digit) level, which covers a range of aggregate occupations under the title of ‘professionals’, ‘managers’ etc., to the detailed (four digit) level that represents specific occupations within the broader aggregate levels. In Table 33, occupations are ordered in the same way they have been set out in the tables in this report, while this is not the most logical way to set out the hierarchies, it has been done this way in order to be consistent with the other tables. Note that the ‘Other Natural and Physical Science Professionals’ and the ‘Veterinarians’ codes have been combined in this specified data set. All other occupations that fall under the three-digit 234 ANZCO code for ‘Natural and Physical Science Professionals’ have been included as separate occupations in these tables.

Table 33: ANZCO codes, hierarchy and classification labels for occupations used in this report

Label	*Broad level (1 digit)*	*2-digit level*	*3-digit level*	*Detailed level (4 digit)*
Actuaries, Mathematicians and Statisticians				2241
Agricultural and Forestry Scientists				2341
Chemists, and Food and Wine Scientists				2342
Environmental Scientists				2343
Geologists and Geophysicists				2344
Life Scientists				2345
Medical Laboratory Scientists				2346
Other Natural and Physical Science Professionals and Veterinarians				2349 and 2347
University Lecturers and Tutors				2421
Engineering Professionals			233	
Health Diagnostic and Promotion Professionals			251	
ICT Professionals		26		
Other Professionals	Remainder of group 2			
Managers	1			
Technicians & Trades Workers	3			
Other occupation (including supplementary codes)	4,5,6,7 & 8			

Other definitional issues to take into account when reading the report are as follows. Throughout the report the strict definitional term ‘natural and physical sciences’ is used interchangeably with the term ‘science and mathematics’, it is meant that these two terms refer to the same thing. In addition, where the term postgraduate is used within this report, it refers to a person who has obtained a postgraduate qualification, rather than a person who is studying for a postgraduate qualification, unless otherwise specified.

A final general note is that many of the tables in this report present data in percentages. Please note that due to rounding, the aggregation of these percentages may not equal 100 exactly.

Data used

A range of data sources have been utilised in the analyses in this report. The following section lists the key data sets used, provides some information about each set including sources and collection method, and outlines any limitations that apply in interpreting and analysing the data from these sources.

Department of Education, Employment and Workplace Relations, Higher Education Collection – Course Completions, 2001 to 2006

The Department of Education, Employment and Workplace Relations (DEEWR) Course Completions files contain details relating to the qualification, field of education, institution and other individual characteristics of students who completed a higher education degree in an Australian university each year. For this report, data for completers between 2001 and 2006 have been used. In the source notes and text these data are referred to as 'DEST data' because they were collected by the Department when it was known as the Department of Education, Science and Training. These data are drawn from the administrative records provided to the department annually by each individual university. It is the most comprehensive national collection of higher education student information available and has been utilised in this research primarily to help quantify the supply of postgraduates in science and mathematics.

There are limitations in these data that relate to issues with most collections that are primarily formulated from administrative data sets. The reliability of the data is contingent upon the accuracy of reporting by each institution in Australia when they provide their statistics to DEEWR. While not specifically identifiable, it is likely that there are instances where the coding of certain variables is incorrect. Despite these possible problems, these incidents are likely to be rare and in the broad analysis of the data have little or no implications on analyses.

For the specific analysis undertaken in this report, the main limitations occur when the data are disseminated at the detailed discipline level. While the numbers are still large and the reliability is relatively robust, there is a need for caution in interpretation in these instances due to the fact that detailed fields of education can be coded differently by different institutions due to the nature of the way in which science and mathematics faculties are structured. In some cases, where two disciplines are closely interlinked within the one department, there may be occurrences where students are listed in the wrong discipline or where all students from the various mix of disciplines are simply coded as ‘not further defined’ or ‘other’.

Australian Bureau of Statistics, Census of Australian Population and Housing, 2006

For the purpose of this research, two Census data matrices have been specified and purchased from the Australian Bureau of Statistics (ABS). Together, these data sets allow fine-grain analysis of all Australian residents who have a postgraduate qualification in the natural and physical science fields. The Census was undertaken across the whole of Australia and data was collected on August 8, 2006. The data, including employment status and residential location, refer to an individual’s situation on that particular date.

Due to the comprehensive nature of this collection, there are fewer limitations with this data source than the others provided. One issue relating to the numbers displayed in the Census-based tables in this report is that they are drawn from matrices that have been confidentialised by the ABS. Thus for very detailed population parameters (cells that have only 1 to 3 cases), the cells provided in the matrix are given a random count of between 1 and 3. In order to limit the occurrence of this, the specifications made for the data sets for this project were carefully constructed to minimise the ‘cell count’ and therefore minimise the number of cells that were confidentialised. This is the reason why two separate data sets were purchased.

The other limitation of the Census data is that research and coursework postgraduates are not classified as a single group. This means that Masters by Research postgraduates, Masters by Coursework postgraduates and Doctorate postgraduates are all included in the Census data used in this analysis. While this is a limitation in that it broadens the scope to just outside the ‘higher degree research’ field, the reality is that there are very few masters by coursework postgraduates in the natural and physical sciences, so this joining of categories has little or no impact on the results.

Department of Immigration and Citizenship, Overseas Arrivals and Departures 2002–03 to 2006–07

Data from the Department of Immigration and Citizenship (DIAC) has been specified and obtained for this project in order to monitor and quantify the flow of professionals in science and mathematics occupations into and out of Australia. The data provided spans a five year period from 2002–03 to 2006–07. They contain details relating to the visa status, length of intended stay (or departure), age, occupation and country of birth. The data include flow from settler arrivals, long term resident returns, long term visitor arrivals, resident departures (permanent and long term) and long term visitor departures.

These data are collected by the immigration department from details recorded on incoming or outgoing passenger cards at Australian airports and sea ports. DIAC note that the data 'describes the number of movements of travellers rather than the number of travellers. That is, multiple movements of individual persons during a given reference period are all counted' (Department of Immigration and Citizenship, 2008). The reference period used for this particular data set is one financial year.

There are a number of limitations related to using these data. In general, the data set relies on the individual passenger to accurately record their details on the form. While the Census has similar problems, these issues are overcome by complex weighting and stratification processes, the DIAC data is not given this rigorous treatment. This means there are likely to be mistakes and misrepresentations in the coding of this data into the final data sets.

More specific to this project, the data collected by DIAC does not include a qualification identifier, and therefore it is not possible to specifically monitor the movement of postgraduates using this source. In using the data set, the analysis focuses strictly on those identifying themselves as professionals in the science and mathematics fields. While this aggregation does capture a number of people who most likely do not have a higher degree qualification, it does still allow indicative monitoring of the movement of highly skilled people in these science-specific occupations.

Graduate Careers Australia, Graduate Destinations Survey, 2007

Graduate Careers Australia (GCA) carries out a survey of all university course completers on an annual basis. This survey asks graduates and postgraduates details about their post-graduation pathways and about their course experiences. The 2007 survey has been used in this analysis. This survey is administered in October 2006 for those who completed their university course in first semester 2006, and April 2007 for those who completed their course in second semester 2006. Therefore, it is essentially capturing a picture of graduate outcomes four months after course completion. Each higher education institution in Australia manages their own survey administration and GCA compiles the final data centrally.

This is a large and detailed data set that provides nuanced information relating to transitions following completion of a university degree. However, like all surveys it has its limitations. The main limitation in this regard relates to response rates. Overall the 2007 GDS response rate was slightly above 50 per cent. Given the large number of responses (more than 115,000), this still provides a large cohort for analysing. However, for this research, the focus is on a small and specific group – higher degree graduates in the natural and physical sciences – which make up 3,600 responses. This means that more detailed dissemination of the data, as is carried out in this report, needs to be interpreted with the understanding that there are standard errors relating to the final figures (these standard errors are different in each table, but increase as more variables are included in the analysis).

Department of Education, Employment and Workplace Relations, Skilled Vacancies Index, 2008

The DEEWR Skilled Vacancies Index (SVI) is based on a count of job advertisements published in Australian newspapers and is published on a monthly basis. The data is collected and maintained by DEEWR staff. Figures from May 2001 to May 2008 have been extracted from the SVI data for use in this analysis.

The SVI is the most comprehensive, detailed and up-to-date collection of job advertisement data in Australia and has been used here because it provides occupational level figures. For this analysis the professional science and mathematics job advertisement figures have been used. The analysis includes using the DEEWR trended data from the SVI for this group as well as using the raw monthly state and detailed job advertisements data. In using the raw data, job numbers have been averaged over 12-month periods in order to provide a simpler picture of the change in demand for certain occupations over the 2001 to 2008 time series.

The SVI data has general limitations, in that it is a count of newspaper advertisements only and therefore provides an *indicative* picture of the size of demand in any individual occupation or groups of occupations. In addition, a specific limitation to this project exists in much the same way as it does in the DIAC data – there is no identification of qualification. This means that specific jobs requiring a higher degree cannot be identified in these data. As with the DIAC data, the analysis of the SVI has focused on professional science occupations only in order to form an indicative picture of the nature of demand for high-skilled workers, a number of which would have postgraduate qualifications.

Department of Education, Employment and Workplace Relations, Higher Education Staff Collection, 2002 to 2006

The DEEWR Staff higher education collection is similar in nature to the DEEWR Course Completions data, except that it contains information relating to the personnel employed by universities in Australia. As with the Completions data, in the source notes and text relating to the Staff collection, these data are referred to as 'DEST data'. For the purpose of this report, only those staff classified as 'academic' have been included in the analyses. The Staff files from 2002 to 2006 have been used in this report.

As for the Course Completions data, there are limitations in the DEEWR Staff files that need to be interpreted with the understanding that they are essentially administrative data files; they have been put together by each Australian higher education institution and merged into one collection by the Department.

For the analysis undertaken here using the Staff data collection, the key limitation to note relates to the dissemination of information at the detailed discipline level. The limitations discussion on the Course Completions data outlined the main reasons for this issue with the DEEWR collections generally. However, in the case of the staff file, extra caution is needed in interpreting the detailed discipline statistics. This is again related to the fact that the structure of science and mathematics faculties within Australian universities differ considerably and the administrative task of allocating each staff member is particularly difficult in cases where disciplines are closely enmeshed within departments or schools. Therefore, the majority of this analysis examines the Staff collection from the broad natural and physical sciences level. In the instance where these data are disaggregated to the discipline level, there is a warning relating to the limitations of interpretation.