Australian Government
Department of Innovation
Industry, Science and Research

Research Workforce Strategy

Discipline Case Studies

Note: These case studies have been compiled by the Department of Innovation, Industry, Science and Research. They consist of an analysis of extant data available at a given point in time and take account of the advice of several expert groups. Issues and ideas proposed in the case studies are not those of the Australian Government and should not be represented as such.

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Abbreviations

ABS	Australian Bureau of Statistics
ACDE	Australian Council of Deans of Education
ACER	Australian Council for Educational Research
AIHW	Australian Institute of Health and Welfare
AMSI	Australian Mathematical Sciences Institute
ANZSRC	Australian and New Zealand Standard Research Classification
APA	Australian Postgraduate Award
ARC	Australian Research Council
ASCED	Australian Standard Classification of Education
CRC	Cooperative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEd	Doctor of Education
DEEWR	Department of Education, Employment and Workplace Relations
DIISR	Department of Innovation, Industry, Science and Research
ERA	Excellence in Research for Australia Initiative
FOR	Field of Research
GDS	Graduate Destination Survey
GIS	Geographic Information Systems
GSM	General Skilled Migration
HDR	Higher Degree by Research
HECS	Higher Education Contributions Scheme
HEIMS	Higher Education Information Management System
IPRS	International Postgraduate Research Scholarship
MODL	Migration Occupations in Demand List
NHMRC	National Health and Medical Research Council
NSF	National Science Foundation
OECD	Organisation for Economic Co-operation and Development
PhD	Doctor of Philosophy
PMSEIC	Prime Minister's Science, Engineering and Innovation Council
R&D	Research and Development
RACI	Royal Australian Chemical Institute
RTS	Research Training Scheme
SOL	Skilled Occupation List
VET	Vocational Education and Training

1 Introduction

1.1 Background to and structure of case studies

This set of six discipline-specific case studies has been compiled to inform the development of a research workforce strategy for Australia.

The Australian Government outlined its intention to develop a research workforce strategy to cover the decade to 2020 in *Powering Ideas: An Innovation Agenda for the 21st Century*. The development of the strategy recognises a need to better position Australia to meet expected shortfalls in the supply of research qualified people and to address concerns regarding the availability of clear career paths for research students and the adequacy of the research training system in preparing them for varied career outcomes.

The purpose of the discipline-specific case studies is to understand variations in how these issues present at the level of individual disciplines. The six disciplines examined – chemical sciences, education, engineering, health, history and archaeology, and mathematical sciences – were selected by a high-level reference group established to support the development of the research workforce strategy. The disciplines were chosen for their capacity to identify a cross-section of issues and potential pressure points across the research workforce.

The Department of Innovation, Industry, Science and Research (DIISR) was assisted in developing the case studies by six expert groups (see **Appendix A**) chosen in consultation with the research workforce strategy reference group and the Learned Academies for their ability to provide strategic advice on the workforce issues faced by their particular discipline. DIISR also drew on a range of previously published reports and studies examining relevant issues (see **Appendix B**).

The quantitative elements of the case studies (Section 1 in each case study) were developed by DIISR and drew on several national and international data sets, including:

- The Department of Education, Employment and Workplace Relations (DEEWR) higher education statistics collection;
- Graduate Careers Australia data in relation to employment outcomes of Higher Degree by Research (HDR) graduates;
- Australian Bureau of Statistics (ABS) survey and census data (Census 2006 and cat. no. 8112.0 Research and Experimental Development, All Sector Summary);
- The Organisation for Economic Co-operation and Development (OECD) online statistical database;
- Thomson ISI, National Science Indicators database; and
- The Australian Research Council (ARC) Excellence in Research Australia (ERA) initiative results from the 2010 assessment exercise. ERA results and analysis for each discipline were supplied by the ARC.

These data sets by no means give a complete picture of each discipline's research workforce and need to be interpreted with caution.

For example, it is difficult to discern from available data the scale of supply for different disciplines through migration and the long term employment pathways of HDR graduates in different disciplines. Similarly, the snapshot provided by data across all areas examined is limited to information available at a set point in time; performance information is thus lagged and may not reflect emerging trends and issues. Finally, the comparability of data across different indicators, disciplines and OECD countries is limited by differences in the data coverage and the timing of data collection. For example, there are variations between what is captured in the classification of a discipline for the purposes of research expenditure and outputs compared to the field of study of an individual possessing, or undergoing training to qualify for, a HDR. Information may be collected at different points in time (see **Box 1**). Similarly, there may be differences in both the coverage and currency of Australian data relative to OECD countries reported on for comparison purposes.

DIISR's intention in presenting the data is thus not to paint a definitive picture of performance but rather to promote discussion of what factors may be of current or emerging relevance (either within individual disciplines or across all areas) and worthy of focus in future years.

Box 2 provides a guide to the interpretation of some of the key data and analysis presented. Further discussion is also provided in the text of each case study.

The qualitative elements of the case studies (Sections 2 to 4 of each case study) have been prepared by DIISR with the assistance of the expert groups listed at **Appendix A**. They are intended to complement the quantitative analysis with the insights of individuals possessing direct experience of issues impacting on each discipline at both national and institutional levels. Section 2 in each case study discusses key influence factors impacting on research workforce performance from the relevant expert group's perspective. Section 3 provides the expert group's assessment of the current and future outlook for the discipline's research workforce. Section 4 outlines the expert group's suggestions for how Australia can better position their discipline's research workforce in the future.

For the 'scorecards' (Section 3) of each case study, expert groups were asked to provide 'traffic light' scores assessing current and future performance of their discipline's research workforce against a set of key indicators. A combined scorecard across all the case studies is at Section 1.3[1] and provides a useful comparative visual guide to key strengths and challenges identified across the disciplines studied.

1.2 Overview of findings

This section presents an overview of the case study findings, structured by the categories reported against for the traffic light indicators. For more detail, refer to the relevant case study.

Quantity of supply through the research training system

(This criterion reports on the scale of supply to the research workforce arising from annual domestic and international student completions of HDR degrees in Australia)

[1] Given the considerable diversity of issues within the history and archaeology discipline grouping, two separate scorecards have been prepared for this case study.

The case studies outline stable growth in the supply of research skills through the research training system in some disciplines but particularly so in engineering. However there are indications that this trend may not continue in the future. In the case of mathematical sciences, chemical sciences and engineering, the expert groups reported concern over declining student engagement at all levels of the education pipeline and a diminishing 'stock' of qualified school teachers in mathematics, statistics and chemistry to support improved levels of engagement in future years.

Supply of HDR candidates in the science and engineering disciplines has been significantly fuelled by international students. However, all disciplines rely to a greater or lesser extent on international students to complement domestic supply, and there was concern across all expert groups that a range of issues may have a negative impact on Australia's ability to attract and retain a sufficient number of international students in future years. Issues which may have an impact include recent changes to migration arrangements, the level of support available to international students through schemes such as the International Postgraduate Research Scholarships (IPRS) program and intensifying global competition for the highly skilled.

Recent enrolment trends in the disciplines of education, history and archaeology are also concerning. For example, education consists largely of part-time students already well advanced in their existing careers, while the number of history PhD candidates has been declining over recent years. The history and archaeology expert group reported a number of factors leading to difficulty in recruiting quality HDR students to Australian universities, including a shortage of appropriate resources (both academic and infrastructure), and high demand for archaeology bachelor degree graduates from the heritage management and mining industries.

Quality of supply through the research training system
(This criterion reports on the abilities, skills and employability of Australian HDR graduates entering the research workforce in Australia.)

History, health, engineering and chemical sciences are presently performing well in terms of the quality of graduating HDR candidates, but expert groups reported concerns in the fields of mathematical sciences, education and archaeology. The challenges affecting the quality of the supply of researchers in the mathematical sciences were perceived to stem partly from the contraction of mathematics and statistics departments in universities, while a lack of necessary research infrastructure in archaeology departments was perceived as a negative influence on the quality of research workforce supply in the archaeology discipline.

Expert groups in most disciplines (with the exception of education) reported challenges in maintaining the quality of supply into the future. For example, the tendency for research and teaching activity to be dispersed across a number of schools and faculties within a university was seen to present a number of challenges to maintaining the quality of the HDR training environment and outputs in the mathematical and chemical sciences.

There was a general recognition across the discipline expert groups that high quality, employable HDR graduates require generic or transferable skills in addition to discipline-specific knowledge. Skills identified as in demand by both private and public sector employers include communication and teamwork (in particular the ability to work in large cross-disciplinary teams), project management, problem solving ability and commercialisation skills. Expert groups argued that the development of such skills was problematic, given the constraints of the current Australian Postgraduate Awards (APA) stipend, which allows for a maximum of 3.5 years for completion of a PhD. Many expert group members felt that this did not allow enough time for generic skills training as well as the rigorous in-depth subject specific training necessary for competence in a particular area.

In addition to difficulties in building required levels of generic or transferable skills, expert group members reported some difficulties in incorporating important discipline-specific skills such as language training (for historians) and statistical skills (for education researchers) into research training programs.

Research workforce equity

(This criterion reports on equity issues across the research workforce.)

The key issue identified across the case studies in relation to research workforce equity was gender inequality.

In disciplines such as chemical sciences and health, expert group members reported particular difficulties faced by female researchers in combining a research career with family responsibilities. Even where female researchers are not lost to the system, the expert groups reported that extended breaks and/or periods of part-time work could have severe and sometimes long-term negative impacts on their careers.

The research workforce supply in engineering and mathematical sciences is currently characterised by a significantly greater proportion of males than females. However a recent trend towards increased enrolments of female PhD candidates, particularly in mathematics, indicates that the gender gap may be narrowing.

In contrast, education, health, history and archaeology are characterised by greater numbers of female than male HDR candidates, however this trend may not extend to the later stages of career progression.

Research workforce shortfalls

(This criterion reports on current and anticipated unmet demand for researchers and for specific research skill sets.)

Despite difficulties in measuring employer demand and demonstrating existing and future pressure points where the supply of HDR qualified researchers is likely to fall below demand, the expert groups all reported concerns in relation to the capacity for current levels of supply to meet demand in the future.

In several cases (for example, health, mathematical sciences and engineering) the root cause of a mismatch between supply and demand was perceived to be the loss of potential researchers to the high salaries of positions in private practice/industry.

Specific skills shortages reported are discussed in the relevant case study.

Employment prospects

(This criterion reports on the ability of HDR graduates to find employment in their chosen field.)

All discipline expert groups (with the exception of history) rated employment prospects within their discipline as good, both currently and into the future. High levels of employer demand in many fields, coupled with slow growth in commencements and completions in HDRs in particular were perceived as likely to contribute to the continuation of positive employment prospects for graduating HDR students for some time.

History experts were less positive about employment prospects within the discipline, noting that history doctorates who obtain academic positions were now a minority within their discipline cohort.

Research career pathway support

(This criterion reports on the adequacy of current researcher career support)

All discipline expert groups reported a need for improved support for researcher career pathways. Key issues identified included, among others, a lack of a clear or defined career pathways [with the notable exception of public sector research agencies such as the Commonwealth Scientific and Industrial Research Organisation (CSIRO)]; a lack of knowledge or understanding of available career opportunities; and difficulty in transitioning to a career as a fully fledged researcher.

The expert groups also reported that barriers to mobility have a negative impact on researcher careers. In particular, high remuneration differentials between the public and private sectors, the need for a high volume, consistent publication record for public sector employment (and conversely limitations on publication in the private sector due to commercial and intellectual property sensitivities) were felt to deter mobility, limiting skills and capability enrichment and the development of networks which could contribute to more productive research careers.

A further, related impediment to mobility cited by expert groups was the difficulty in returning to a research career after an employment break, particularly in view of the impact of a protracted break in publication record on the ability to attract ARC or National Health and Medical Research Council (NHMRC) competitive grants. As noted in the equity section, researchers with family obligations, particularly women, are affected by this issue.

General points

Overall, the case studies identify some areas of significant variation across different disciplines. For example, the nature of the HDR student cohort differs markedly between the disciplines examined with respect to gender, age, training needs and primary modes of study among other areas. Similarly employment destinations differ across disciplines for HDR graduates.

These differences – if verified across a wider discipline base – highlight the importance of careful examination of discipline-specific issues and needs in policy design and implementation to ensure that measures are effective across the full research workforce.

BOX 1: Guide to the scope of case studies

In all but one of the six case studies (health being the exception) the scope of the discipline (and hence data collected and analysed) has been determined by the respective divisions in the ABS Australian and New Zealand Standard Research Classification (ANZSRC). All data used in the case studies sourced from the ABS can be assumed to be compatible with ANZSRC.

Almost all data and analysis relating to HDR candidates has been sourced from DEEWR's *Higher Education Information Management System* (HEIMS) and this data is compatible with the ABS *Australian Standard Classification of Education* (ASCED).

The two classifications are not directly comparable, but for some purposes, including for five of these discipline case studies, a concordance can be constructed to allow data based on different classifications to be compared, with varying degrees of accuracy.

In the case of engineering and education, the two classifications are sufficiently similar to allow very good concordance. In history and archaeology and mathematical sciences there is a small problem with the 'level' at which data is available, affecting the amount of detail in the data sourced from HEIMS. For chemical sciences, a workable concordance has been constructed to ensure reasonable data compatibility. In the health discipline, there is no viable concordance between ANZSRC and ASCED, so data relating to 'health' from HEIMS and to 'medical and health sciences' from the ABS are not compatible.

The degree to which data from the OECD and Graduate Destination Survey (GDS) are compatible with that from ABS and HEIMS is difficult to estimate in the absence of detailed specifications for their collections

BOX 2: Guide to interpretation of key data presented in the case studies

Academic staff are:
1) People for whom salaries are the subject of determinations made by the Industrial Relations Department or Remuneration Tribunal in respect of ‘academic and related staff’.
2) People who are referred to in Section 12A (1) of the Remuneration Tribunal Act 1973).
3) People who are employed on a contract basis to perform the function of teaching-only, research-only or teaching-and-research, even though their remuneration is not subject to the determination of the Industrial Relations Department or the Remuneration Tribunal. See academic classification from DEEWR Higher Education Staff Data Collection.

The **Census measure of Doctorate holders** estimates the number of research qualified individuals in the Australian population includes those who hold a research-based qualification (usually a PhD), holders of higher doctorates (awarded for lifetime achievement in a field, not necessarily for research) and holders of largely coursework based professional doctorates.

HDR enrolment numbers refer to the numbers of PhD or Master degree by research candidates that have been admitted to the HDR program and have not formally indicated that they have withdrawn from or deferred their studies before the census date. A full-time student has an aggregated student load of 0.75 or more for all the courses being undertaken while a part-time student has an aggregated student load of less than 0.75 for all the courses being undertaken.

HDR completion numbers refer to the numbers of PhD or Master degree by research candidates that completed all the academic requirements of the HDR program in the given year. In the case of HDRs, completion is when the thesis or portfolio is approved by the examiners, and may be some time after the candidate’s last official enrolment.

HDR commencement numbers refer to the numbers of PhD or Master degree by research candidates that commenced in the program for the first time between 1 January and 31 December of the current year.

HDR time to complete is calculated as the elapsed time (in years) that the PhD or Masters degree by research candidates took to complete their qualifications. For example, if the PhD candidate commenced in 2002 and completed all the requirements of the program in 2006, it took four years for the PhD candidate to complete the course.

Research and development expenditure corresponds to all expenditure incurred by businesses, higher education, state and territory governments, profit and non-profit organisations in undertaking research and development (R&D), comprising creative work undertaken on a systematic basis to increase the stock of knowledge and the use of this knowledge to devise new applications.

Graduate destination survey results presented in each case study (when available) include information on employment destinations, nature of employment (i.e. full time or part-time) or activities (i.e. full-time study) and starting salaries of the HDR graduates who have recently completed their qualifications. The data is collected in April/May and September/October of each year, around 1 to 6 months after completion of the requirements of students' courses of study.

Research Training Scheme eligible candidates include New Zealand citizens. This departs from the usual definition of **domestic students** which excludes New Zealanders until they are granted Australian permanent residence status.

ERA assesses research quality within Australia's 41 higher education providers using a combination of indicators and expert review by committees comprising experienced, internationally-recognised experts. Evaluations are informed by four broad categories of indicators: Indicators of research quality (ranked outlets, citation analysis, ERA peer review, and peer-reviewed Australian and international research income), Indicators of research volume and activity (total research outputs, research income and other research items), Indicators of research application (research commercialisation income, plant breeders’ rights, patents, registered designs and NHMRC-endorsed guidelines) and Indicators of recognition (including a range of esteem measures).

1.3 Research workforce score-cards

		Quantity of supply through the research training system	Quality of supply through the research training system	Research workforce equity	Research workforce shortfalls	Employment prospects	Research career pathway support		Quantity of supply through the research training system	Quality of supply through the research training system	Research workforce equity	Research workforce shortfalls	Employment prospects	Research career pathway support
CURRENT	**Chemical Sciences**	Green	Green	Amber	Amber	Green	Red	FUTURE	Red	Amber	Amber	Red	Green	Red
	Education	Amber	Amber	Amber	Amber	Green	Red		Red	Green	Amber	Red	Green	Red
	Engineering	Green	Green	Amber	Amber	Green	Amber		Amber	Amber	Amber	Red	Green	Red
	Health	Amber	Green	Amber	Amber	Green	Red		Red	Amber	Amber	Amber	Green	Red
	History	Amber	Green	Amber	Amber	Amber	Red		Amber	Amber	Amber	Amber	Amber	Red
	Archaeology	Amber	Amber	Green	Amber	Green	Amber		Red	Amber	Green	Red	Green	Amber
	Mathematical sciences	Amber	Amber	Amber	Red	Green	Amber		Red	Amber	Amber	Red	Green	Amber

Legend:

Green	Green (performing well/stable/positive outlook)	Amber	Amber (some challenges/weaker than expected performance)	Red	Red (poor performance/area (s) of concern/significant challenges)

2 Chemical Sciences

For the purposes of this case study, the definition of 'chemical sciences' corresponds to that outlined in Division 3 of the *Australian and New Zealand Standard Research Classification* and includes analytical chemistry, inorganic chemistry, macromolecular and materials chemistry, medicinal and biomolecular chemistry, organic chemistry, physical chemistry (including structural), theoretical and computational chemistry, and other chemical sciences (including organometallic chemistry, environmental chemistry, atmospheric chemistry, and forensic chemistry). It is acknowledged, however, that not all issues will be applicable to these areas equally.

2.1 How is Australia tracking?

The following areas have been selected for analysis:

- The scale of the chemical sciences research workforce in Australia – PhDs (and to some extent Masters by Research) in the workforce;
- The chemical sciences research environment in Australia – research and development expenditure and ERA 2010 results;
- Supply to the chemical sciences research workforce – HDR completions in Australia and long-term or permanent migration; and
- Demand for chemical sciences researchers – employability and remuneration.

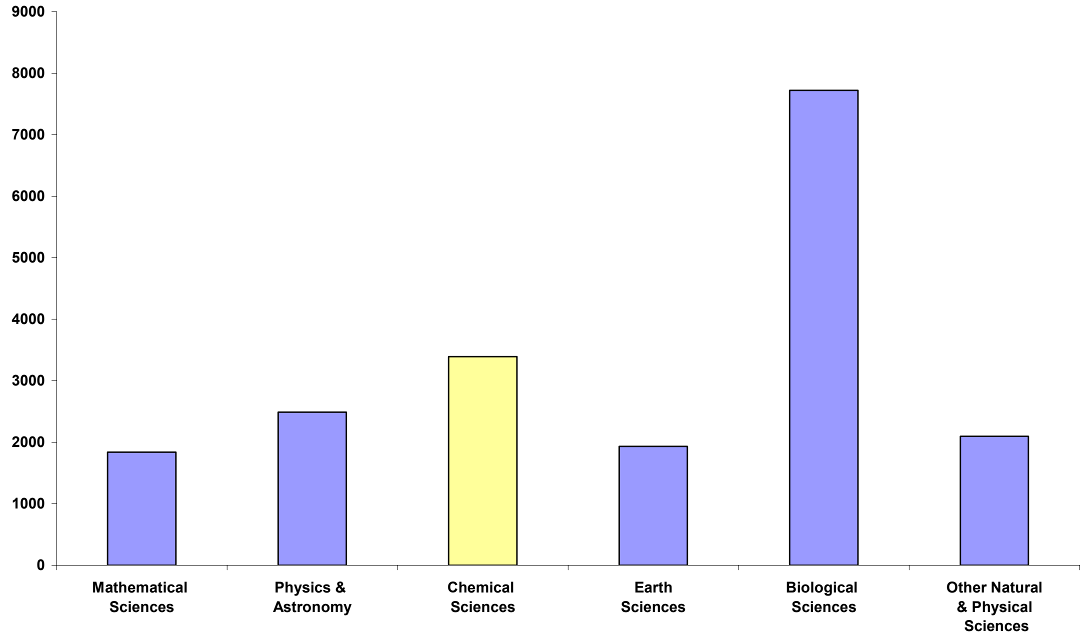
2.1.1 The chemical sciences research workforce and its research environment

PhD qualified individuals in the workforce

Key Points

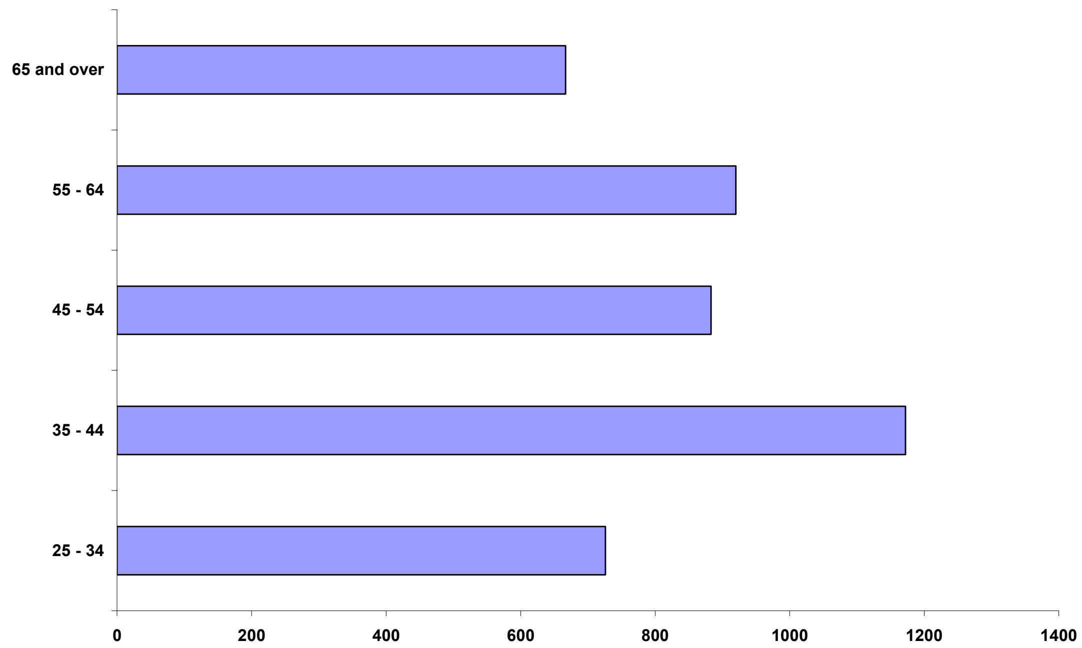
- *The number of individuals in the workforce with a chemical sciences HDR qualification gives an indication of the scale of Australia's research human capital in the discipline (i.e. our capacity for research in this discipline).*
- **Figure 1** indicates that chemical sciences PhDs represent approximately 4.7 per cent of Australia's PhD workforce in 2006. The relatively small number of chemical sciences PhDs compared to disciplines such as biological sciences (10.6 per cent) may be influenced by Australia's industry structure – in particular, the scale of the chemical and pharmaceutical industries. An Australian Council for Educational Research (ACER) study conducted for DIISR in 2009 projected that the chemical sciences PhD workforce will grow by over 38 per cent by 2020.
- According to ABS 2006 Census data, the top employment sectors of chemical sciences PhDs in 2006 were education and training, public administration, professional, scientific and technical services (excluding computer system design and related services). Data limitations make it difficult to establish how many of these individuals are research active or to make cross-country comparisons.
- Within the university sector, a study by Graeme Hugo (2008) indicates a relatively low proportion (39.5 per cent) of academic staff in the chemical sciences discipline were in the age bracket of 50 years and over in 2006, compared to other disciplines – for example, in the mathematical sciences (52.7 per cent).
- Analysis of the 2006 Census data indicates that the largest proportion of persons with doctoral level qualifications in chemical sciences was in the 35-44 age bracket (**Figure 2**).
- Chemical sciences academic units within universities experienced 19.5 per cent growth in academic staff numbers over the period 2002 to 2007 (Edwards and Smith, 2010).

Figure 1: Number of Doctorates Employed, by Field of Education, 2006



Source: ABS Census of population and housing 2006, special tabulation.

Figure 2: Age of Doctorates, Chemical Sciences, 2006



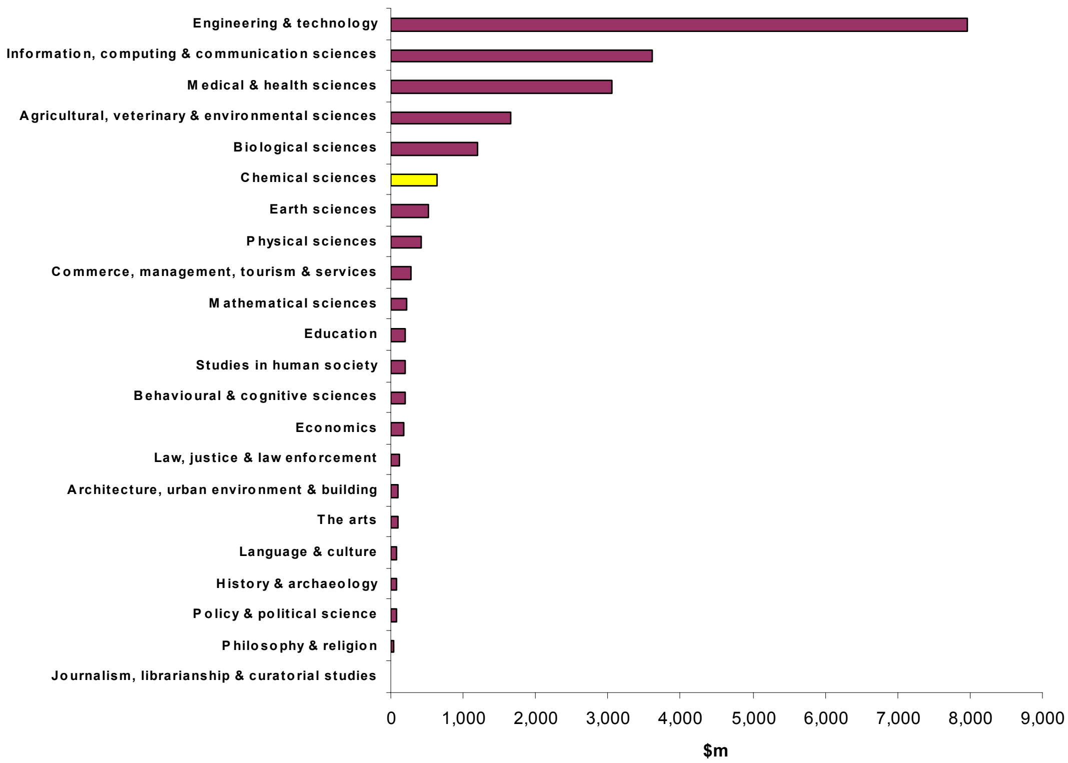
Source: ABS Census of population and housing 2006, special tabulation.
Note: Doctorates aged 15-24 years are excluded due to very low numbers.

R&D expenditure on the chemical sciences

Key Points

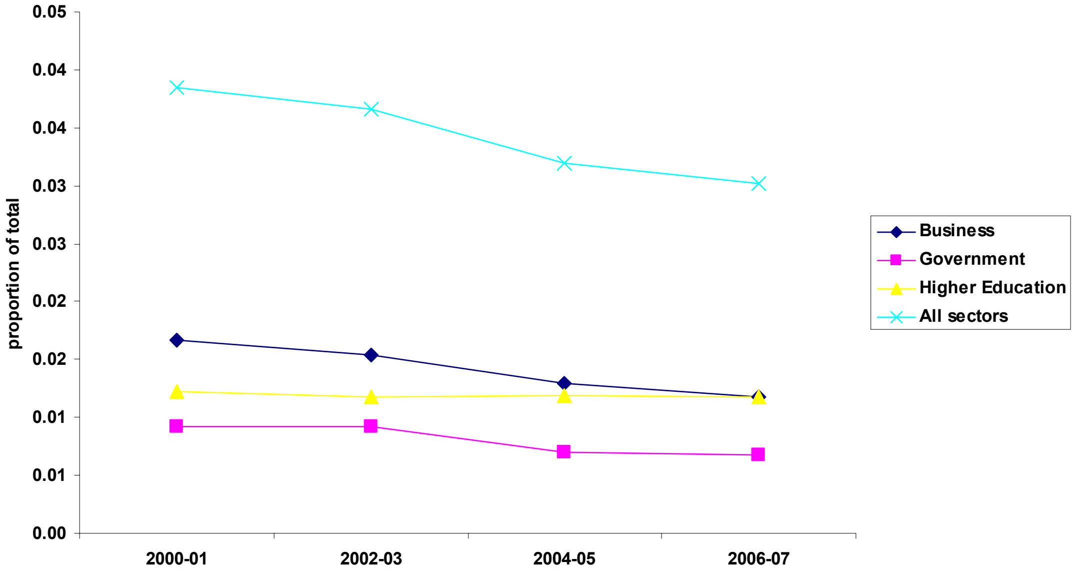
- *The scale of the research workforce in chemical sciences is likely to be influenced by a number of factors. Investment is a particularly important factor, as it influences the demand for research staff in different sectors of the economy (business, government, universities, not-for-profit organisations, etc)*.
- Data from the ABS on expenditure on R&D in the field of chemical sciences stood at $635 million (about three per cent of the total R&D expenditure) in 2006-07.
- Chemical sciences ranked number six in terms of R&D expenditure by field of research in 2006-07 (**Figure 3**). This figure ranks expenditure against all major fields of research as identified by the ABS in accordance with international practice. R&D expenditure in chemical sciences has declined as a share of total R&D expenditure, from 3.85 per cent in 2000-01 to 3.02 per cent in 2006-07.
- R&D expenditure in chemical sciences is performed mainly in the business and the higher education sectors (**Figure 4**).

Figure 3: R&D expenditure by field of research, 2006-07



Source: ABS cat. No. 8112.*0 Research and Experimental Development, All Sector Summary, 2006-07.*
Note: The major sources of funds for R&D expenditure were from the Commonwealth Government, state and territory governments, business, overseas and other Australian sources.

Figure 4: Chemical sciences share of total R&D expenditure by performing sector



Source: ABS cat. No. 8112.*0 Research and Experimental Development, All Sector Summary* 2006-07.
Note: The *All sectors* figure includes expenditure on R&D performed by the private non profit sector as well as the business, government and higher education sectors.

ERA 2010 results for Chemical Sciences

The ERA 2010 results show that in the Chemical Sciences field, 26 higher education institutions were assessed at the broad two-digit level with a national rating of 3.5. Two institutions are performing well above world standard (a rating of 5). Nine institutions are performing at above world standard (a rating of 4) and 15 institutions are performing at world standard (a rating of 3).

At the specific four-digit level, Australia is performing well in the following areas:

- Theoretical and Computational Chemistry with an average rating of 4.5
- Macromolecular and Materials Chemistry with an average rating of 4.1

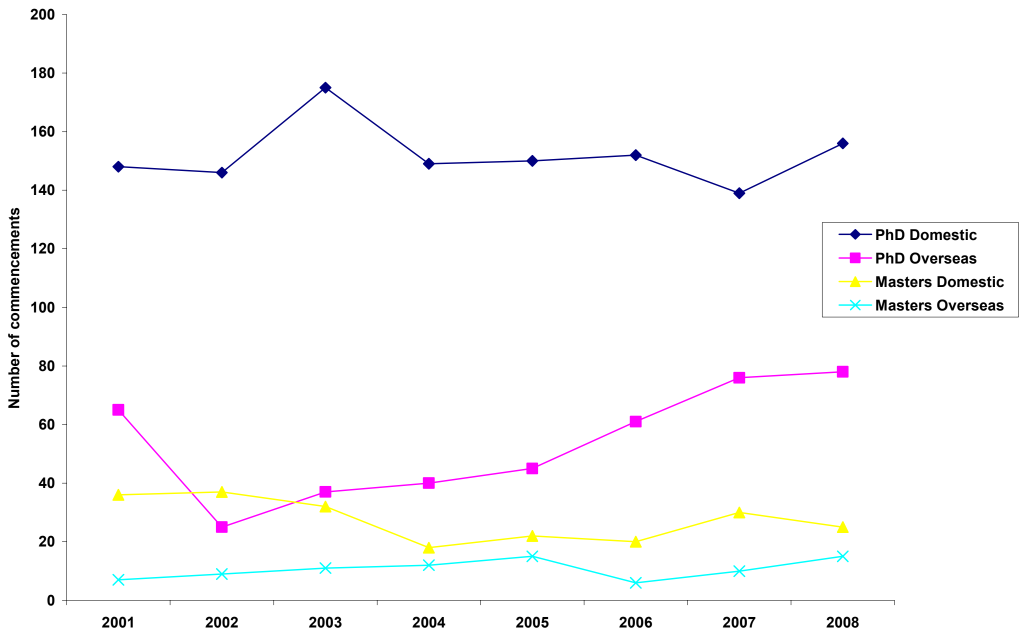
2.1.2 Supply to the chemical sciences research workforce

HDR commencements and completions

Key Points

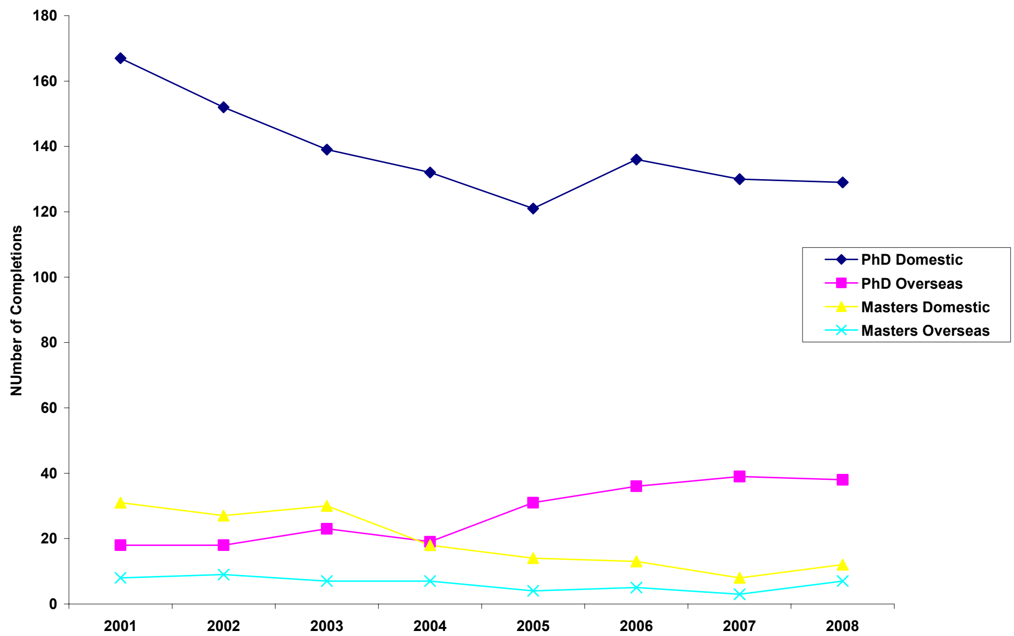
- *With respect to inflows of chemical sciences HDR skills, the primary source is Australia's research training system in the form of completions of domestic and international Doctorate by Research and Masters by Research students.*
- *Examination of historic trends of both commencements and completions provides a gauge (in combination with graduate destination surveys and migration data) of the pipeline of HDR skills that can be expected to be available to the research workforce in future years.*
- **Figure 5** shows that domestic PhD commencements in chemical sciences have remained relatively constant over recent years, while overseas PhD commencements have demonstrated a strong upward trend. In 2008, PhD commencements in chemical sciences represented 2.52 per cent of all PhD commencements for all disciplines. Masters by Research commencement numbers (including overseas students) declined from 2001 and 2006, however they appear to have levelled off from 2007 to 2008.
- **Figure 6** shows that domestic PhD completions in chemical sciences have slowly trended downward over time (most markedly over 2001 to 2005), with a decline of 23 per cent over 2001-2008, while overseas PhD completions have trended upward, increasing by more than 100 per cent over 2001 to 2008. Generally, Masters by Research completions in the chemical sciences have declined over time, in line with a general cross-disciplinary trend towards a decline in the Masters by Research qualification.
- **Figure 7** indicates the size of the commencing chemical sciences PhD cohort in comparison to other disciplines in natural and physical sciences. PhD commencements in chemical sciences appear to be maintaining a similar growth in comparison to most natural and physical sciences fields (with the exception of the 'other natural and physical sciences' category, which has been growing faster than other fields within this disciplinary group). In 2001, PhD commencements in chemical sciences accounted for l5 per cent of all PhD commencements in natural and physical sciences. In 2008, it was 12 per cent.
- **Figure 8** shows the size of chemical sciences PhD completions in comparison to other disciplines in natural and physical sciences. The proportion of PhD completions in chemical sciences stood at 12 per cent of all PhD completions in natural and physical sciences in 2008, compared to 16 per cent in 2001.

Figure 5: Chemical sciences HDR commencements, 2001-2008



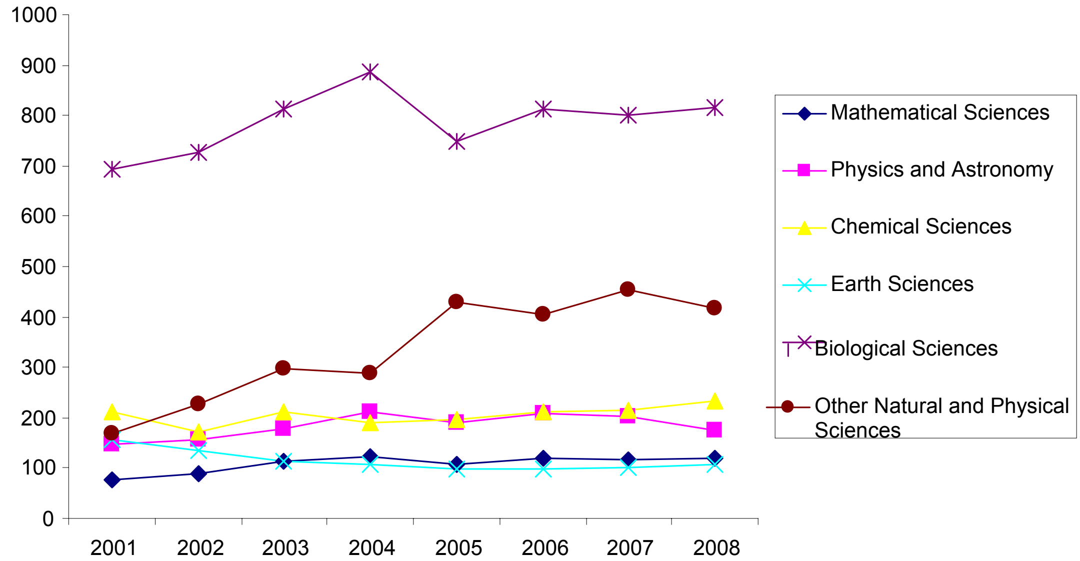
Source: DEEWR University statistics, unpublished data.

Figure 6: Chemical sciences HDR completions, 2001-2008



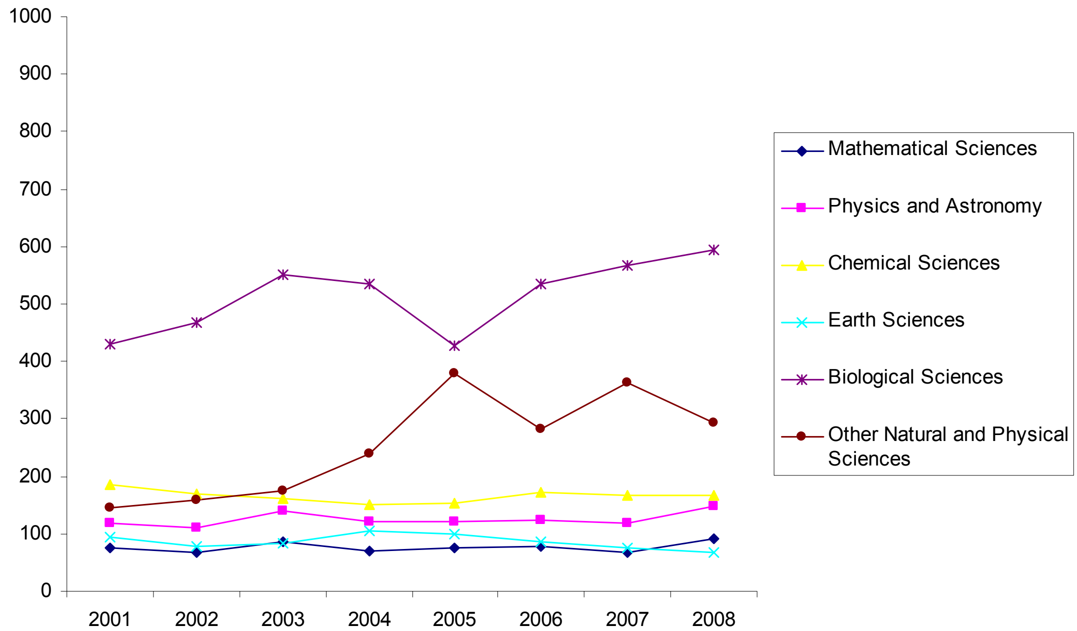
Source: DEEWR University statistics, unpublished data.

Figure 7: Comparison of HDR commencements in the natural and physical sciences, 2001-2008



Source: DEEWR University statistics, unpublished data.
Note: Other Natural and Physical Sciences includes Medical Science, Forensic Science, Food Science and Biotechnology, Pharmacology, Laboratory Technology and Natural and Physical Sciences, not elsewhere classified (n.e.c.).

Figure 8: Comparison of HDR completions in the natural and physical sciences, 2001-2008



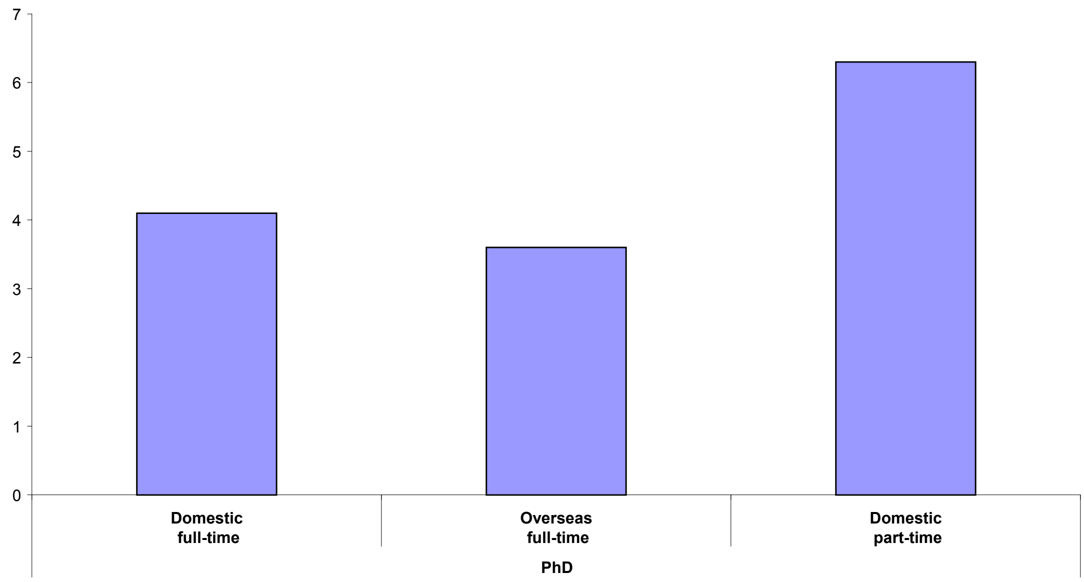
Source: DEEWR University statistics, unpublished data.
Note: Other Natural and Physical Sciences includes Medical Science, Forensic Science, Food Science and Biotechnology, Pharmacology, Laboratory Technology and Natural and Physical Sciences, not elsewhere classified (n.e.c.).

HDR time to complete

Key Points

- *The time taken to complete HDR studies and mode of study (full-time versus part-time status) provides an indicator of the efficiency of the pipeline from research training to the workforce.*
- **Figure 9** indicates that, on average, domestic full-time chemical sciences PhDs complete in 4.1 years (the same as the average for PhD candidates across all fields) while domestic part-time PhDs complete in 6.3 years (compared to 6 years, on average, for domestic part-time candidates across all disciplines) in 2008.
- The majority of domestic students that completed their PhDs in chemical sciences in 2008 were in full-time study in 2008 (85 compared to 44 students in part-time study).
- Examination of the data reveals that part-time students in chemical sciences are concentrated in a small number of institutions. Part-time status may reflect a range of factors, including arrangements where students are concurrently working in the institution or local industry or where students have changed their status to accommodate periods beyond their scholarship support and/or thesis write up.
- Overseas PhD candidates that completed their studies in chemical sciences in 2008 were all in full-time study in 2008 and, on average, completed their studies in 3.6 years.

Figure 9: Chemical sciences HDRs average time to complete, 2008



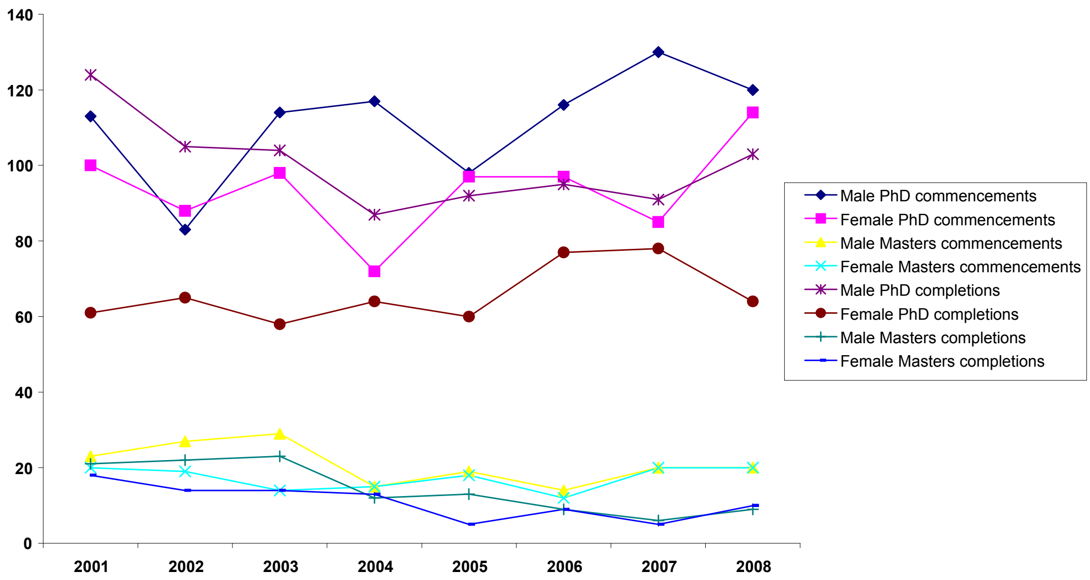
Source: Published and unpublished DEEWR Unistats data.
Note: Domestic and overseas Masters students are not included, as the sample size is too low.

Demographic data – commencements and completions by age and gender

Key Points

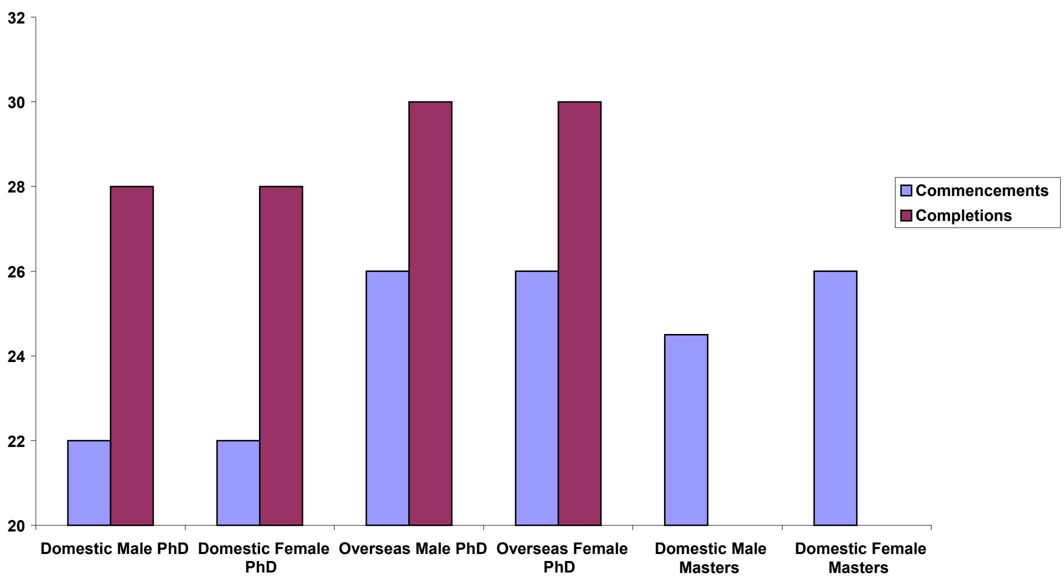
- *The age of chemical sciences HDR students provides a useful (but not conclusive) gauge of the potential workforce contributions of graduates, while gender may reveal any persistent inequalities in participation in HDR degrees between genders.*
- There were more male than female candidates commencing PhD and Masters by Research studies in chemical sciences in 2008. However, a sharp increase in female commencement numbers from 2007 to 2008 (34% increase) suggests that the number of females commencing chemical sciences PhDs is on the rise.
- Gender differences are more pronounced in PhD completions than in commencements. For example, while 51 per cent of commencing PhD candidates were male and 49 per cent were female, 62 per cent of male candidates and 38 per cent of female candidates completed their PhDs in 2008. No significant gender difference was observed in Masters by Research commencements and completions (**Figure 10**).
- **Figure 11** shows that chemical sciences HDR students tend to be younger than students in other fields of education. In 2008, the median age of domestic PhD commencing students in chemical sciences was 22 years while the median age of domestic PhD commencing students in other natural and physical sciences was 24 years. Similarly, the median age for a completing domestic PhD chemical student was younger at 28 years compared to the median age of domestic PhD completion for other natural and physical sciences at 32 years.
- Overseas PhD students in chemical sciences were slightly older than the domestic cohort. The median age for commencing overseas PhD candidate was 26 years for male and 25 years for female. Similarly, overseas PhD candidates complete their studies at a slightly older age than their domestic counterparts. On average, overseas PhD candidates complete at 30 years.

Figure 10: Chemical sciences commencements and completions by gender, 2001 to 2008



Source: Published and unpublished DEEWR Unistats data.

Figure 11: Median ages of commencing and completing chemical sciences HDRs, 2008



Source: Published and unpublished DEEWR Unistats data.
Note: Overseas Masters students and domestic Masters completions are not included as the sample size is too low.
The chart shows median ages for two different cohorts – those that commenced and completed their HDRs in 2008.

Supply through migration

Key Points

- *A further key source of supply of chemical sciences HDR-qualified individuals to Australia is through both temporary and permanent migration.*
- *While available data make it difficult to discern the scale of supply for the chemical sciences through migration, previous studies (ACER, 2009) have estimated that approximately 22 per cent (including international students staying on in Australia following completion of their studies) of Australia's overall supply of HDR skills is achieved through this source.*
- Chemists can currently migrate to Australia under a number of visa classes in the general skilled migration scheme. Within the general skilled migration program, chemists can apply under the Skilled Occupation List (SOL) Schedules 1, 2, 3, and 4. As a result, chemists are eligible to apply under the Employer Nomination Scheme and State Sponsored Scheme. For example, the Western Australian Skilled Migration Occupation List (WASMOL) identified chemists as one of the skilled occupations in high demand in various industries in Western Australia.
- While quantification of the scale of supply of chemical sciences PhDs to the workforce from international sources is limited by the granularity of data collected, analysis of data showing those born overseas as a proportion of all chemical sciences PhDs suggests that international sources may be highly significant in maintaining Australia's base of chemical science researchers.

Note: SOL Schedule 1 applies only to General Skilled Migration (GSM) applicants who lodged their application prior to 1 July 2010. SOL Schedule 2 applies to previous visa holders or those who applied for skilled independent work visas before 8 February 2010 and who are now applying for new work visas. This includes those who held student visas as of 8 February 2010 and may submit their applications until 2012. SOL Schedule 3 applies to all new GSM applications, including applicants eligible for transitional arrangements. SOL Schedule 4 applies to visa applicants sponsored by state or region to work in Australia.

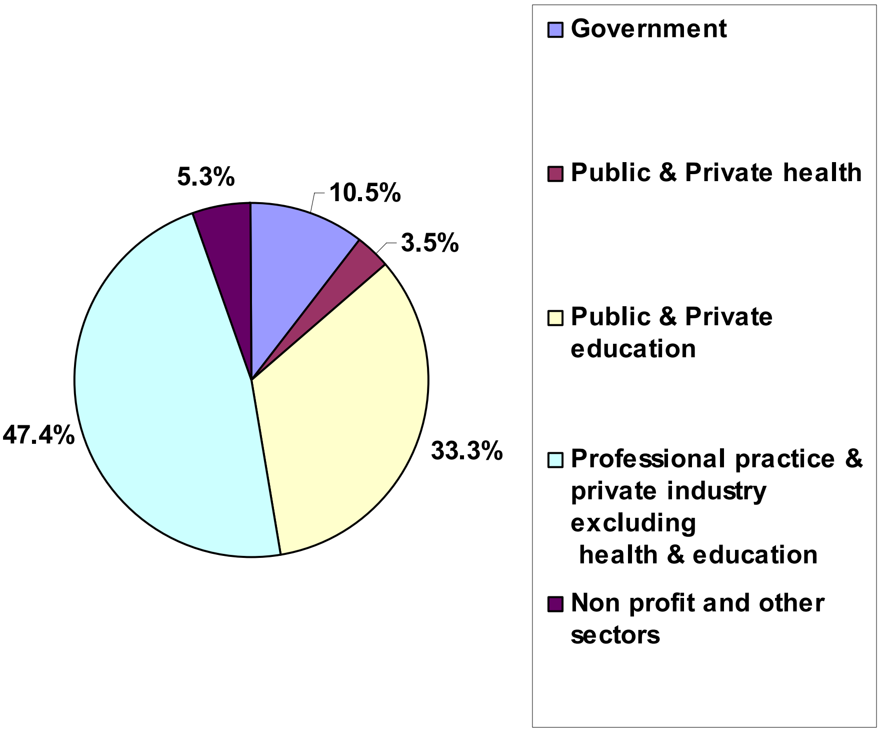
[2] Applicants who have a skill listed on the Western Australian Skilled Migration Occupation List (WASMOL) may be eligible to apply for Western Australian State Migration Sponsorship. Copy of the Western Australia Skilled Migration List can be downloaded from: http://www.dtwd.wa.gov.au

2.1.3 Demand and career prospects for chemical sciences researchers and HDRs

Key Points

- *The immediate employment outcomes (employability and sector of employment) of chemical sciences researchers and HDR graduates gives a sense of employer demand for research skills in this area. Graduate reflections on their preparedness for employment additionally provide a gauge of any mismatch between experience and skills garnered through research training and subsequent employment needs.*
- According to the Grads Online database (a graphical presentation tool based on the 2007 GDS), recent chemistry HDR graduates (4 to 6 months out from submission of a thesis) were most likely to be employed in the private sector, which includes professional practice and private industry, in 2007 (**Figure 12**).
- According to the 2008 GDS, participating chemistry HDR graduates had starting salaries of around $59,000 on average. By way of comparison, HDR graduates in mathematics had starting median salaries of about $63,500. However, these comparative figures should be interpreted with caution as the median salary rankings by field of education have not been stable for research Masters/PhD graduates across years. This is partially due to the small number of cases available for analysis in some fields and partially because salaries at this level of award are less divergent than is the case for the other postgraduate award levels. In the case of chemistry, there were 56 valid responses to the survey, representing 2.8 per cent of the total valid responses.
- The 2008 GDS results also indicate that almost 87.6 per cent of chemistry HDR graduates were employed full-time; 4.5 per cent were in full-time study; 1.1 per cent in part-time or casual employment and not seeking full-time employment; and 6.7 per cent were unavailable for full-time study or full-time employment. By way of comparison, 70.2 per cent of mathematics HDR graduates were employed full-time; 6.4 per cent were in full-time study; 12.8 per cent in part-time or casual employment and not seeking full-time employment; and 10.6 per cent were unavailable for full-time study or full-time employment.
- Responses to the 2008 GDS indicate that the majority (77.2%) of chemistry HDR graduates considered their HDR qualification a formal requirement or important to their job – percentages significantly above the average across all disciplines (72%).

Figure 12: Employment destinations of full-time employed chemists HDR graduates, by industry sector, 2007



Source: Grads online database of the Graduate Careers Council of Australia Ltd.
Note: Chemistry is used as a proxy indicator in the absence of chemical sciences as fields of study.
Note: Government includes federal, state and local government; Health includes private and public hospitals and other related organisations.

2.1.4 Summary points

Taken together, the quantitative trends examined in this case study suggest the following:

- Australia's chemical sciences doctorate-qualified workforce represents a small (about 4.7%) component of Australia's total doctorate-qualified workforce in 2006 census data, concentrated mainly in education, public administration and professional, scientific and technical services (except computer system design and related services).
- Within the university sector, academics in chemical sciences in 2006 had a younger profile than many other disciplines with only 39.5 per cent of all staff aged 50 years or more (compared, for example, to mathematical sciences with 52.7 per cent of academic staff aged over 50). More broadly, the 2006 population of PhD qualified individuals who gained their qualification in chemical sciences was comparatively younger than most other disciplines, with most PhDs in chemical sciences being in the 35-44 year age bracket.
- Despite the fact that R&D expenditure in the chemical sciences represented only three per cent of Australia's overall R&D expenditure in 2006-07, chemistry's research output was above the world average for relative impact measure over 2004 to 2008, indicating a strong capability within the Australian chemical sciences research workforce.

- Australia's supply of chemical research skills through the research training system from domestic students has declined significantly in recent years. Growth in international student numbers is positive, however, and over time may help to offset domestic trends, if a proportion of these international students stay in Australia and join the workforce following the completion of their studies.
- On average, chemical sciences HDR candidates commence their courses at an earlier age (22 years) than most other disciplines and finish their studies after 4 years in full time study or 6.3 years in part-time study. This has positive implications for their potential research workforce contributions, if graduates can be drawn into active research roles.
- Employment prospects of chemical sciences HDR graduates appear positive, with the private sector being the most common immediate employment destination of graduates in 2007. Responses from the Graduate Destination survey in 2008 reveal that almost 88 per cent of chemistry graduates found jobs in full-time employment with a median salary level reported at $59,000 annually. In comparison, 70 per cent of mathematics graduates found jobs in full-time employment with a median salary of $63,500 per year.

2.2 What are the key influence factors (current and future)?

Pipeline issues

The expert group members were of the view that chemistry as a science is underrepresented throughout the K-10 National Science Curriculum, resulting in poor awareness of chemistry and associated career opportunities at this critical formative stage of student's educational development. Moreover, the 2005 report by the Royal Australian Chemical Institute (RACI)[3] noted that many primary and secondary teachers are not adequately qualified to teach science, including chemistry; a finding echoed by the expert group. Weak awareness of career opportunities and poor teaching environments were also considered by the expert group to be contributing to the declining uptake of chemistry studies at subsequent levels of higher education.

Members of the expert group suggested that public attitudes to chemistry may be one factor inhibiting entry into chemistry courses, expressing concern that in the minds of many people, chemistry, particularly industrial chemistry, is associated with widespread concern over issues such as industrial pollution and the toxicity associated with chemicals.

The declining profile of chemistry as an individual discipline

The expert group agreed with the findings of the 2005 RACI report[4] that university chemistry schools now rarely stand as separate units but are increasingly becoming part of integrated multidisciplinary departments comprised of schools of science, engineering, medicine, etc. The group noted that as a result of this issue, chemistry departments teach chemistry skills to increasing numbers of students who need to study chemistry for other science, technology and medical specialisations.

As observed by one member of the expert group, this trend is exacerbated by marketing attempts to capture students interested in forensic science and

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[3] The Royal Australian Chemical Institute (2005), *The Future of Chemistry Study: Supply and Demand of Chemists*
[4] ibid.

environmental science by rebadging chemistry courses, often with the addition of new specialist units. The counterpoint is that there is a chemical content in a number of other degree streams, and graduates from these streams can gain employment as chemists in a wide range of areas.

Attracting young chemists to RACI

The expert group expressed concern that RACI has a diminishing membership, and in particular that fewer young chemists are joining the organisation[5]. The group felt that this could adversely affect the future of the chemistry profession in Australia, as young chemists were needed to invigorate the organisation and to ensure that RACI continues to provide leadership in the chemistry field.

Graduate employability

There were differing views within the expert group about the attractiveness of HDR chemistry graduates to industry employers. While some members reported an apparent expectation by industry that HDR graduates be job-ready, others felt that industry was happy to leave fundamental education to the universities and preferred internal training to teach newcomers whatever job-specific skills are necessary to their organisation.

Members agreed that while there may be value in 'generic skills' training during an HDR, this should not be at the expense of research and discipline-specific training.

Mobility and career issues

Expert group members considered the capacity of researchers to move between public and private sector employers as important to both providing viable career pathways for researchers and for supporting the cross-fertilisation of ideas, experience and knowledge. However, members reported a number of impediments to mobility, citing differing remuneration structures and research cultures between academia and industry as particularly problematic.

The capacity of researchers to return to the academic workforce after a long absence was also considered by the expert group to constitute a major challenge. For example, researchers who have spent a period in private sector research may not have the publication record expected of academic researchers. Women were identified as being particularly vulnerable to the negative impact of career breaks due to childbearing responsibilities. The expert group highlighted the importance of family-friendly workplaces as one way to help mitigate this issue.

ARC funding

The expert group highlighted the importance of the ARC Linkage grants for Academe-Industry collaboration in the chemical sciences and the valuable opportunities such grants provide for industry to influence academic research. However, they expressed concern that the scale and focus of training of Australian chemical sciences PhDs is invariably linked to the limited funding available through these and other ARC grants (as almost the only government source of chemistry

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[5] Scholes, Colin. (2010). "Attracting Young Chemists to the RACI", Chemistry in Australia, September 2010, pp. 16-17.

funding in Australia), rather than being aligned with national training needs in the discipline.

Challenges in hiring qualified chemical scientists

The expert group members highlighted several difficulties in hiring high quality post-doctorates in chemistry in Australia, noting that many suitable candidates are either already working or employed in a post-doctoral position overseas. The group felt that the difficulty of finding highly qualified graduates in chemical sciences was also being experienced by new start-up companies, suggesting an undersupply of PhDs in chemistry in Australia.

Members expressed concern that efforts to overcome local hiring difficulties by employing overseas post-doctorates as visiting scholars, research officers or ARC research associates was limited both by current immigration and visa arrangements and by ARC requirements that chief investigators not use grants to pay salaries of visiting scholars. Members considered that these recruitment processes were in urgent need of improvement.

2.3 Chemical sciences research workforce score-card

Score-card

	Quantity of supply through the research training system	Quality of supply through the research training system	Research workforce equity	Research workforce shortfalls	Employment prospects	Research career pathway support
Current	🟢	🟢	🟠	🟠	🟢	🔴
Future	🔴	🟠	🟠	🔴	🟢	🔴

Legend:

🟢	Green (performing well/stable/positive outlook)	🟠	Amber (some challenges/weaker than expected performance)	🔴	Red (poor performance/area (s) of concern/significant challenges)

2.4 How can Australia better position itself for the future?

Efforts to address pipeline issues

One of the greatest areas for concern identified for the chemical sciences research workforce is the pipeline from primary schooling through to undergraduate education (see Section 2.2). It seems inevitable that if the decline in undergraduate enrolments continues it will have a flow on effect at the postgraduate level.

While this issue is outside the scope of the research workforce strategy, the expert group members were of the opinion that the education sector should work to increase the supply of chemical scientists by encouraging more emphasis on, and better teaching of, chemistry in years K-10. The expert group were of the opinion that chemistry should be explicitly included as a subject (as opposed to subsumed under 'science' more generally) in the early science curriculum and greater participation in chemistry in secondary education should be encouraged. The group were concerned that failure to identify chemistry as an individual discipline in the early years of science contributes to a lack of awareness of the need for chemical knowledge across science-based activities.

The expert group proposed that better promotion of chemistry to potential students, parents and the community would assist in improving the pipeline. The group suggested that one avenue to achieve this would be through televisual media, in much the same way that the public awareness of forensic science has been improved through popular crime shows.

Public understanding of chemical sciences

To address negative public attitudes associated with chemistry, the expert group suggested that Australia should launch a campaign similar to the United Kingdom- *Public Understanding of Science.* This initiative arose from a perceived need in the scientific community to increase public knowledge of science in order to make it possible to exercise responsible democratic influence over public issues that are increasingly based on science and its applications. Any action in this area would clearly need to build on existing work within Questacon, CSIRO, RACI, Biotechnology Australia and other organisations in this area.

The expert group were also of the view that science journalists had an important role to play in improving public understanding of chemistry and that chemists need to understand the public impact of their work and develop enhanced communication skills.

Young Chemists Australia in RACI

The expert group were of the view that the key to addressing the issue of attracting young chemists to RACI is to help them see the relevance of the organisation in their careers. The group suggested that RACI could follow the model of Engineers Australia through its subgroup *Young Engineers Australia* which organises social member events for professional and personal development, networking opportunities and intergenerational mentoring.

Mobility of Researchers between Academia and Industry

The expert group members suggested that Australia may consider schemes along the lines of those run by the National Science Foundation (NSF) to address the difficulty of researchers moving between academia and industry. The NSF schemes provide financial support to allow industry practitioners to spend blocks of time in academia and vice versa. Clearly any action in this area would need to build on existing schemes in Australia, such as the Enterprise Connect Researchers in Business scheme, which have been making positive traction in this area in recent years.

Research Training

Apart from the generic skills training of PhD graduates, the expert group proposed that it may be useful to add entrepreneurship or innovation as part of a coursework component in HDR training. They surmised that PhD graduates may be more attractive for industry positions if their PhD training includes a better understanding of business principles.

Research Grants/Scholarships

The expert group recommended that financial support for PhD students through scholarships such as the APA should be extended to four years to allow sufficient time for high quality research training.

The group also highlighted the importance of winning financial support from industry to supplement funding provided through the ARC.

International Postgraduate Research Scholarships (IPRS)

Members of the expert group suggested that the number of scholarships under the IPRS should be increased. They noted that Australia's ability to attract high quality international PhD students would be enhanced if they did not have to pay foreign student fees or if more fee-waiving scholarships were made available, and if the students were better supported in undertaking their studies.

However, the expert group felt that, on balance, the preferred approach would be for Australia to cultivate home-grown chemical scientists in order to improve the domestic skills base.

3 Education

For the purposes of this case study, the definition of 'education' corresponds to that outlined in Division 13 of the *Australian and New Zealand Standard Research Classification.* This includes education systems, curriculum and pedagogy, and specialist education studies. In practice, this definition is almost indistinguishable from that of Division 7 of the *Australian Standard Classification of Education*.

3.1 How is Australia tracking?

The following areas have been selected for analysis:

- The scale and characteristics of the education research workforce in Australia – PhDs, DEds[6] (and in some cases Masters by Research) in the workforce;
- The education research environment in Australia – research and development expenditure, and ERA 2010 results;
- Supply to the education research workforce – HDR completions in Australia and through long-term or permanent migration;
- Demand for education researchers – employability and remuneration; and
- The education research workforce and its research environment.

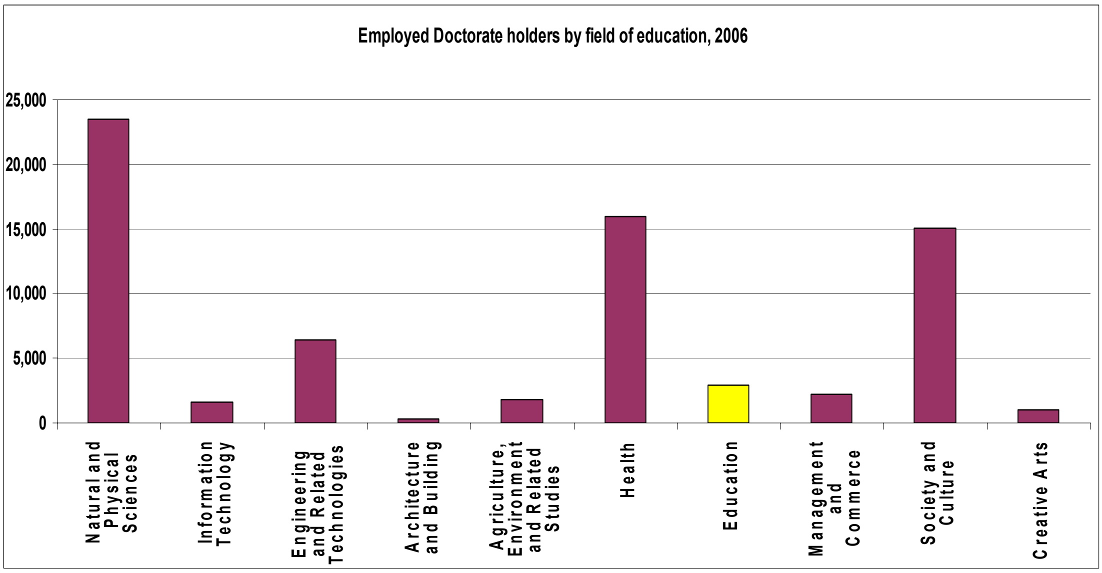
PhD qualified individuals in the workforce

Key Points

- *The number of individuals in the workforce with an education HDR qualification gives an indication of the scale of Australia's research human capital in the discipline (i.e. its potential capability).*
- **Figure 13** indicates that in 2006 education PhDs represented approximately four per cent of Australia's PhD workforce.
- Limitations of available data make it difficult to establish how many education PhD-qualified individuals are research active or to make robust cross-country comparisons.
- The majority (81%) of education PhDs in 2006 were employed in the education and training industry. Within this industry, the university sector is the primary location of educational research.
- The PhD workforce in post-school education industry is projected by recent ACER modelling conducted for DIISR in 2009 to grow by just over 7.7 per cent by 2020, while for the school education industry the projected growth rate for the PhD workforce is 49.4 per cent.
- According to the DEEWR staff collection 69 per cent of university staff in the Education Academic Organisational Group in 2008 were classified as research active. The age profile of staff in this discipline is the oldest (Hugo, 2010) of all academic organisational groupings (62.8% of academic staff in teacher education and 60.4% of academic staff in general education were over the age of 50 in 2006), suggesting significant replacement demand in future years. This is consistent with the 2006 Census data, which indicates that the largest proportion of persons with a doctoral level qualification in education were in the age bracket of 55-64 years **(Figure 14**).

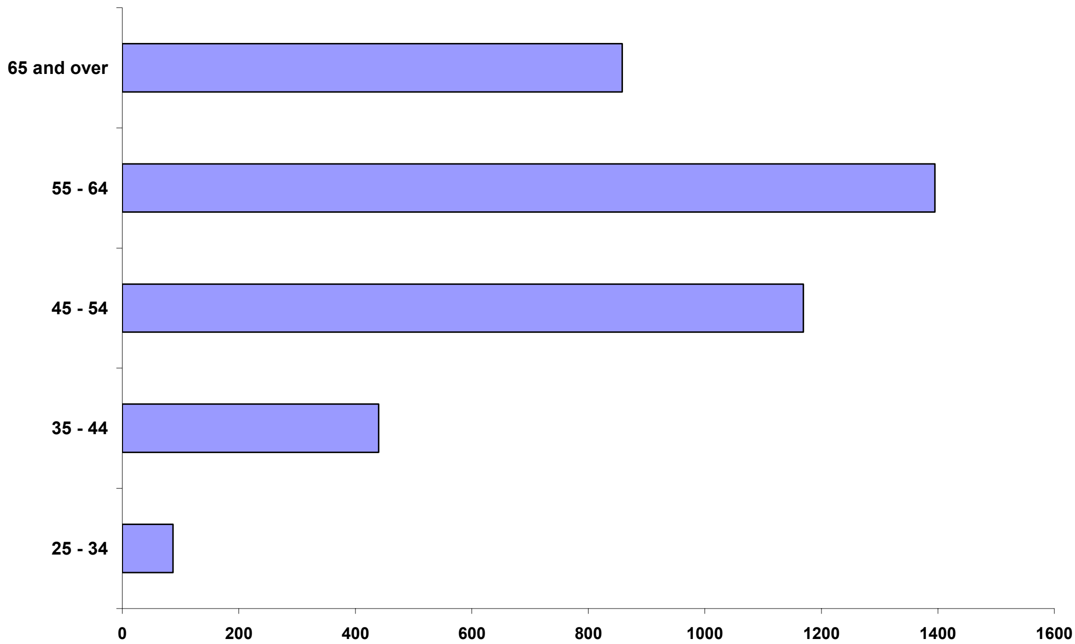
[6] Education is one of a small number of fields where the number of professional doctorate holders rivals the number of PhDs. Doctor of Education degrees qualify as research doctorates under the 'two-thirds rule' (where at least 66 per cent of the course must be original research) and are included in DEEWR statistics (in fact it is not possible to disaggregate PhDs and DEds in these statistics). For brevity and consistency with other case studies, any mention of PhDs is also deemed to include DEds, except where explicitly excluded.

Figure 13: Number of Doctorate holders employed, by Field of Education, 2006



Source: ABS *Census of population and housing 2006*, special tabulation.

Figure 14: Age of Doctorates, Education, 2006



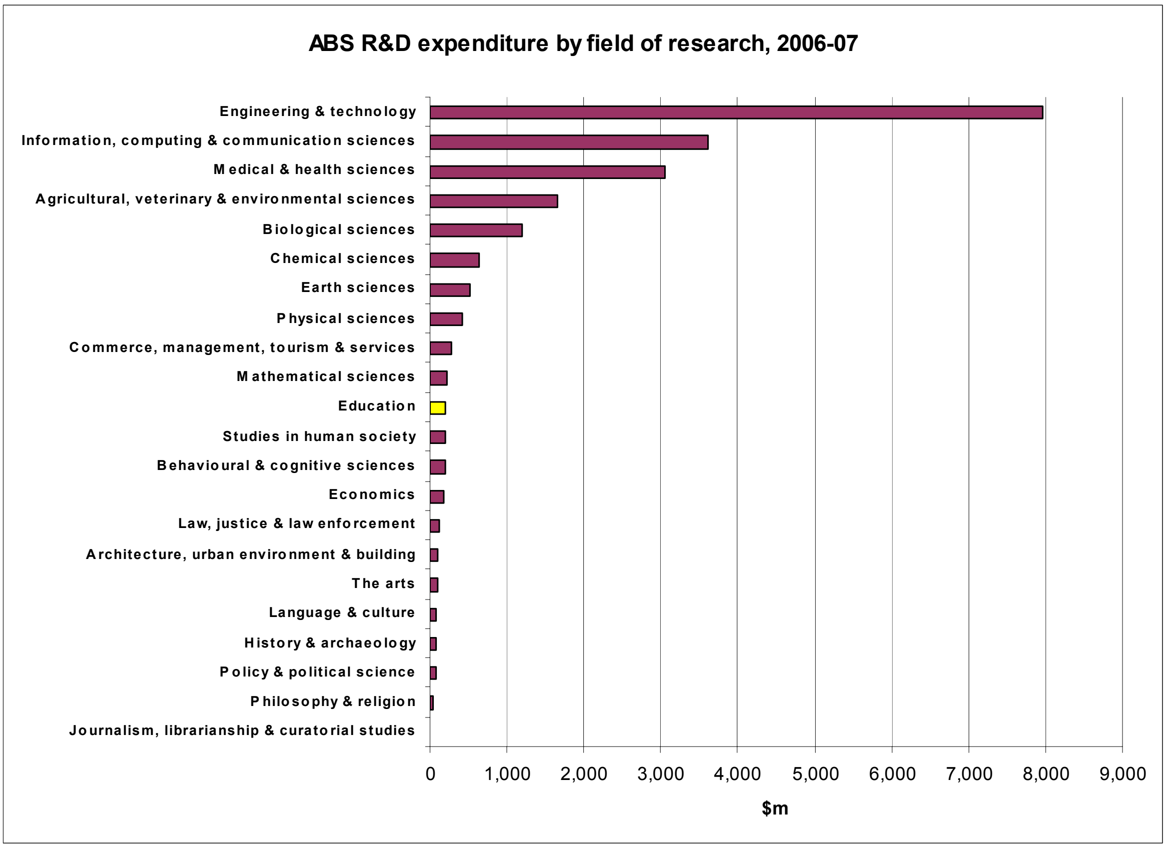
Source: ABS Census of population and housing 2006, special tabulation.
Note: Doctorates aged 15-24 years are excluded due to very low numbers.

R&D expenditure on education

Key Points

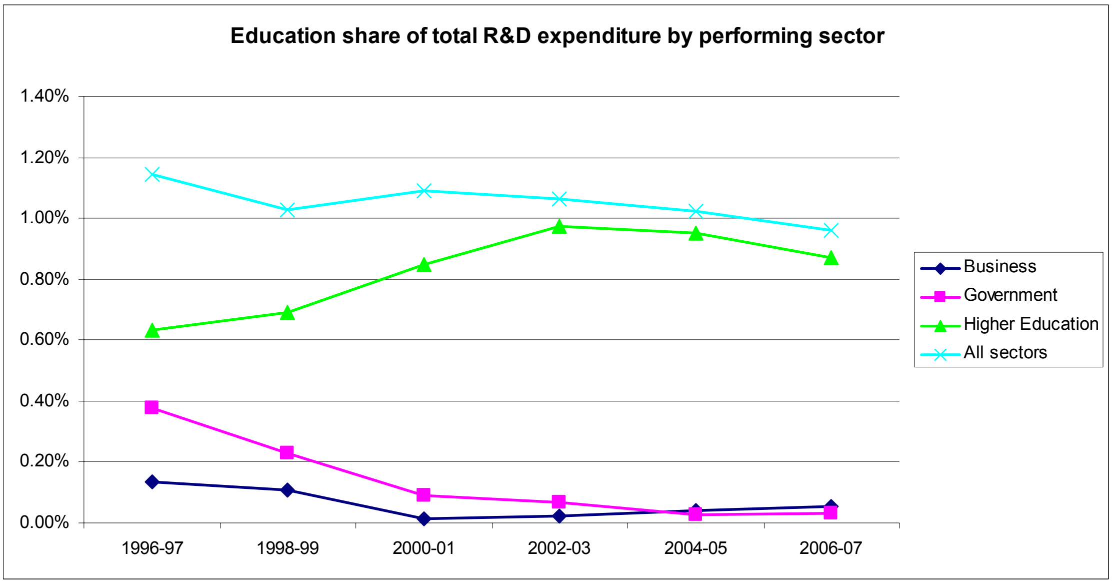
- *The scale of the research workforce in education is likely to be influenced by a number of factors. However, the level of investment by different research performing sectors of the economy is particularly important, as it influences demand for research staff within those sectors.*
- Expenditure on R&D in the field of education stood at $201 million, which was about 0.96 per cent of the total R&D expenditure in 2006-07. Education ranked number 11 in terms of R&D expenditure by field of research (**Figure 15**).
- Since 2002-03, R&D expenditure in education has occurred primarily in the higher education sector (**Figure 16)**. This is consistent with, but well above the incidence of, investment in most other disciplines.
- R&D expenditure in education has declined as a share of total R&D expenditure from 1.14 per cent in 1996-97 to around 0.96 per cent in 2006-07.

Figure 15: R&D expenditure by field of research, 2006-07



Source: ABS cat. No. 8112.*0 Research and Experimental Development, All Sector Summary.*

Figure 16: R&D expenditure on education by sector



Source: ABS cat. No. 8112*.0 Research and Experimental Development, All Sector Summary.*

ERA 2010 results for Education

The ERA 2010 results show that in the Education field, 39 higher education institutions were assessed at the broad two-digit level with a national rating of 2.2. Three institutions are performing at above world standard (a rating of 4) and 12 institutions are performing at world standard (a rating of 3).

At the specific four-digit level, Specialist Studies in Education is the best performer in the area with an average rating of 2.5

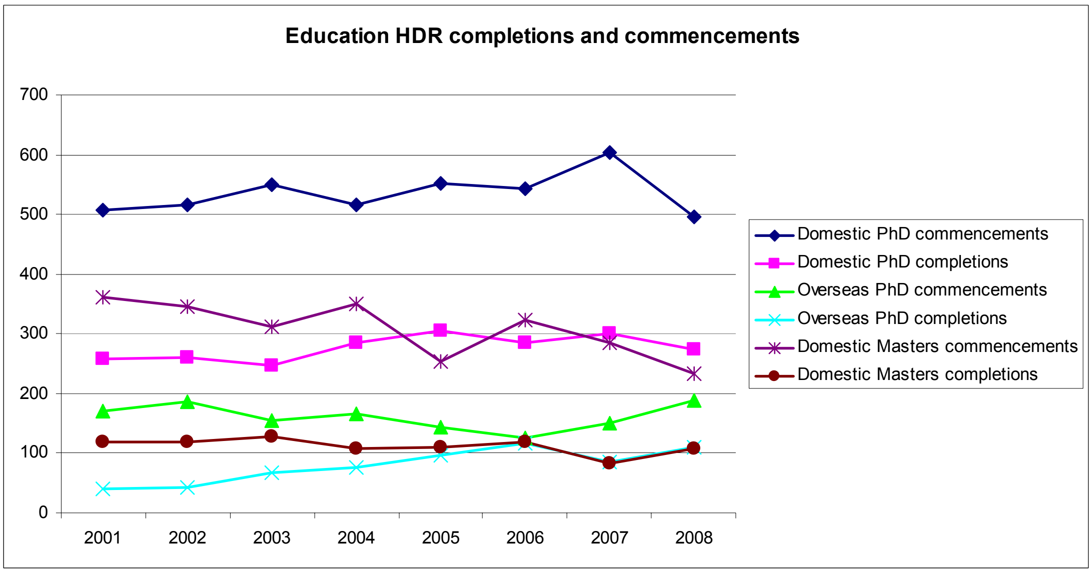
3.1.1 Supply to the education research workforce

HDR commencements and completions

Key Points

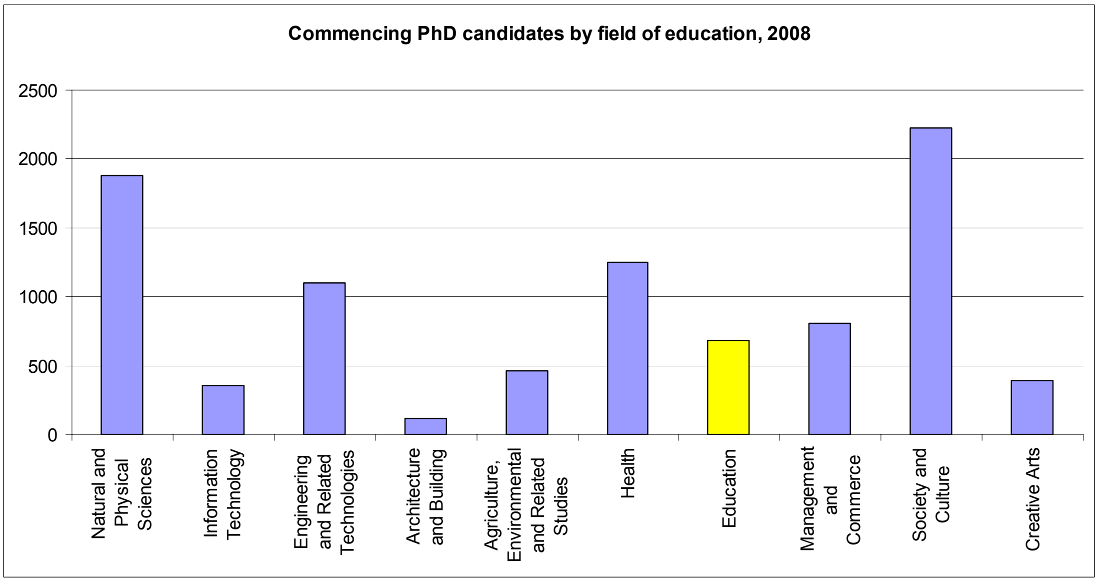
- *Australia's education research workforce is in constant flux due to ongoing inflows and outflows of HDR qualified individuals, the shorter than average research careers of education HDR graduates, and shifts in the number of research active staff in different parts of the economy.*
- *With respect to inflows of education HDR skills, the dominant source is Australia's research training system through completions of domestic and (some) international HDR students. Examination of historic trends of both commencements and completions provides a gauge (in combination with graduate destination surveys and migration data) of the pipeline of the skills that can be expected to be available to the workforce in future years.*
- **Figure 17** shows that the number of domestic PhD commencements very slowly trended upward over time before a significant drop in 2008. Domestic PhD completions have followed a similar upward trend.
- International PhD completions have trended upward over 2001 to 2008, with numbers more than doubling over this period. However, international PhD completions in education represent only 13 per cent of the total education completions in 2008, compared to 22 per cent of PhD completions for all disciplines.
- Masters by Research degree commencements in education have, like almost all fields of HDR study, been declining over time. Completions at this level have remained relatively steady over 2001 to 2008.
- **Figure 18** shows that commencing education PhDs represent a small but significant share (7.4%) of all PhD commencements.
- **Figure 19** illustrates that Australia out-performs most other OECD member countries in its share of education graduates, compared to all graduates of 'advanced research degrees' – the international measure closest to our PhD.

Figure 17: Education HDR commencements and completions, 2001-2008



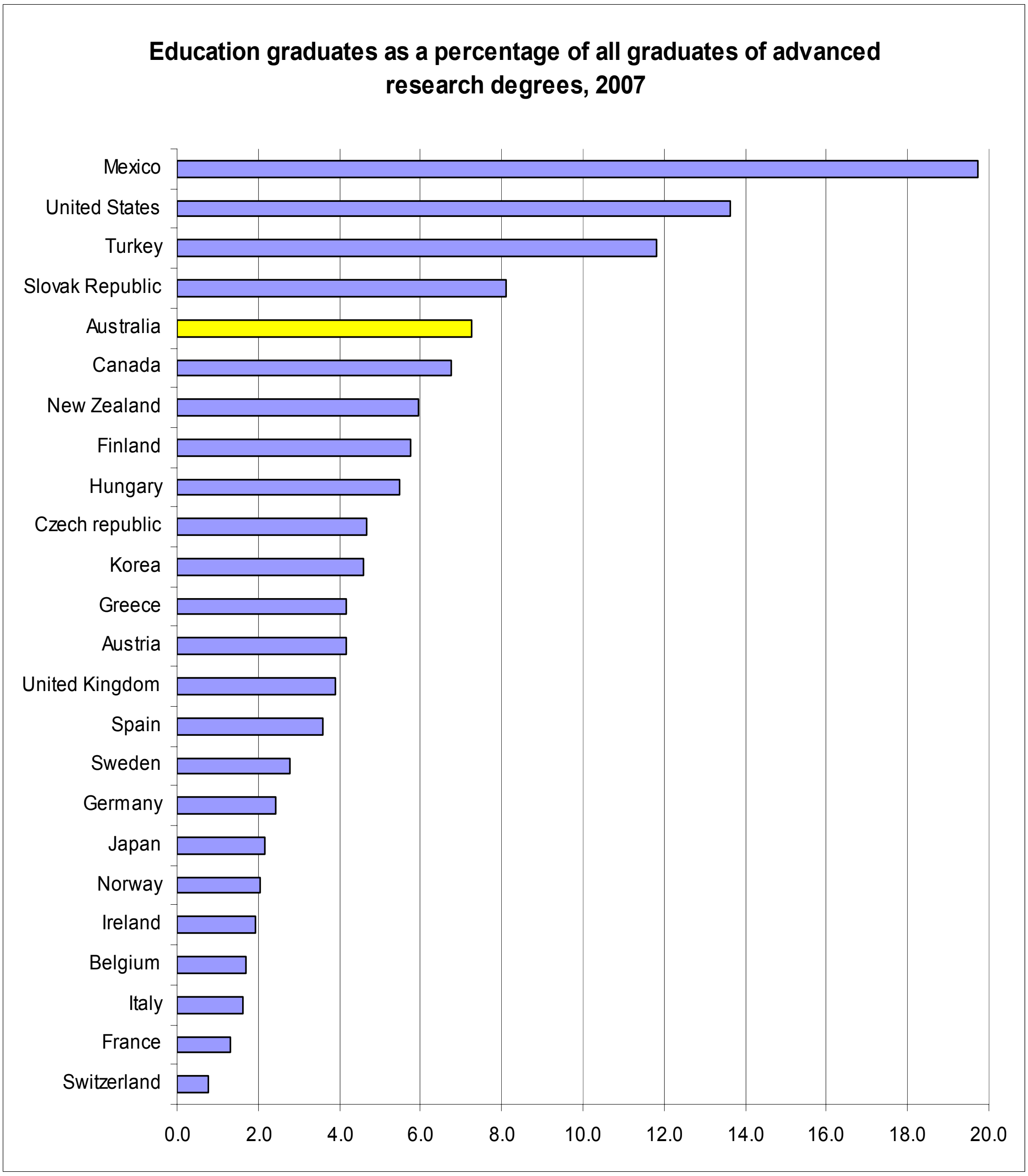
Source: DEEWR University statistics, unpublished data.

Figure 18: PhD commencements by 2-digit field of education, 2008



Source: DEEWR University statistics, unpublished data.

Figure 19: Education graduates as a percentage of all graduates of advanced research degrees, 2007



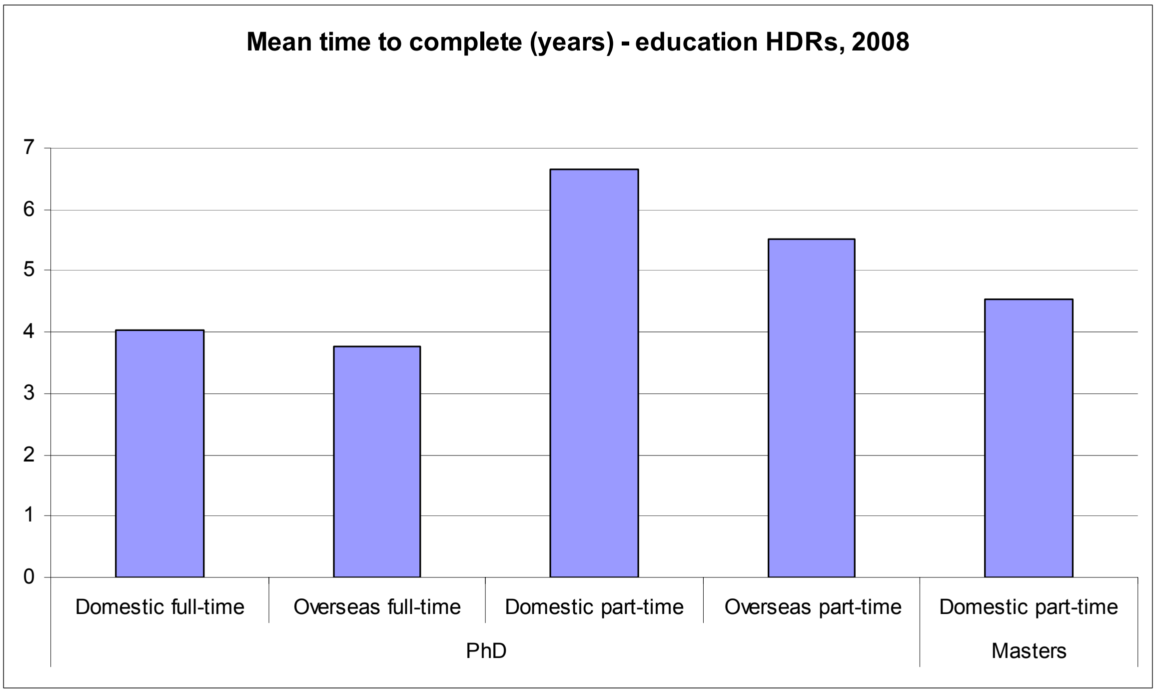
Source: OECD statistics online database.
Note: This data should be approached with care – differences in higher education systems can produce anomalous results when countries try to standardise their information to possibly incompatible OECD reporting requirements.

HDR time to complete

Key Points

- *The time taken to complete HDR studies and mode of study (full-time versus part-time) provides an indicator of the efficiency of the pipeline from research training to the workforce.*
- **Figure 20** indicates that in 2008, on average, domestic full-time education PhDs complete in 4.1 years (the same as the average for PhD candidates across all fields) while domestic part-time PhDs complete in 6.7 years, compared to an overall mean completion time of 6.0 years for domestic part-time candidates across all disciplines. The majority of domestic PhD students in education in 2008 were in part-time study (203 compared to 72 in full time study).
- The vast majority of domestic Masters by Research candidates in education in 2008 were enrolled on a part-time basis (99 compared to 9 full-time candidates in 2008). The mean completion times for part-time domestic masters by research candidates was 4.5 years compared to the average for all disciplines of 4.3 years.
- There was a more even distribution of part-time and full-time education HDR candidates from overseas (60 to 67) in 2008. Full-time overseas PhD candidates completed in 3.8 years on average, compared to 5.5 years for part-time candidates.

Figure 20: Mean times to complete for education HDR students, 2008



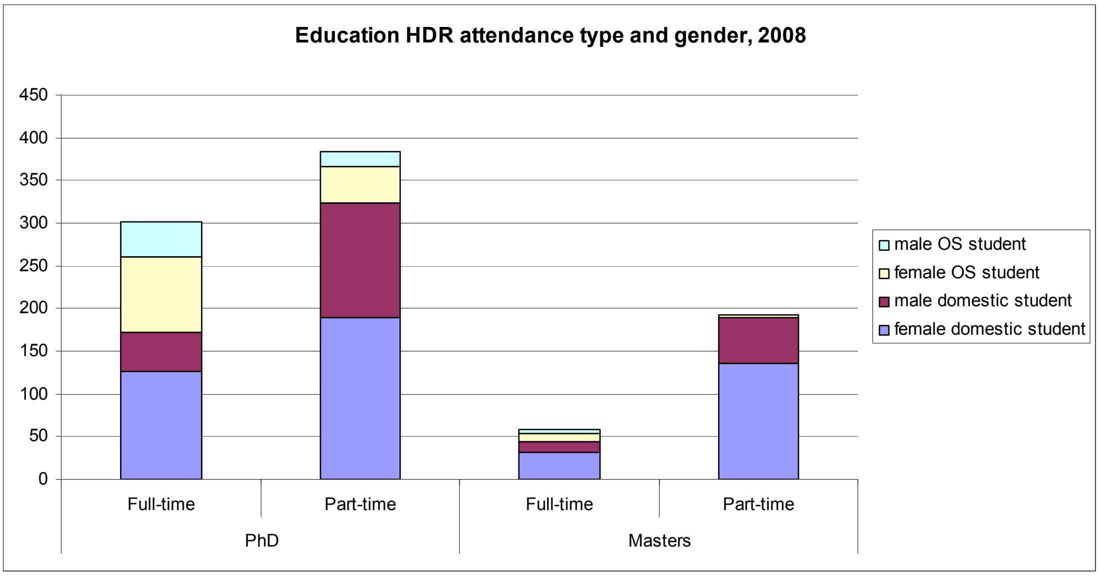
Source: DEEWR University statistics, unpublished data.

Demographic data – commencements and completions by age and gender

Key Points

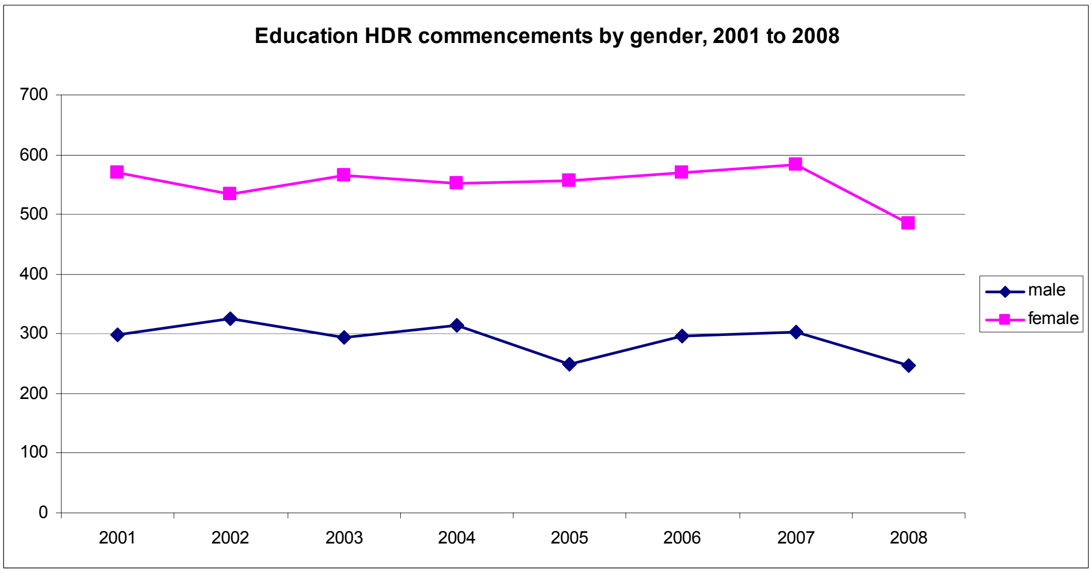
- *The age of education HDR students provides a useful gauge (but not conclusive) of the potential extent of workforce contributions of graduates over time, while gender may reveal any persistent inequalities in participation in HDR degrees between the genders.*
- **Figure 21** shows a significant gender imbalance between domestic male and female candidates enrolled in education HDRs in 2008. The nearly 2:1 average ratio of females to males in education is in contrast to many disciplines that have a gender imbalance in the other direction. Other disciplines with a similar ratio to education are nursing and some other health professions.
- **Figure 22** shows that the gender gap in participation in education HDRs widened over the period 2002 to 2007, before reducing (in parallel with an overall reduction in enrolments, in 2008).
- **Figure 23** shows that education HDR students tend to be older than those in other disciplines. The median age for commencing male PhDs was 46 years in 2008 (double that for candidates in, for example, mathematical sciences) while the median age for commencing female PhDs was 43 years in 2008. Overseas PhD students were considerably younger, on average, than their domestic counterparts, with commencing male and female PhD median ages of 36 and 33 years respectively.
- Median ages of males and females on completion of domestic PhDs in education were the same, at 49 years, as were the completion ages for overseas PhDs (43 years each for males and females).
- The older commencement and completion ages of education HDR students suggests their education research careers will be shorter than those experienced by HDR-qualified researchers in other disciplines.

Figure 21: Full-time and part-time education HDR candidates by gender and citizenship, 2008



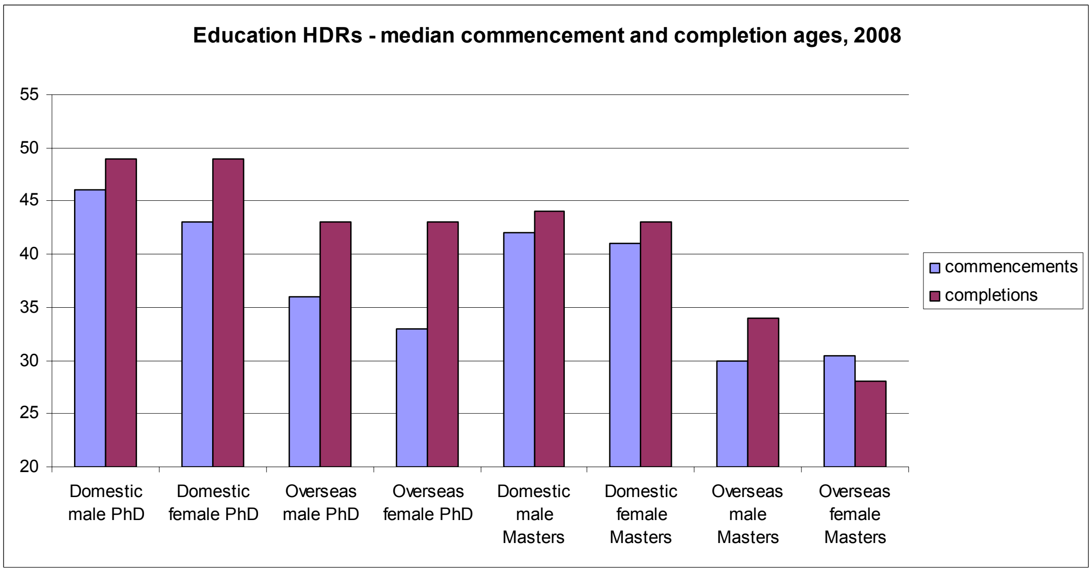
Source: Published and unpublished DEEWR Unistats data.

Figure 22: Education HDR commencements by gender



Source: Published and unpublished DEEWR Unistats data.

Figure 23: Median commencement and completion ages for education HDR candidates, 2008



Source: Published and unpublished DEEWR Unistats data.
Note: The chart shows the median ages for two different cohorts – those that commenced and completed their HDRs in 2008.

Supply through migration

Key Points

- *A further source of supply of education HDR-qualified individuals to Australia is through both temporary and permanent migration.*
- *While available data makes it difficult to discern the scale of supply for education through migration, previous studies (ACER, 2009) have estimated that approximately 22 per cent (including international students staying on in Australia following completion of their studies) of Australia's overall supply of HDR skills is achieved through this source.*
- Education researchers can currently migrate to Australia under a number of visa classes. Within the general skilled migration program, secondary school teachers can apply under the SOL Schedules 2 and 4. Education researchers are eligible to apply under the Employer Nomination Scheme (including for positions as tutors or lecturers) and have access to a variety of temporary visa classes for work, collaboration or study.
- While quantification of the scale of supply of education PhDs to the workforce from international sources is limited by the granularity of data collected, analysis of Census data reveals that one-third of education Doctorate holders were born overseas (compared with an overall proportion of 46 per cent overseas born Doctorate holders) in 2006.

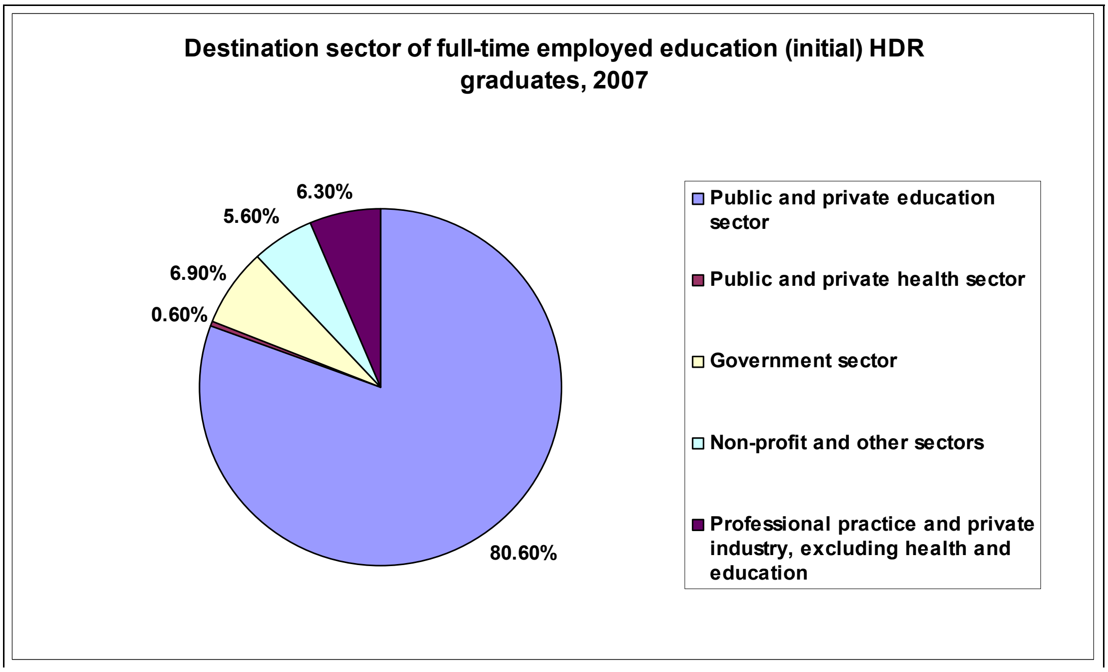
Note: SOL Schedule 2 applies to previous visa holders or those who applied for skilled independent work visas before 8 February 2010 and who are now applying for new work visas. This includes those who held student visas as of 8 February 2010 and may submit their applications until 2012. SOL Schedule 4 applies to visa applicants sponsored by state or region to work in Australia.

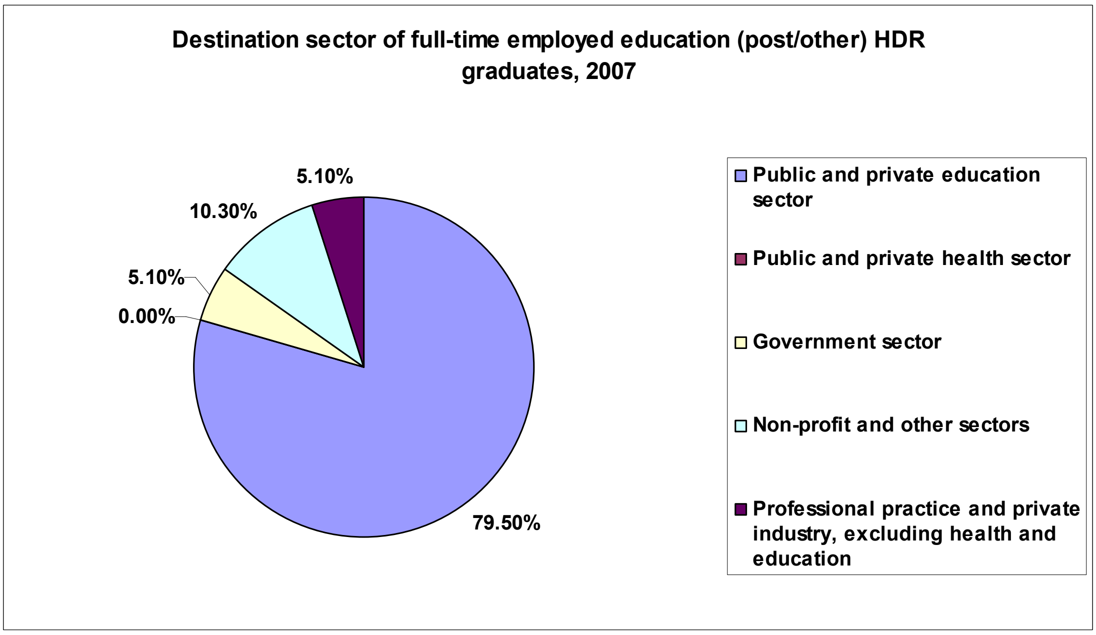
3.1.2 Demand and career prospects for education researchers and HDRs

Key Points

- *The immediate employment outcomes (employability and sector of employment) of education researchers and HDR graduates gives a sense of employer demand for research skills in this area. Graduate reflections on their preparedness for employment also provide a gauge of the match between experience and skills garnered through research training and subsequent employment needs.*
- The Grads Online website, using data from the 2007 Graduate Destination Survey, shows that education is the major sector of postgraduate employment of HDRs in education, with around 80 per cent of new full-time employed graduates working in the sector in 2007 (**Figure 24**). This finding is consistent with Census data which indicated that approximately 81 per cent of education PhDs in Australia were employed in the education and training sector in 2006.
- The 2008 Graduate Destination Survey reports that HDR graduates in education had starting salaries of around $74,000, on average. The survey results indicated that 72 per cent of graduates were employed full-time, seven per cent were seeking full-time work, four per cent were studying, 11 per cent were in part-time work but not looking for full-time employment and six per cent were unavailable for work or study.
- Responses to Australia's 2008 Graduate Destination Survey indicate that the majority (67.4%) of education HDR graduates considered their HDR qualification a formal requirement for or important to their job – percentages marginally below the average across all disciplines (72%).

Figure 24: Destination sector for full-time employed education HDR graduates, 2007





Source: Graduate Careers Council of Australia *Grads Online* website.
Note: *Education (initial)* includes initial teacher education, pre-service (courses leading to first professional teaching qualification). *Education (post/other)* includes education courses other than those related to teacher education and post-initial teacher education (post-initial teaching qualification courses).

3.1.3 Summary points

Taken together, the quantitative trends examined in this case study suggest the following:

- Australia's education doctorate-qualified workforce is a small (approximately 4.0%) component of Australia's total doctorate-qualified workforce, concentrated mainly in public and private education sector.
- In spite of the small size of its research workforce, education performs strongly in comparisons of relative citation impacts between countries, performing well above the world average and ahead of other social sciences.
- Within the university sector, education academics are employed mainly in teaching/research roles and are more likely to be within the older (50+) age-brackets than their counterparts in other academic organisational units, suggesting significant replacement demand within this sector in future years. This data is consistent with 2006 Census data which reveals that the largest proportion of persons with doctoral level qualifications in education were in the age bracket of 55-64 years.
- Australia's supply of education researchers through the research training system is currently primarily female and has been growing slowly. However, a sharp decline in education HDR completions in 2008 suggests this growth trend may not continue.
- Australia produces more education HDRs as a share of total advanced research program completions than most other OECD countries and more as a share of completions than our major comparator countries, excepting the USA.
- On average, education HDR candidates commence their courses at much later ages than most other disciplines and commence their research careers at the time of life when some other professionals are contemplating retirement. Employability and employment prospects, however, appear positive.

3.2 What are the key influence factors (current and future)?

The demographics of the education research workforce

The age profile of education HDRs (students and qualified individuals) is a significant influence on both current education research careers and the future of the education research workforce in Australia.

Age at commencement and time taken to qualify are of particular importance from an education research workforce planning perspective, given their capacity to produce a bottleneck in future years as age-related retirements increase and an insufficient pool of suitably qualified and experienced individuals is available to replace departing staff. The unique nature of education research, which requires greater nation-specific knowledge (i.e. relevant to the unique education environment in a given country), limits the extent to which international sources can be expected to meet this demand.

The older commencing age of education HDR students can also result in considerable pressures on students as they struggle to balance their predominantly part-time studies with family and other life responsibilities. This is an important consideration in any efforts to improve uptake of HDR training and retention within education research careers. The key challenge is that as many education HDR candidates have a number of years in the workforce behind them they often find themselves in a position where they have to make significant financial sacrifices to undertake their degrees, while coping with family responsibilities (the highly feminised nature of the education research workforce may also contribute to this pressure)[7]. This may act as a substantial disincentive to undertake careers in education research.

Finally, the older completion age of education HDRs means that they tend to have a much shorter career as an established, independent researcher than typically experienced in other discipline areas. This may have a considerable impact on the nature and cost of research activity. Similarly, programmatic research built up over the 20-30 year research career is less common in education than in other discipline areas (**Figure 25**).

[7] Australian Council of Deans of Education (2010) *Renewing the Academic and Research Workforce in Education: Challenges and Opportunities*.

Figure 25: The journey to the academic workforce[8]

A year 12 school leaver entering a Science course or a Science/Education course, direct from school.

The choice	**SCIENCE**	**SCIENCE/EDUCATION**
The journey	BSc(hons) (4 yrs)	BSc/BEd or BSc/GradDip (4 yrs)
		Teaching experience 4+ yrs
		Masters with research thesis component (1.5 yrs full time but most likely 3-4 yrs part time)
	PhD (3-4 yrs)	PhD (4 yrs full time but likely to be 6-7 yrs part time – on average)
Elapsed study time (FTE)	7-8 yrs	8.5-9.5 yrs
Time span to PhD completion	7-8 yrs	14-16+ yrs
Cost	4 x HECs	4 x HECS 1.5 x (mostly) full fees
	PhD fee free	PhD fee free
Scholarship	Possible scholarship	No scholarship because of part time study
Entry to research workforce	26 yrs of age	40+ yrs of age and often older

The research training experience in education

The expert group were of the view that the high prevalence of part-time candidature (an issue connected with the age profile for education HDRs discussed above) in both domestic and international education HDRs, with students often studying off-campus while maintaining their jobs, makes it difficult to build a vibrant research culture among education HDRs.

Adding to this effect, the expert group reported that many older education HDR candidates come to research training with their topic already selected – often based on their individual teaching or school administration experience – and have no real connection with other research taking place in the university. Many education

[8] Adapted from: Australian Council of Deans of Education (2009) *Background briefing paper 7 for Julia Gillard*.

academics take on supervision of a number of HDR candidates, many part-time and all with different research interests, making it difficult to build collegiality.

The expert group were also concerned about the heavy demands placed upon HDR supervisors. Many education faculties have a high proportion of staff who are relatively new to academia and thus for a number of reasons less likely than their more experienced colleagues to be in a position to supervise many HDR candidates. As a result the majority of supervision tends to fall to a few more experienced staff. This is exacerbated by the tendency to load experienced staff with other roles such as administration. Without explicit measures to free up experienced staff for supervision, efforts to increase the proportion of full-time students may be in vain.

Reporting of research outcomes and the profile of education research

The expert group emphasised that education research by its very nature is highly interdisciplinary, drawing on the disciplines of history, philosophy, anthropology, sociology and psychology and more derivative fields such as policy studies, cultural studies, curriculum studies and studies of pedagogy and practice. The group noted that this interdisciplinary character results in education research being reported on under a wide range of Field of Research (FOR) codes, and consequently having a lower perceived profile and relevance than is actually the case (with consequences in turn for the attractiveness of the field to aspiring HDR students).

The fragmentation of the research effort

The expert group reported that in the absence of sources of long-term program based funding, much of the effort at HDR and researcher level is project based and limited to small scale discovery and applied research, with little or no substantial funding, and constrained to individual and small teams of researchers. While many universities self-fund institutional-level research centres that have cross-sector and international alliances and partnerships, there are no large government or industry funded, program-based educational research centres in Australia. Similarly, while there are many cross-institutional/cross-sector ARC funded research projects in the field of education, the scope of collaboration is generally constrained by the limited and short-term nature of research in education.

The expert group were of the view that these constraints create an educational research sector that, despite its high productivity, is characterised by large numbers of small scale, individual or small-team studies that lack the critical mass and cohesiveness to support major advances in the field. As a result, the group felt that education research tends not to build towards an accumulative and integrated evidence base that leads to eventual major breakthroughs on serious issues or problems.

Career pathways and mobility

The expert group considered that education researchers have somewhat limited career pathway options compared to other disciplines, with research being largely confined to academic settings (along with a number of government or quasi-government research agencies), and with a tendency for careers to be structured around teaching or dual teaching-research academic roles rather than research-dedicated positions.

The group identified two factors reinforcing this issue: support structures and disincentives to inter-sectoral movements.

With respect to the former, the expert group noted that few, if any, post-doctoral positions are available for those graduates who want to focus on a research-intensive versus traditional academic career. This issue is further exacerbated by the lack of large scale research teams or national centres for education research which might be expected to provide a number of post-doctoral positions.

With respect to the latter, the expert group highlighted the fact that pay differentials between sectors can have a significant impact on mobility. In particular, given that a major component of education HDRs are mid-to-late career professionals, moving into an academic career at an entry-level level A or level B position post involves a very significant pay cut. In short, it is much easier to become a school principal than to become an academic. The expert group suggested that 'scholarships', funded at an appropriate level based on the skills and background of the people involved, are one mechanism that could facilitate mobility between government and academic roles.

International students – retention and employment

The expert group emphasised the value of international students to the education research workforce but pointed to two significant barriers to their retention and employment as education researchers in Australia.

Firstly, the group noted that a high proportion of education research students are funded by their governments and required to return to work in their home countries and are thus less likely than their self-funded counterparts in other disciplines to pursue research careers in Australia. This limits the potential to remedy a shortfall in education researchers through international HDR students.

Secondly, the group noted that where international students do choose to stay in Australia following completion, their lack of exposure to and understanding of Australian early childhood/school/VET education and its structures and institutional practices is a barrier to their employment as academics. This is because teaching teachers requires a practical and cultural understanding of how education operates in Australia. International HDR graduates thus need additional support before they are employable and/or fully productive as academics.

Skills issues

Members of the expert group identified quantitative skills as the key shortage for the education research discipline now and into the immediate future. In particular, the group noted that it is difficult to obtain staff with an adequate mix of professional knowledge and quantitative skills and such staff or skills consequently need frequently to be sourced from other disciplines, for example psychology.

The group emphasised that a lack of quantitative skills impacted not only on the ability of education researchers to conduct research, but also on the capacity of education HDR training graduates to redress the balance of skills in this area.

Further noted areas of skills shortage included staff qualified and experienced in early childhood research and staff experienced in supporting the learning needs of tertiary students from non-traditional backgrounds.

3.3 Education research workforce score-card

Score-card

	Quantity of supply through the research training system	Quality of supply through the research training system	Research workforce equity	Research workforce shortfalls	Employment prospects	Research career pathway support
Current	🟠	🟠	🟠	🟠	🟢	🔴
Future	🔴	🟢	🟠	🔴	🟢	🔴

Legend:

🟢	Green (performing well/stable/positive outlook)
🟠	Amber (some challenges/weaker than expected performance)
🔴	Red (poor performance/area(s) of concern/significant challenges)

3.4 How can Australia better position itself for the future?

Valuing and promoting evidence-based research in education

The expert group emphasised the need to promote at a national level the importance of education and the potential contributions of education research to educational, social and economic outcomes in Australia with a view to:

- building consensus with government and industry that substantial funding needs to be directed to build Australia's capacity to engage in systematic, large-scale education research programs;
- encouraging greater long term collaborations between Australian universities and government and industry partners to build critical mass of expertise and effort (see below); and
- facilitating greater strategic and long-term planning for the direction of the discipline and its contributions to mainstream policy and professional practice.

Building critical mass

A number of issues reported on by the expert group (for example, the prevalence of short-term funding, lack of career structures and support for large-scale collaboration between education researchers and research teams, and the tendency for HDR students to work in isolation) indicate that measures to promote critical mass may be of benefit.

The expert group suggested that national education research centres, such as Cooperative Research Centres or Centres of Excellence, would provide the ideal environment to build critical mass, position education as a key national research priority and revitalise research training within the education research disciplines.[9] The group were of the view that such centres are essential to support innovative responses to social and economic change and promote excellent research. Education research centres of excellence would also act as a vibrant research hub to attract the best domestic and international HDR students and encourage a younger cohort of these students into research careers in the field of education.

Renewing and retaining the education research workforce

The expert group suggested a number of actions that would contribute to improving the supply of education researchers to Australia:

- Improved and more flexible stipends and top-up grants to encourage honours graduates to select research training in the face of attractive salaries for beginning teachers, and to encourage expert professionals to undertake research training rather than continue in higher paid careers as senior teachers or public servants. This might include consideration of HECS undergraduate fees remissions for each year in a HDR graduate program.
- Support by government employers for secondments of professional expert staff to universities to either undertake HDR studies or to teach HDR students. This might

[9] For discussion of a possible model for education centres of excellence, see *Transforming Knowledge and the Transmission of Knowledg*e, The Prime Minister's Science, Engineering and Innovation Council (PMSEIC) working group on transforming learning and transmitting knowledge, presented at the PMSEIC meeting, 18 March 2010. http://www.innovation.gov.au/Section/pmseic/Pages/21.aspx

include secondment to work on employer-defined research projects that include HDR training.
- o Strategies to retain retired staff in active research and supervisory roles.

The expert group also suggested targeted incentives to address areas of skills shortage (such as quantitative research methods), including tax-exempt appointments and incorporation of greater quantitative skills development training into education HDRs. The group noted that the latter would best be complemented by an extension of the timeframe for HDR support.

Finally, the group suggested that internal supply could be bolstered by measures to enable international education HDR graduates to take up academic positions in Australian universities. Suggested initiatives included a reduced teaching load for beginning international researchers to allow them to gain the necessary understanding of the Australian education system or, alternatively, targeted education and training programs during their HDR candidature.

Improving the information base

The expert group noted the absence of robust longitudinal data to support an ongoing evidence base for workforce planning in the education research field. The group saw value in such studies being conducted more frequently in future years.

It was suggested that a national data repository for teacher education would be valuable in allowing greater accessibility and use of relevant data.

The group also saw value in addressing a perceived low visibility of research career options in education (and other disciplines). The key objective of such actions would be to attract younger graduates to a career in education research.

4 Engineering

For the purposes of this case study, the definition of 'engineering' research corresponds to that outlined in Division 9 of the ANZSRC. This includes aerospace engineering, automotive engineering, biomedical engineering, chemical engineering, civil engineering, electrical and electronic engineering, environmental engineering, food sciences, geomatic engineering, manufacturing engineering, manufacturing engineering, maritime engineering, materials engineering, mechanical engineering, resources engineering and extractive metallurgy, interdisciplinary engineering, and other engineering. It is acknowledged, however, that not all issues will be applicable to these areas equally.

4.1 How is Australia tracking?

The following areas have been selected for analysis:

- The scale of the engineering research workforce in Australia – PhDs in the workforce (however, a number of engineer researchers have commented that much engineering research is conducted by engineers with no formal research qualifications);
- The engineering research environment in Australia – research and development expenditure and ERA 2010 results;
- Supply to the engineering research workforce – HDR completions in Australia and long-term or permanent immigration to Australia; and
- Demand for engineering researchers – employability and remuneration.

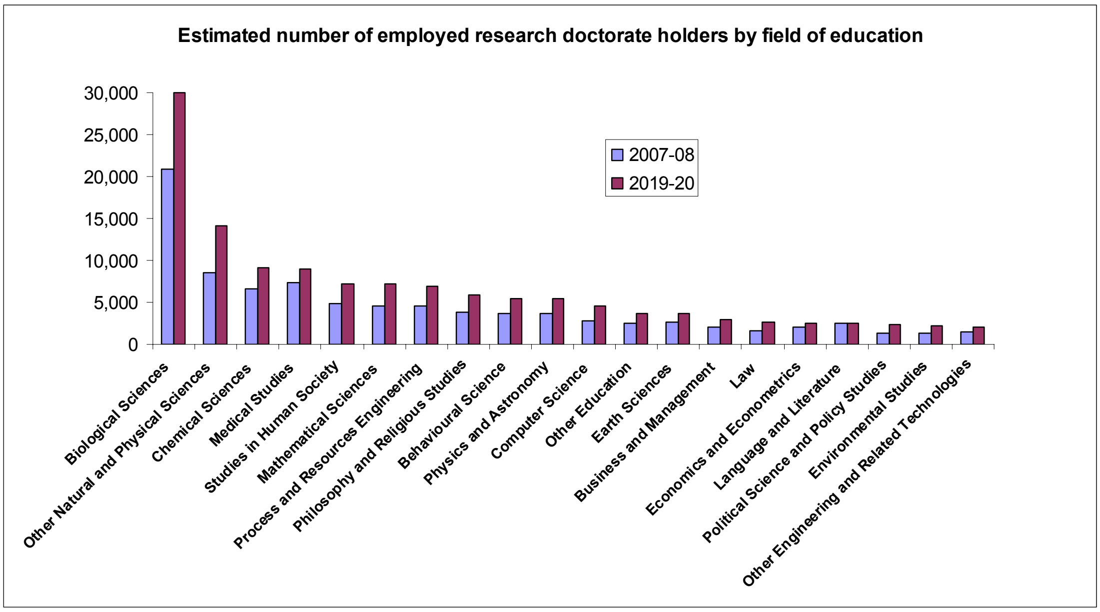
4.1.1 The engineering research workforce and its research environment

PhD qualified individuals in the workforce

Key Points

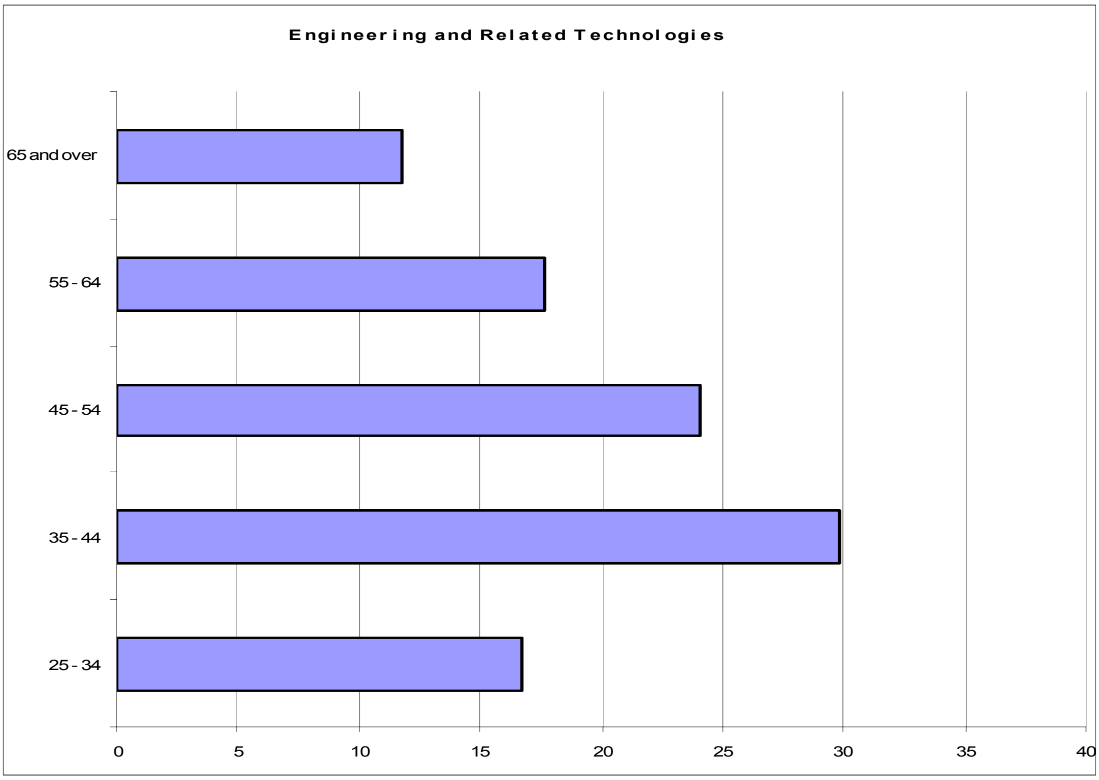
- *The number of people in the workforce with an engineering HDR qualification gives an indication of the scale of Australia's research human capital in the discipline – i.e. our capacity for research in this discipline*.
- ABS census data indicates that engineering PhDs represented approximately 8.9 per cent of Australia's PhD workforce in 2006.
- ACER modelling conducted for DIISR in 2009 indicates that the PhD workforce in process and resources engineering and other engineering and related technologies (the only sectors for which we have data) is projected to grow by over 40 per cent by 2020 (**Figure 26**).
- Data limitations make it difficult to establish how many of these people are research active or to make robust cross-country comparisons.
- **Figure 27** indicates that most doctorate holders in engineering in the workforce are in the 35 to 44 age bracket, with significant cohorts in both the 45 to 54 and 55 to 64 brackets.
- Within the university sector, a 2010 study for Universities Australia by Graeme Hugo indicates that a moderate proportion (41.2%) of academic (predominantly research active) staff in engineering were in the older age brackets (50+) in 2006, suggesting the potential for reasonably strong replacement demand for engineering research staff in this sector in future years.

Figure 26: Estimated number of employed research Doctorate holders, by field of education, 2007-08 to 2019-20



Source: Australian Council for Education Research, *Supply, Demand and Characteristics of the Higher Degree by Research Population in Australia*, Report for the Department of Innovation, Industry, Science and Research, June 2009, p. 54.

Figure 27: Age distribution of engineering Doctorate holders, 2006



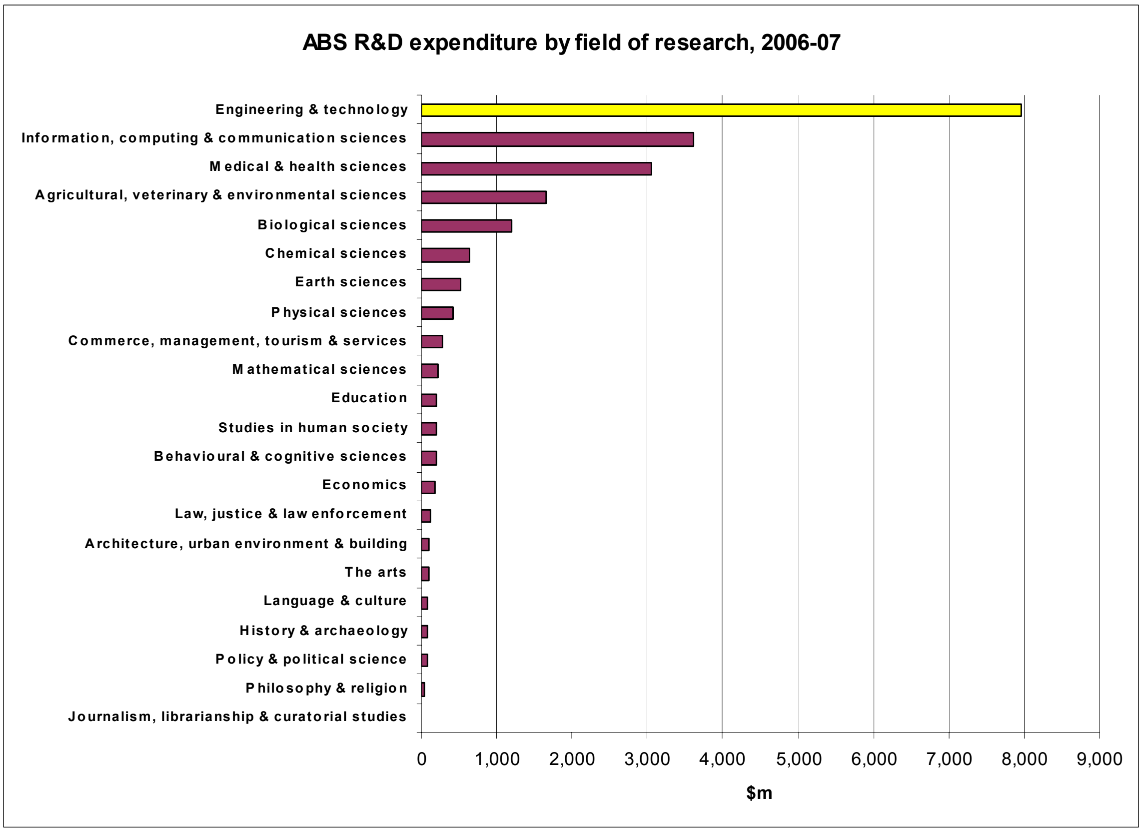
Source: ABS 2006 Census of population and housing 2006, special tabulation

R&D expenditure on engineering

Key Points

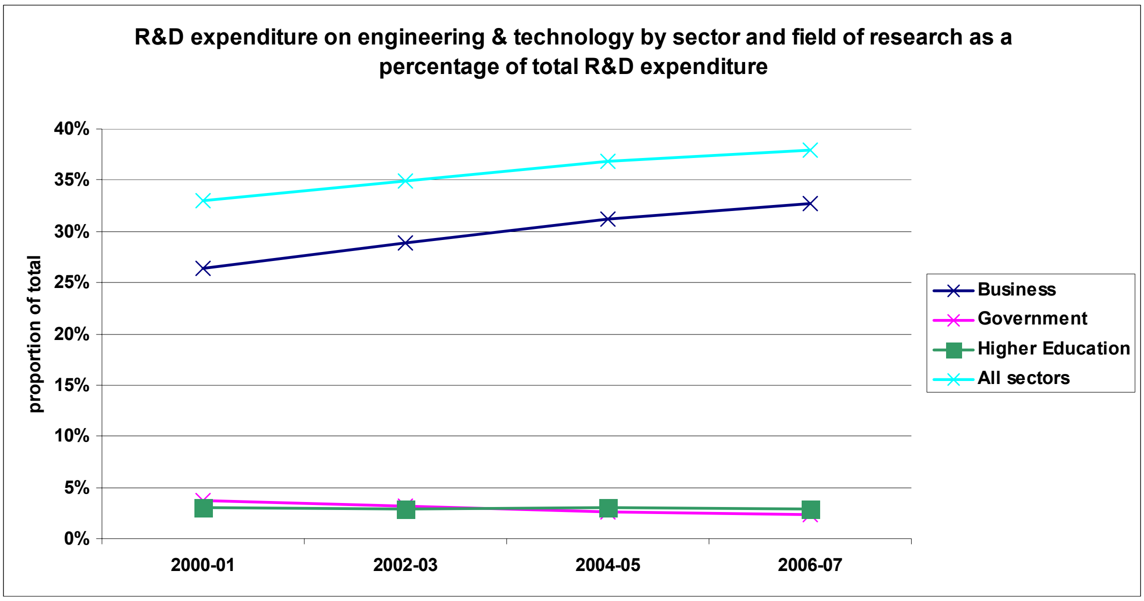
- *The scale of the engineering research workforce is likely to be influenced by a number of factors. Investment is particularly important in this context as it influences the demand for research staff in different sectors of the economy (e.g. business, government, universities, not-for-profit organisations etc).*
- Expenditure on R&D in the field of engineering and technology was $7.95 billion in 2006-07. Expenditure has trended upwards as a share of total R&D spending from around 33 per cent in 2000-01 to 38 per cent in 2006-07. Engineering and technology is ranked first in terms of R&D expenditure by field of research (**Figure 28**). This figure ranks expenditure against all major fields of research as identified by the ABS in accordance with international practice.
- R&D expenditure in engineering is performed mainly in the business sector, although expenditure in both the government and higher education sectors is also significant in dollar terms (**Figure 29**).

Figure 28: R&D expenditure by field of research, 2006-07



Source: ABS cat. No. 8112.*0 Research and Experimental Development, All Sector Summary, 2006-07.*
Note: The major sources of funds for R&D expenditure were from the Commonwealth Government, state and territory governments, business, overseas and other Australian sources.

Figure 29: Engineering share of total R&D expenditure by performing sector



Source: ABS cat. No. 8112.*0 Research and Experimental Development, All Sector Summary* 2006-07.
Note: The *All sectors* figure includes expenditure on R&D performed by the private non profit sector as well as the business, government and higher education sectors.

ERA 2010 results for Engineering

The ERA 2010 results show that in the Engineering field, 31 higher education institutions were assessed at the broad two-digit level with a national rating of 3.0. Three institutions are performing well above world standard (a rating of 5). Six institutions are performing at above world standard (a rating of 4) and 13 institutions are performing at world standard (a rating of 3).

At the specific four-digit level, Australia is performing well in the following areas:

- Aerospace Engineering with an average rating of 5.0
- Interdisciplinary Engineering with an average rating of 4.5
- Resources Engineering and Extractive Metallurgy with an average rating of 4.1
- Manufacturing Engineering with an average rating of 4.0
- Environmental Engineering with an average rating of 4.0

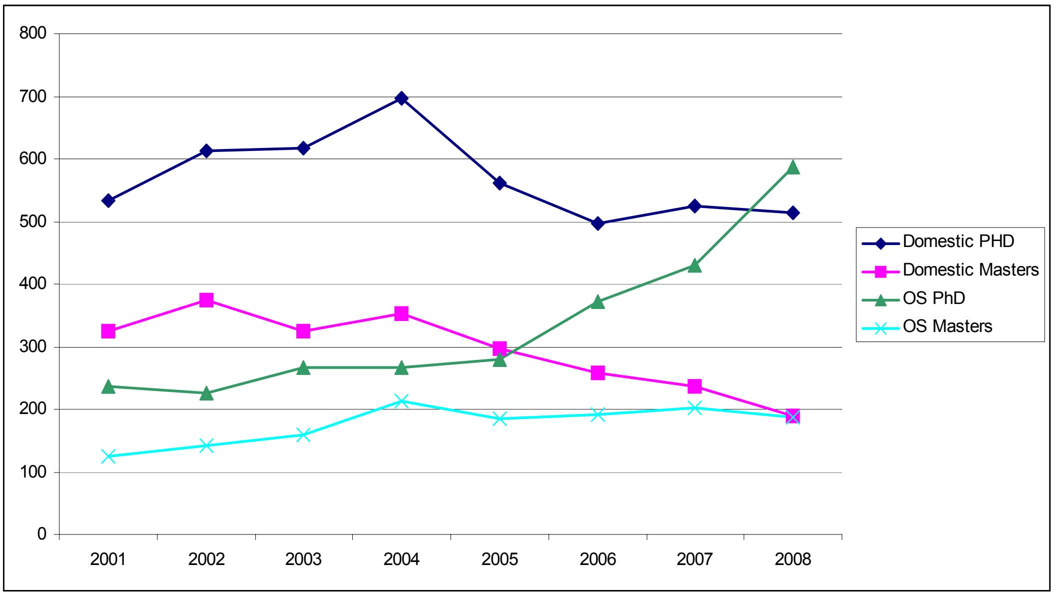
4.1.2 Supply to the engineering research workforce

HDR commencements and completions

Key Points

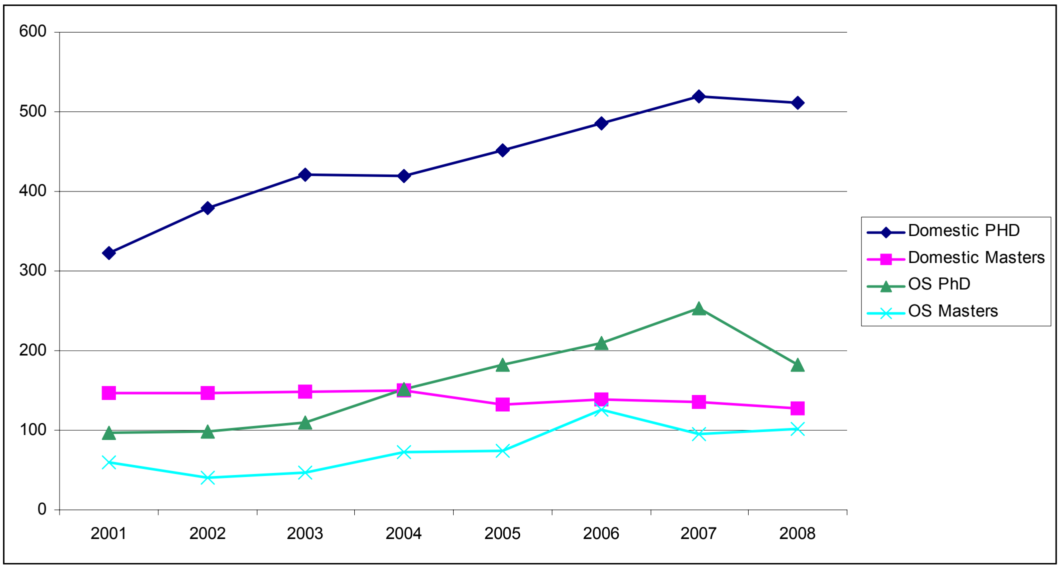
- *Australia's engineering research workforce is in constant flux due to ongoing inflows and outflows of HDR qualified people and shifts in the number of research active staff in different sectors of the economy.*
- *With respect to inflows of engineering HDR skills, the primary source is Australia's research training system through completions of domestic and international Doctorate by Research and Masters by Research students. Examination of historic trends of both commencements and completions provides a gauge (in combination with graduate destination surveys and migration data) of the pipeline of the skills that can be expected to be available to the workforce in future years.*
- **Figure 30** shows that the number of domestic PhD commencements in engineering appears to have levelled out, following strong growth between 2001 and 2004 and contraction between 2004 and 2006. In contrast, overseas PhD commencement levels have trended upward since 2022, with particularly strong growth from 2005.
- **Figure 31** shows that domestic PhD completions in engineering have followed an upward trend from 2001 to 2007, with a small decline in 2008. Overseas PhD completions have followed a similar trajectory, with a somewhat larger fall in 2008.
- Masters by Research numbers (both in completions and commencements) in engineering are slowly declining for domestic students, in line with a general cross-disciplinary trend towards a decline in the Masters by Research qualification. In contrast, overseas Masters by Research numbers in engineering have grown gradually over the period from 2001 to 2008.
- **Figure 32** indicates the size of the commencing engineering PhD cohort in comparison to other fields of education. This illustrates that engineering is the fourth largest research discipline by field of education for commencing PhD students.
- **Figure 33** illustrates that Australia performs moderately in comparison to other OECD member countries in its share of engineering graduates compared to all graduates of 'advanced research degrees' – the international measure closest to our PhD. Australia's output exceeds or is on par with the United Kingdom, the United States, New Zealand and Germany, but lags behind Korea, Japan, Canada and the Netherlands.
- **Figure 34** shows that the prior educational pathway to an engineering HDR is quite different for those undertaking a PhD compared to Masters by Research. Excluding overseas students whose prior highest educational attainment was either not recorded or had no Australian equivalent, 40 per cent of commencing engineering PhD candidates in 2008 had completed an undergraduate qualification and 38 per cent had completed a postgraduate qualification, compared to 52 per cent and 23 per cent of Masters by Research candidates respectively.

Figure 30: Engineering HDR commencements, 2001-2008



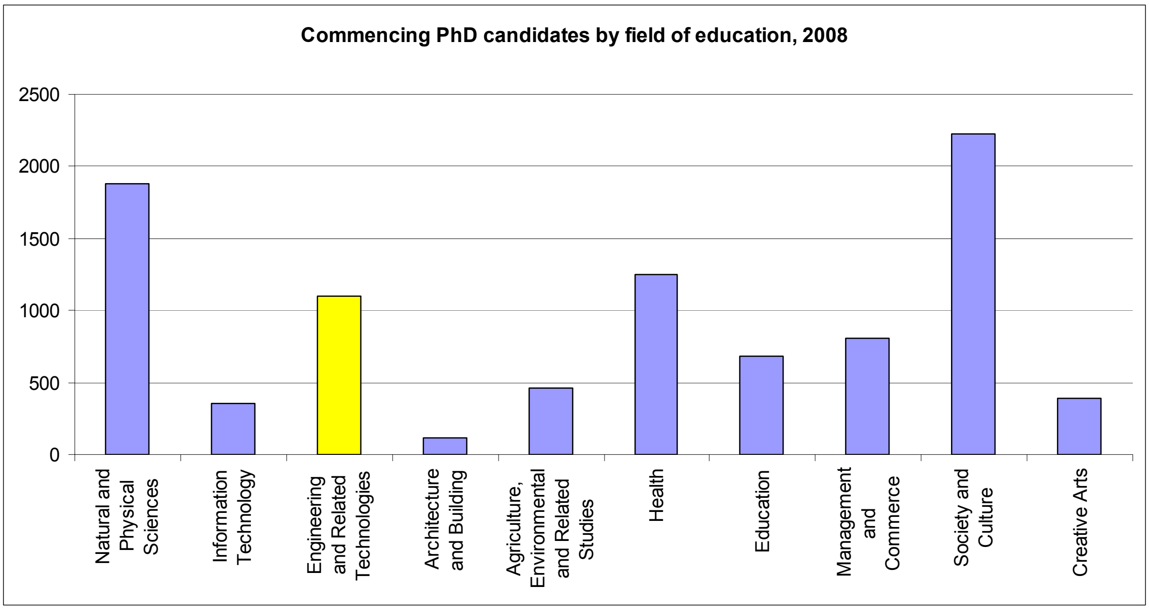
Source: DEEWR University statistics, unpublished data.

Figure 31: Engineering HDR completions, 2001-2008



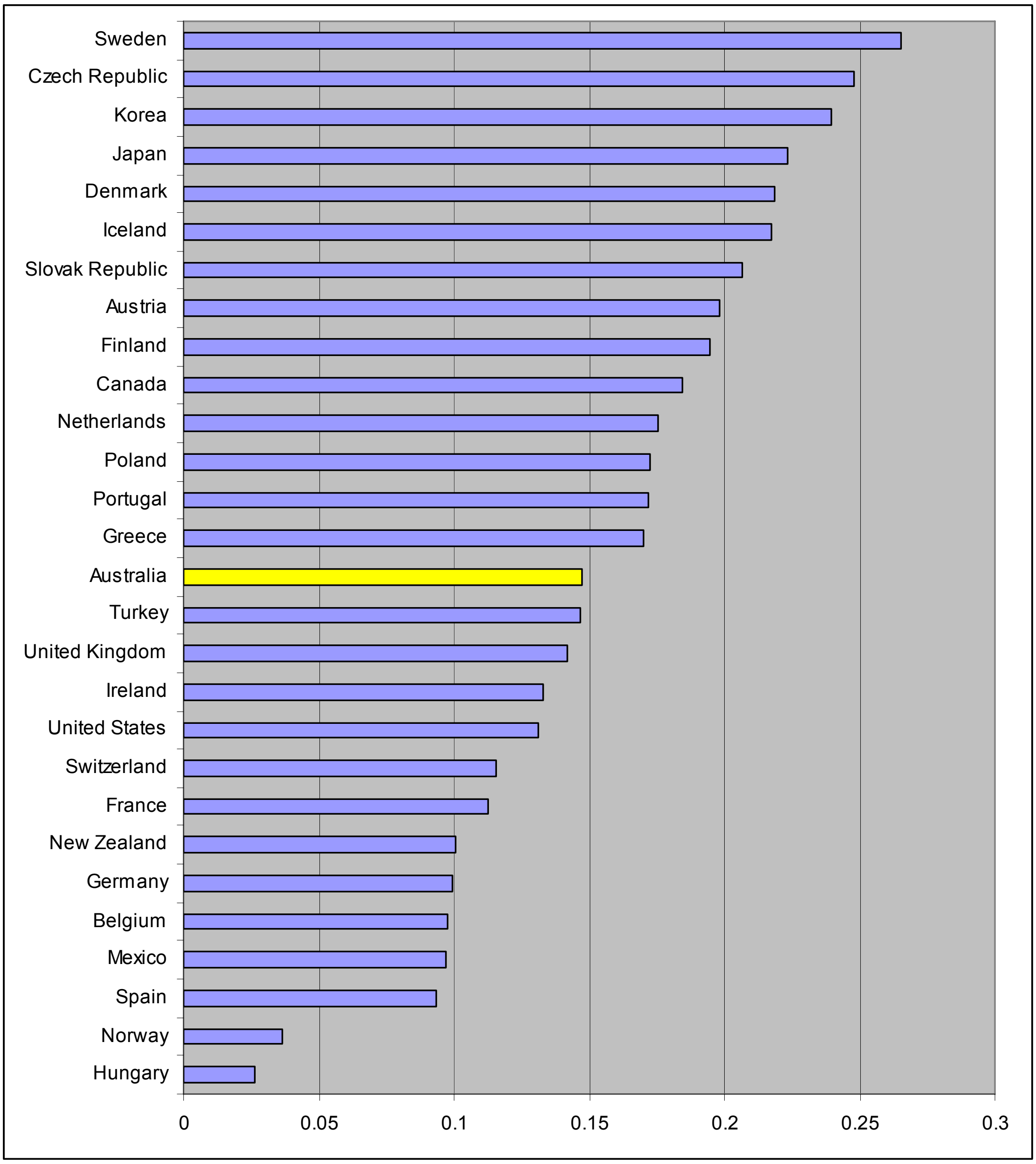
Source: DEEWR University Statistics, unpublished data.

Figure 32: HDR commencements by field of education, 2008



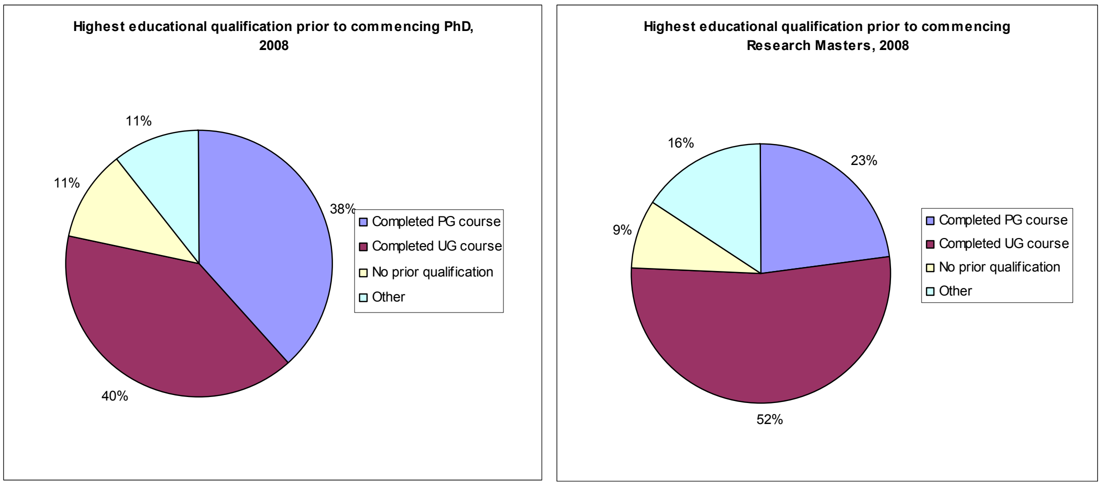
Source: DEEWR University statistics.

Figure 33: Engineering graduates as a percentage of all graduates of advanced research degrees, 2007



Source: *OECD Stat Extracts* Online Database.
Note: This data should be approached with care – differences in higher education systems can produce anomalous results when countries try to standardise their information to possibly incompatible OECD reporting requirements.

Figure 34: Highest educational qualification prior to commencing an engineering HDR, 2008



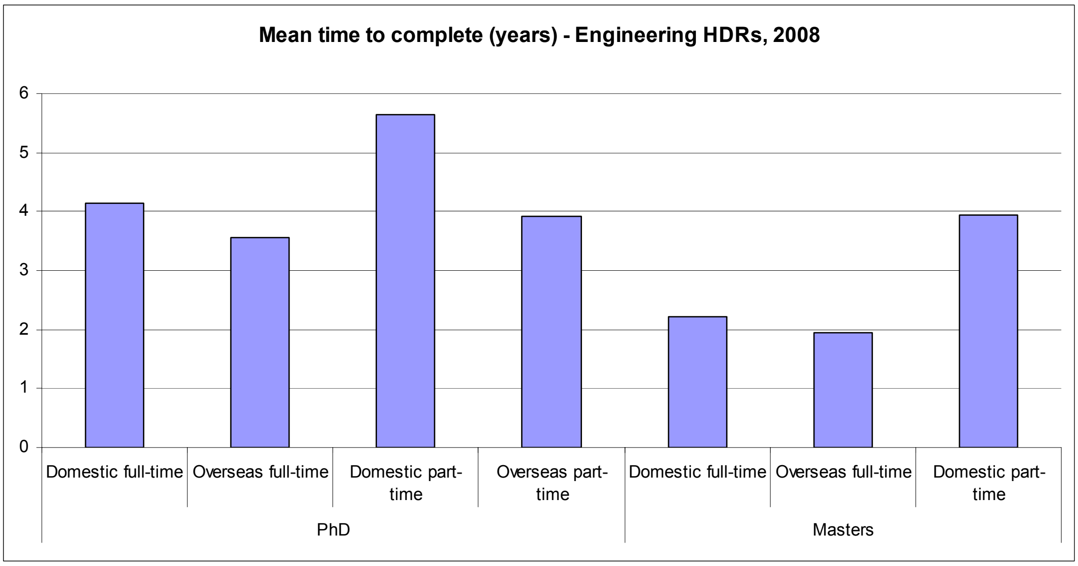
Source: DEEWR University statistics.
Note: *No prior qualification* includes those whose prior qualification was not stated. *Other* includes school and VET qualifications and qualification unknown.

HDR time to complete

Key Points

- *The time taken to complete HDR studies and mode of study (full-time versus part-time status) provides an indicator of the efficiency of the pipeline from research training to the workforce.*
- **Figure 35** indicates that on average, domestic full-time engineering PhDs complete in 4.1 years while domestic part-time PhDs complete in 5.6 years, compared to an overall mean completion time of 4.1 years and 6 years for full-time and part-time candidates respectively.
- For overseas engineering PhD candidates the average candidacy was 3.6 years for full-time and 3.9 years for part-time (noting that international candidates would usually only enrol on a part-time basis for a small proportion of their overall candidacy).
- The majority of both domestic and international HDR students were in full-time study in 2008.

Figure 35: Engineering HDRs average time to complete, 2008



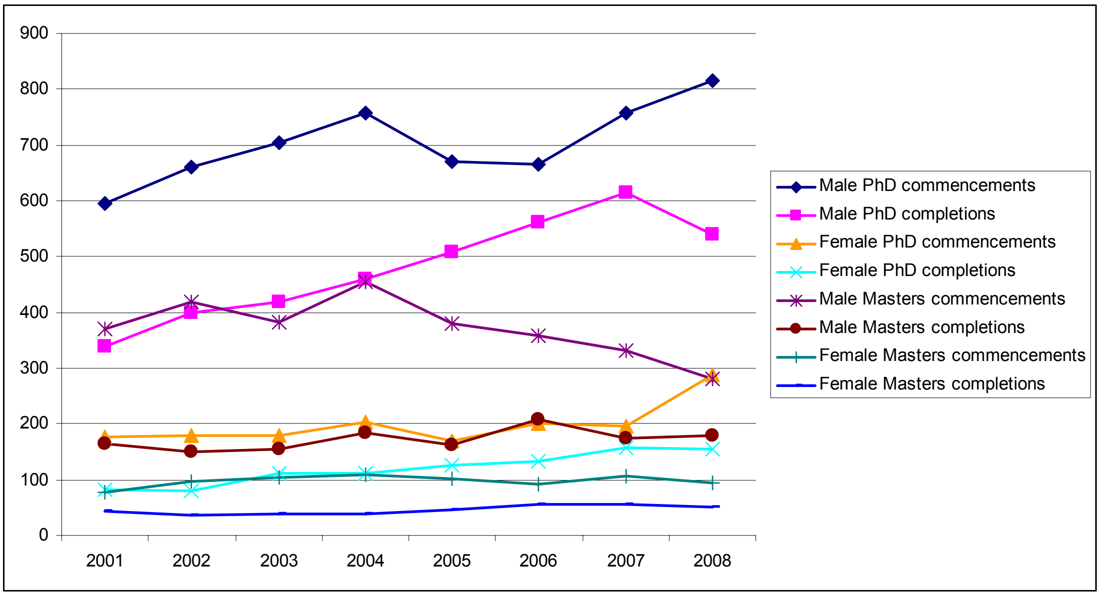
Source: Published and unpublished DEEWR Unistats data.
Note: International part-time Masters by Research candidates are not included as the sample size is too small.

Demographic data – commencements and completions by age and gender

Key Points

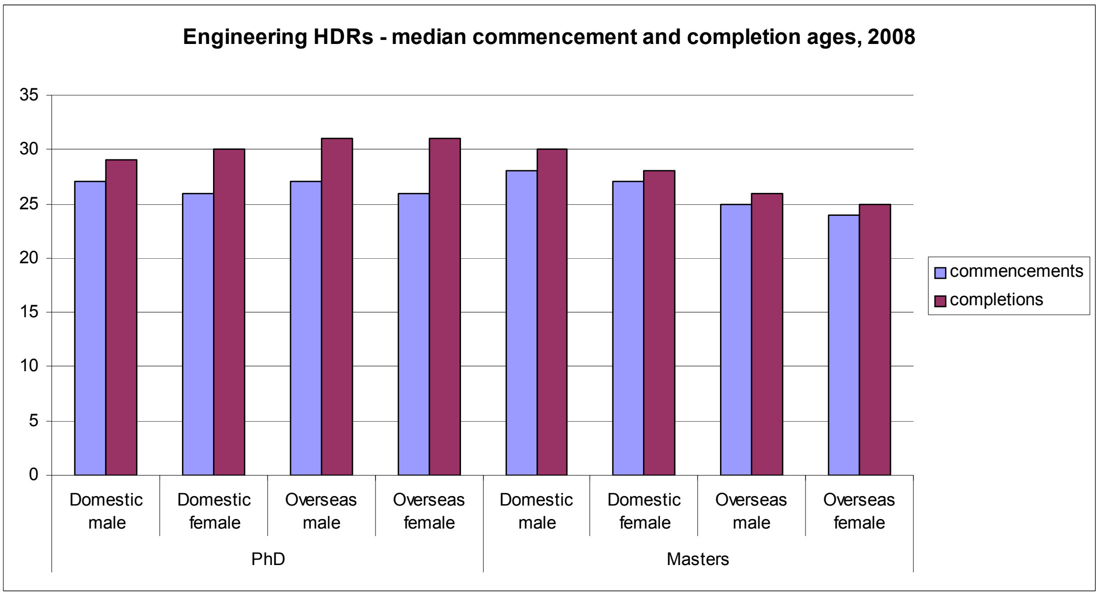
- *The age of engineering HDR candidates provides a useful (but not conclusive) gauge of the potential workforce contributions of graduates, while gender may reveal any persistent inequalities in participation in HDR degrees between the genders.*
- **Figure 36** shows a significant variation between male and female commencements and completions. The ratio of female commencements in engineering has only marginally changed from 2001 to 2008 (23% rising to 26%), with similar results for completions (females represented 20% of completions in 2001 and 22% in 2008).
- While the gender gap is narrowing, it is still more pronounced than the cross-disciplinary average. In 2008, for example, nearly 51 per cent of commencing PhD candidates were female.
- **Figure 37** shows that engineering HDR candidates tend to be younger than the median for all disciplines (33 years for domestic HDR completions). The median age for commencing male PhDs was 27 years while for commencing female PhDs it was 26 years in 2008. International PhD students' age profiles match their domestic counterparts.
- Domestic male and female median ages at completion were 29 and 30 respectively in 2008. Median ages of male and female completions in international PhDs in engineering were both 31.

Figure 36: Engineering commencements and completions by gender, 2001 to 2008



Source: Published and unpublished DEEWR Unistats data.

Figure 37: Median ages of commencing and completing engineering PhDs, 2008



Source: Published and unpublished DEEWR Unistats data.
Note: The chart shows median ages for two different cohorts – those who commenced and completed their HDRs in 2008.

Supply through migration

Key Points

- *A further key source of supply of engineering HDR-qualified individuals to Australia is through both temporary and permanent migration.*
- *While available data makes it difficult to discern the scale of supply for engineering through migration, previous studies (ACER, 2009) have estimated that approximately 22 per cent (including international students staying on in Australia following completion of their studies) of Australia's overall supply of HDR skills is achieved through this source*.
- Engineers can currently migrate to Australia under a number of visa classes. Within the general skilled migration program, engineers can apply under the SOL Schedules 2, 3 and 4. They are also eligible to apply under the Employer Nomination Scheme and State Sponsored Scheme. For example, the Western Australian Skilled Migration Occupation List (WASMOL) identified chemical engineers, civil engineers, geotechnical engineers, electrical engineers, electronics engineers, mechanical engineers, production or plant engineer, mining engineer, and petroleum engineers as skilled occupations in high demand in various industries in Western Australia.
- While quantification of the scale of supply of engineering PhDs to the workforce from international sources is limited by the granularity of data collected, ABS 2006 census data reveals that a majority (61%) of doctorate holders in engineering were born overseas, suggesting that international sources may be highly significant in maintaining Australia's base of researchers in this discipline.

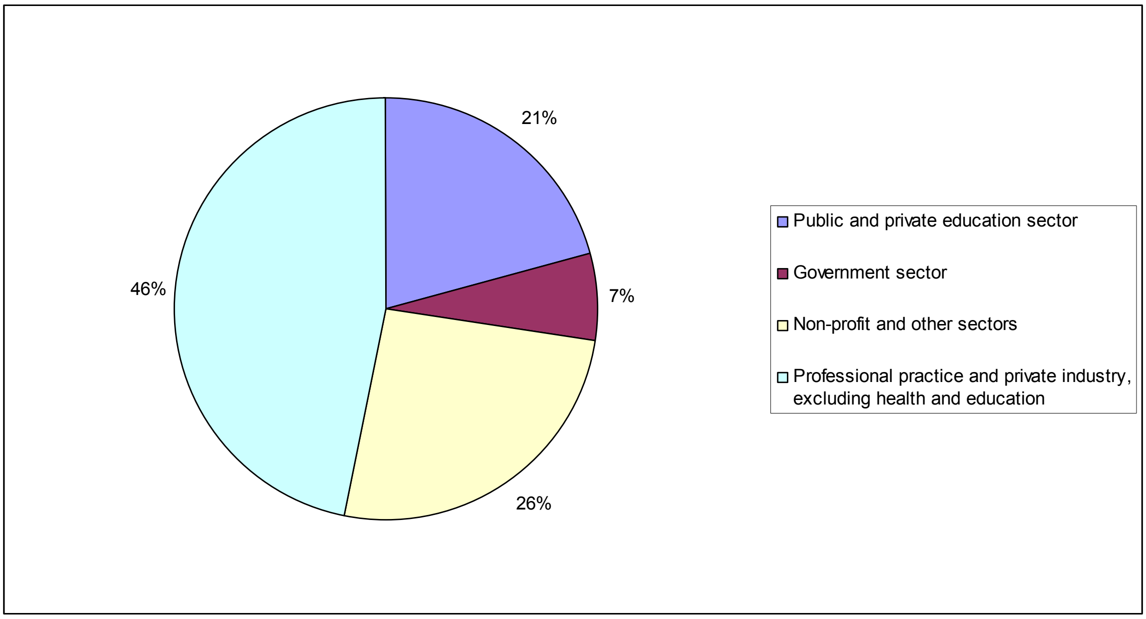
Note: SOL Schedule 2 applies to previous visa holders or those who applied for skilled independent work visas before 8 February 2010 and who are now applying for new work visas. This includes those who held student visas as of 8 February 2010 and may submit their applications until 2012. SOL Schedule 3 applies to all new general skilled migration applications. SOL Schedule 4 applies to visa applicants sponsored by state or region to work in Australia.

4.1.3 Demand and career prospects for engineering researchers and HDRs

Key Points

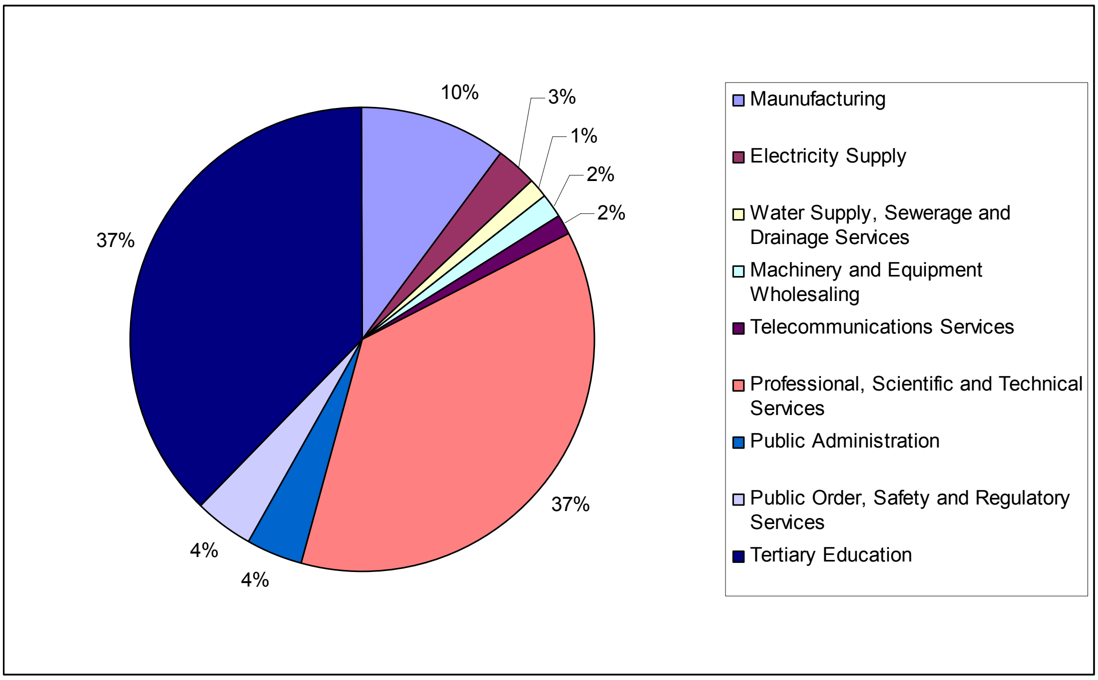
- *The immediate employment outcomes (employability and sector of employment) of engineering researchers and HDR graduates gives a sense of employer demand for research skills in this area. Graduate reflections on their preparedness for employment additionally provide a gauge of any mismatch between experience and skills garnered through research training and subsequent employment needs.*
- According to the Grads Online website which uses 2007 Graduate Destinations Survey, recent engineering HDR graduates were most likely to be employed in professional practice and private industry **(Figure 38)**.
- Examination of 2006 Census data relating to industry of employment for engineering Doctorate holders shows a reasonably similar pattern to that for recent graduates. The major change is in the increased proportion of engineers employed in education, particularly tertiary education (**Figure 39**).
- The 2008 Graduate Destination Survey reports that the starting salaries for full-time employed engineering HDR graduates ranged between $65,000 and $80,000 for individual disciplines in 2008.
- Responses to the 2008 Graduate Destination survey also indicate that the majority (67.9%) of engineering HDR graduates considered their HDR qualification a formal requirement or important to their job – percentages similar to the average across all disciplines (72%).

Figure 38: Employment sector destinations for full-time employed engineering HDR graduates, 2007



Source: Grads online database of the Graduate Careers Council of Australia Ltd.

Figure 39: Industry sector of employment for engineering Doctorate holders, 2006



Source: ABS Census 2006 special tabulation.

4.1.4 Summary points

Taken together, the quantitative trends examined in this case study suggest the following:

- Australia's engineering doctorate-qualified workforce is a small (just under 9% of the total) but significant component of Australia's total doctorate-qualified workforce.
- R&D expenditure in engineering is significantly greater than in any other field of research at the two-digit ANZSRC level. Australia performs above the world average in comparisons of relative citation impact in this discipline.
- Australia's supply of domestic engineering research skills through the research training system is currently stable and there is a strongly growing stream of international HDR candidates. However, declining numbers of school and undergraduate students with the necessary scientific and mathematical base to proceed through to advanced engineering training suggests that this may not remain the case in the future, putting at risk Australia's continuing good performance in this area. Furthermore, persistent gender imbalance in the attainment of engineering PhDs suggests that Australia still has some way to go to build female participation in this discipline.
- Employment prospects of engineering HDR graduates appear very positive, with the private sector being the most common immediate employment destination of graduates (i.e. around four to six months out from graduation).

4.2 What are the key influence factors (current and future)?

Pipeline issues

It is apparent from various sources[10] that the number of students from the secondary education system with the necessary grounding and skills to engage in engineering is decreasing, and that this trend is exacerbated by a shortage of specialist mathematics and science teachers in many jurisdictions.

While pipeline issues are not the focus of this study, clearly the supply of researchers is critically affected by both the number and the capacity of students wishing to undertake HDR studies. This is likely to be influencing both recent commencement and completion trends and can be expected to impact on future engineering HDR availability through the research training system if not addressed.

A corollary to the pipeline issue is the lack of information about research careers in primary and especially secondary education. This issue, while again out of scope of the research workforce strategy, has been identified by a number of disciplines.

Workforce demand in non-academic/non-research areas

The expert group expressed concern that good students in engineering are being 'head-hunted' by industry before commencing or completing their HDR studies and that high starting (and continuing) salaries for most engineers have attracted graduates away from postgraduate study. It is also evident that businesses are targeting high-performing undergraduates with offers of employment upon graduation and prior to any opportunity to consider postgraduate options. Such developments place considerable pressure on universities to provide additional incentives for students to undertake HDR study – incentives they are not always in a position to offer, in spite of the calibre of the student and the need to maintain a steady flow of HDR graduates in the discipline.

Lack of generic skills in recent graduates

In the opinion of the expert group, recent graduates often lack generic and specific skills for working in industry. In particular, communication skills and knowledge of commercialisation of research processes were raised as gap areas.

Impediments to mobility

The expert group reported significant impediments to the ability of researchers to move between public and private sector employment.

The group noted that while the salary differential between entry-level academic positions and starting salaries in private enterprise is well established, the differential at higher levels is also prohibitive and growing, meaning that a researcher wishing to make the transition to academia faces a massive drop in salary.

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[10] For example: Group of Eight (2009) *Review of Education in Mathematics, Data Science and Quantitative Disciplines;* Australian Academy of Science (2006) *Mathematics and Statistics: Critical Skills for Australia's Future, The National Strategic Review of Mathematical Sciences Research in Australia;* Engineers Australia *The Engineering Profession: A Statistical Overview 2010;* among others.

In addition, the group reported that there is often poor appreciation within industry of the value proposition of employing HDR graduates, both in research and non-research areas.

Areas of potential future shortfall
Almost all areas of specialisation in engineering were identified as experiencing unmet demand for skilled engineers. While the extent to which this unmet demand relates to research skills is not clear, it is likely that ongoing growth in these industries is likely to be accompanied by skills deepening, including increased utilisation of higher degree by research skills as companies are exposed to intensifying global competition.

Lack of data on the research activities of non-HDR engineering researchers
There is an understanding within the engineering research community that a significant amount of (mostly applied) research is conducted by engineers who do not hold HDRs, however there is a lack of data to confirm that this is the case and quantify the research effort of HDR and non-HDR researchers.

4.3 Engineering research workforce score-card

Score-card

	Quantity of supply through the research training system	Quality of supply through the research training system	Research workforce equity	Research workforce shortfalls	Employment prospects	Research career pathway support
Current	🟢	🟢	🟠	🟠	🟢	🟠
Future	🟠	🟠	🟠	🔴	🟢	🔴

Legend:

🟢	Green (performing well/stable/positive outlook)
🟠	Amber (some challenges/weaker than expected performance)
🔴	Red (poor performance/area(s) of concern/significant challenges)

4.4 How can Australia better position itself for the future?

Continuing efforts to address pipeline issues

The greatest area for concern with engineering is the pipeline from primary schooling through to undergraduate education. While there has not so far been a marked impact on HDR enrolments, it seems inevitable that if the decline in undergraduate enrolments continues there will be a flow-on effect at the postgraduate level.

While pipeline issues are outside the scope of the research workforce strategy, the expert group were of the view that a concerted effort needs to be made, building on existing positive initiatives across government and the education sector, to increase the supply of engineers by encouraging greater participation in mathematics and science in the school years.

Employer satisfaction with the quantity and quality of engineering HDR graduate skills

Members of the expert group suggested that greater industry involvement in research training and in the early, formative stages of a research career would assist in improving the match between engineering HDR attributes/capabilities and employer needs. More industry oriented post-doctoral positions and internships were suggested as potential means to facilitate this outcome, along with strategic workshops focused on key research areas such as robotics, medical engineering, energy and water.

Members also suggested that further work was required to build industry awareness of the potential contributions of HDR-qualified individuals to organisational capacity. Finally, members suggested that greater effort is needed on the part of industry to present HDR employees with realistic long-term career pathways and professional development that includes management and leadership elements.

Addressing information gaps

Much of the currently available information about the state of engineering does not relate directly to the training of or demand for research-trained individuals. In addition, there is little information available to support an understanding of the contribution or 'value-add' of a HDR to progression through an engineering career (for example, as defined by Association of Professional Engineers, Scientists and Managers responsibility levels).

There is an opportunity for improved data gathering both by universities and by government to fill these gaps. Members of the expert group highlighted the importance of private enterprise engagement in helping to identify and prioritise information gaps for this purpose.

Collaboration to provide better career pathway options

The expert group considered that better collaboration between industry, academia and government research bodies was one way to enhance the careers of engineering researchers. Members suggested some specific areas of collaboration be investigated, including: workshops for staff from universities and CSIRO to explore industry research training opportunities; encouraging strategic international collaborations between universities and key overseas industry partners; and, establishing strategically oriented industry/university workshops in key research sectors including robotics, medical engineering, energy and water.

5 Health

For the purposes of this case study, ‘health’ is described as the research disciplines directly corresponding to the educational field of Division 6 – Health of the *Australian Standard Classification of Education*, excluding veterinary science. It is not possible to list the differences between this definition and that of Division 11 – Medical and Health Sciences of the *Australian and New Zealand Standard Classification of Research* (ANZSRC) as the scope of both collections are essentially different and a suitable concordance between the classifications does not exist.
Note: ABS Research and Experimental Development data reported in this case study refers to the definition of medical and health sciences from ANZSRC Division 13.

5.1 How is Australia tracking?

The following areas have been selected for analysis:

- The scale of the health research workforce in Australia – PhDs in the workforce (noting that a significant number of professional clinical staff are engaged in research activities without formal high-level research qualifications);
- The health research environment in Australia – research and development expenditure and ERA 2010 results;
- Supply to the health research workforce – HDR completions in Australia and through long-term or permanent migration; and
- Demand for health researchers – employability and remuneration.

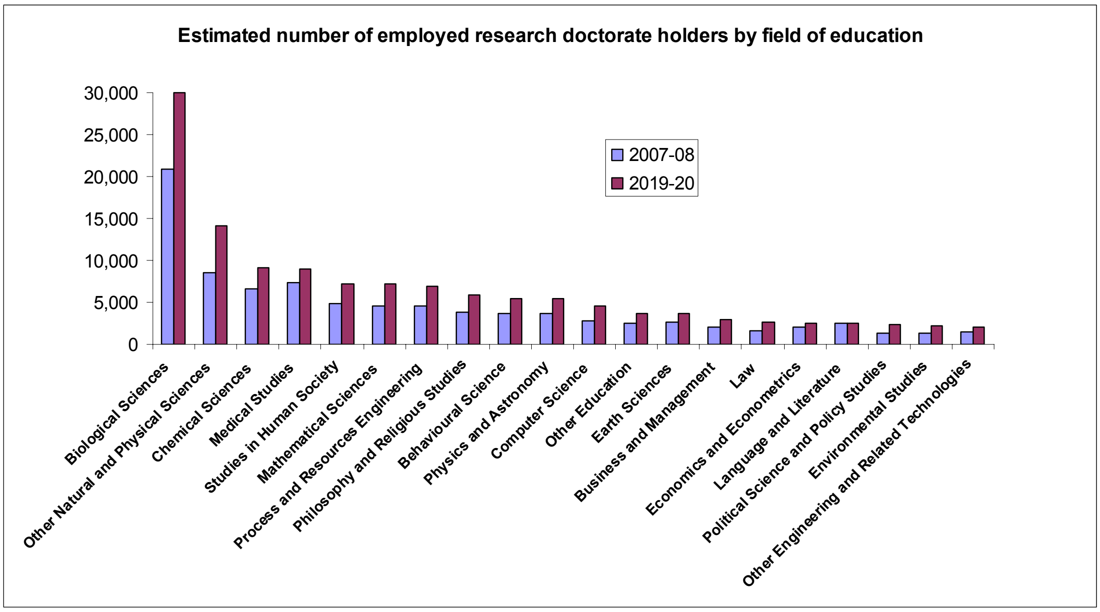
5.1.1 The health research workforce and its research environment.

PhD qualified individuals in the workforce

Key Points

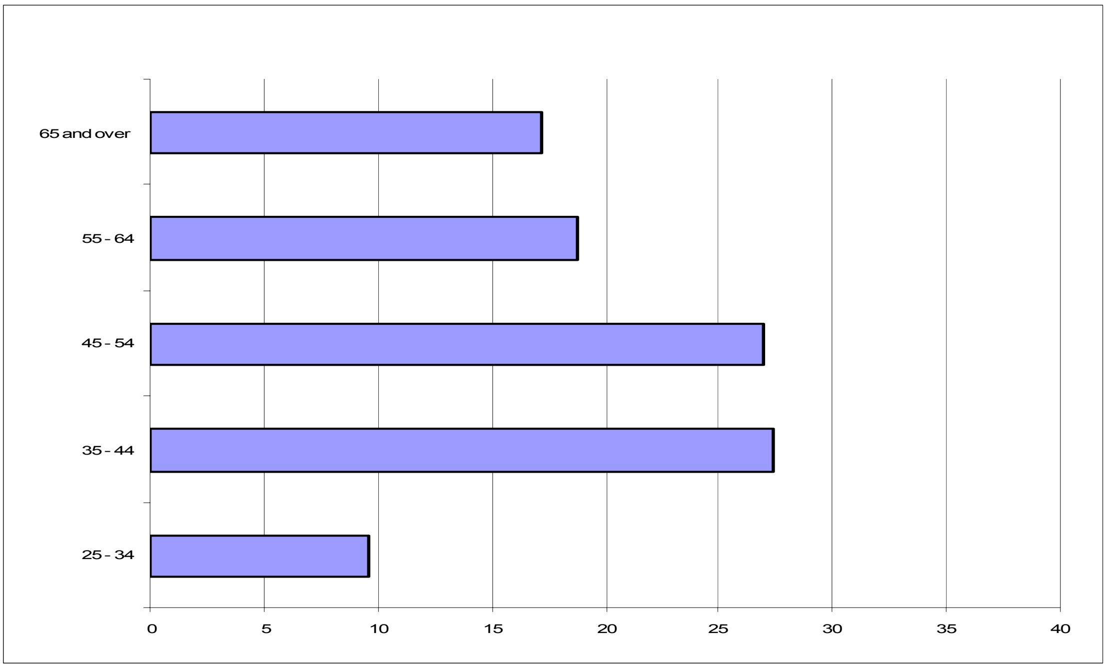
- *The number of individuals in the workforce with a health HDR qualification gives an indication of the scale of Australia's research human capital in the discipline – i.e. our capacity for research in this discipline.*
- That said, health also has a large professionally trained (not necessarily research-trained) clinical workforce that also undertakes or assists in research projects.
- Census data from 2006 indicates that health Doctorate holders represent approximately 21 per cent of Australia's employed Doctorate workforce. Care must be taken in interpreting this data to represent the research workforce as health, and in particular medicine, has a significant proportion (around 54%) of Doctorate holders having a professional Doctorate based on their clinical training – most often originating from holding a fellowship in one of the professional colleges, rather than a research qualification.
- Data limitations make it difficult to establish how many health doctorate holders identified in the Census data are research active or to make robust cross-country comparisons.
- The PhD workforce in medical studies is projected by recent ACER modelling (2009) to grow by just over 22.6 per cent by 2020 (**Figure 40**).
- Within the university sector, a 2010 study for Universities Australia by Graeme Hugo indicates that a moderate proportion (around 40%) of academic (predominantly research active) staff in a number of disciplines within the health discipline were in the older age brackets (50+) in 2006. The main area for concern regarding the age profile in health research is in nursing (where 51% of the academic workforce was aged 50 or over in 2006). However, very strong growth in undergraduate nursing places since 2000 may have a flow-on effect to post-graduate study and the research workforce in the future.
- **Figure 41** shows that most doctorate holders in health in 2006 were in the 35 to 44 year age bracket with significant numbers in the 45 to 54 and 55 to 64 year brackets.

Figure 40: Estimated number of employed research Doctorate holders, by field of education, 2007-08 to 2019-20



Source: Australian Council for Educational Research, *Supply, Demand and Characteristics of the Higher Degree by Research Population in Australia*, Report for the Department of Innovation, Industry, Science and Research, June 2009, p. 54.

Figure 41: Age distribution of health Doctorate holders, 2006



Source: ABS Census of population and housing 2006, special tabulation.

Clinicians and nurses engaged in research[11]

Key points

- *Medicine is one of a few traditional areas where research can flourish in the absence of formal HDR qualifications.*
- The Australian Institute of Health and Welfare (AIHW) estimates that the average employed medical clinician spends 6.7 hours per week (out of 43.4 total hours worked) engaged in research.
- Among non-clinicians, the amount of time engaged in research is significantly greater, as shown in **Table 1.**
- Grossed-up estimates from the AIHW medical labour force survey conducted in 2007 indicate that there were 62,700 employed medical practitioners in clinician roles out of a total workforce of 67,200.
- The survey also estimated that there were 1,150 medical practitioners employed as researchers.
- In the corresponding nursing and midwifery labour force survey, also conducted in 2007, the AIHW estimated that there were 2,000 registered nurses and 130 enrolled nurses employed as researchers, out of total labour forces of 212,000 and 51,000 respectively.

Table 1: Employed medical practitioners: average hours spent in different roles by main occupation, 2007

	Medical roles							
Occupation of main job	**Clinician**	**Admin-istrator**	**Teacher/ Educator**	**Researcher**	**Public health physician**	**Occupational health physician**	**Other**	**Total**
Clinician	*40.6*	*6.7*	*4.6*	*6.7*	*6.7*	*6.9*	*5.9*	*43.4*
Primary care	37.3	5.8	4.7	5.9	6.0	6.7	5.8	39.0
Hospital non-specialist	46.5	8.4	4.3	6.8	5.6	4.5	8.4	47.5
Specialist	39.6	7.2	4.8	6.8	7.5	7.7	5.7	44.5
Specialist-in-training	47.8	6.3	3.9	6.3	5.8	8.9	5.8	49.6
Other clinicians	32.9	8.1	4.8	9.3	5.3	4.5	5.3	34.8
Non-clinician	*11.5*	*27.6*	*13.2*	*26.7*	*28.2*	*28.3*	*21.3*	*39.0*
Administrator	12.3	33.7	6.3	8.7	11.1	8.3	9.5	43.8
Teacher/Educator	12.0	8.8	23.1	9.6	13.8	4.1	7.4	34.2
Researcher	11.1	7.5	6.0	33.4	8.3	6.0	12.4	43.0
Public health physician	10.9	10.8	7.4	10.5	34.1	13.6	12.6	39.4
Occupational health physician	9.9	11.0	4.9	—	8.3	31.8	12.7	36.1
Other	9.9	6.3	4.3	9.4	1.0	9.4	24.2	27.7
Total	**39.7**	**10.0**	**5.7**	**12.2**	**17.4**	**17.5**	**10.9**	**43.1**

Note: Table cells do not add to totals because the averages are based on the population reporting hours in each occupation, rather than all practitioners.
Source: AIHW Medical Labour Force Survey, 2007.

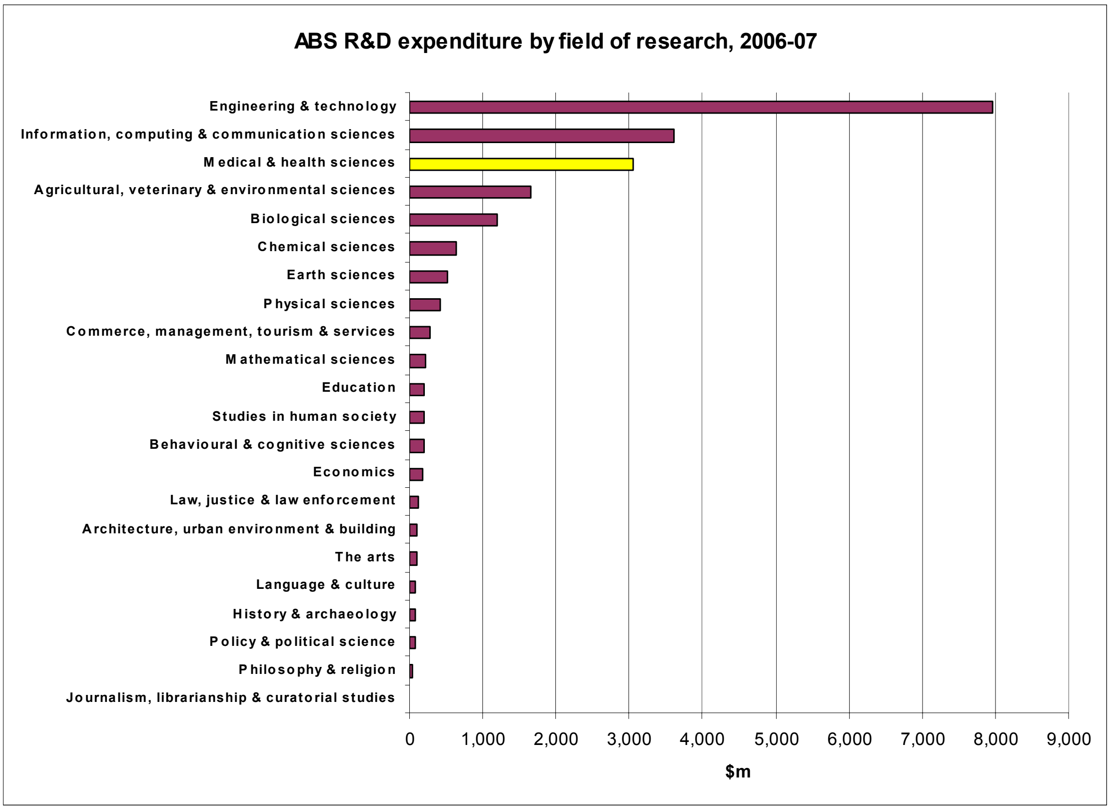
[11] The Australian Institute of Health and Welfare (AIHW) surveys give no guidance as to who is a researcher and what is included in research. It is likely therefore that the scope of 'research' for these surveys would exceed those for the ANZSRC or Frascati manual.

R&D expenditure on health

Key Points

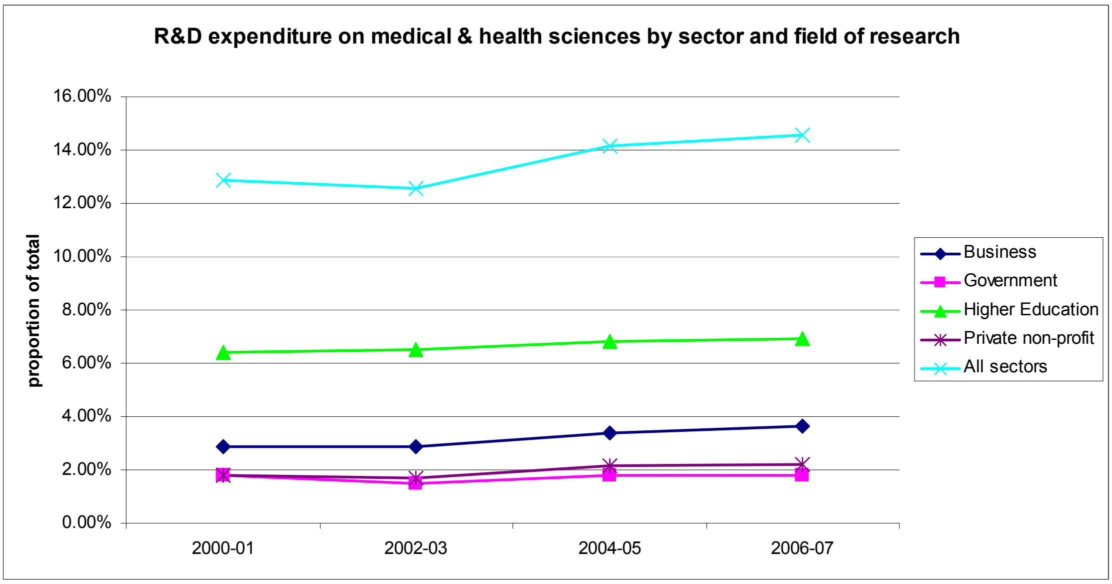
- *The scale of the research workforce in health is likely to be influenced by a number of factors. Investment in the sector is particularly important in this context as it influences the demand for research staff in different sectors of the economy (e.g. business, government, universities, not-for-profit organisations etc).*
- Expenditure on R&D in the field of *medical and health sciences* (note: the ABS does not record R&D expenditure for health alone) stood at $3.05 billion in 2006-07. Expenditure has trended upwards as a share of total R&D spending from around 12.9 per cent in 1996-97 to 14.5 per cent in 2006-07. Medical and health sciences is ranked number three in terms of R&D expenditure by field of research (**Figure 42**). This figure ranks expenditure against all major fields of research as identified by the ABS in accordance with international practice.
- While R&D expenditure in medical and health sciences is performed mainly in the higher education sector (**Figure 43)**, expenditure by the business sector is increasing at a faster rate than that for the higher education sector.

Figure 42: R&D expenditure by field of research, 2006-07



Source: ABS cat. No. 8112.*0 Research and Experimental Development, All Sector Summary, 2006-07.*
Note: The major sources of funds for R&D expenditure were from the Commonwealth Government, State and Territory governments, business, overseas and other Australian sources.

Figure 43: Medical and health sciences share of total R&D expenditure by performing sector



Source: ABS cat. No. 8112.*0 Research and Experimental Development, All Sector Summary* 2006-07.
Note: the *All Sectors* figure includes expenditure on R&D performed by the private non profit sector as well as the business, government and higher education sectors.

ERA 2010 results for Medical and Health Sciences

In ERA 2010 the Medical and Health Sciences fields consist of Biomedical and Clinical Research (BCH) and Public and Allied Health Sciences (PAH).

For BCH the ERA 2010 results show that 35 higher education institutions were assessed at the broad two-digit level with a national rating of 3.2. Nine institutions are performing well above world standard (a rating of 5). Three institutions are performing at above world standard (a rating of 4) and 12 institutions are performing at world standard (a rating of 3).

For PAH the ERA 2010 results show that 38 higher education institutions were assessed at the broad two-digit level with a national rating of 2.7. One institution is performing well above world standard (a rating of 5). Seven institutions are performing at above world standard (a rating of 4) and 14 institutions are performing at world standard (a rating of 3).

At the specific four-digit level in both BCH and PAH, Australia is performing well in the following areas:

- Immunology with an average rating of 4.5
- Cardiovascular Medicine and Haematology with an average rating of 4.5
- Oncology and Carcinogenesis with an average rating of 4.3
- Medical Physiology with an average rating of 4.3

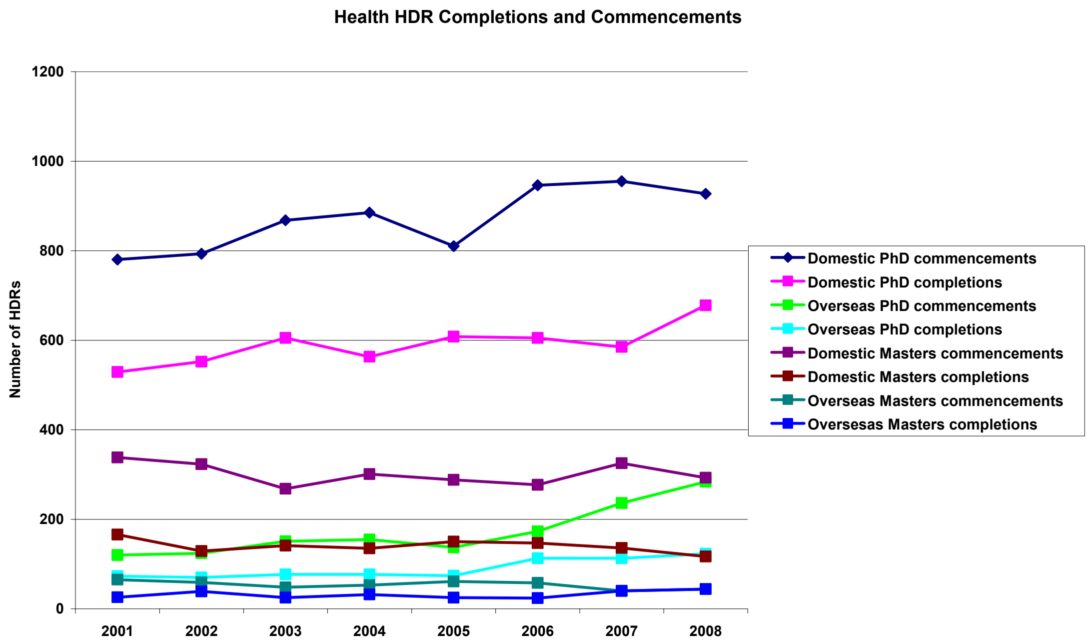
5.1.2 Supply to the health research workforce

HDR commencements and completions

Key Points

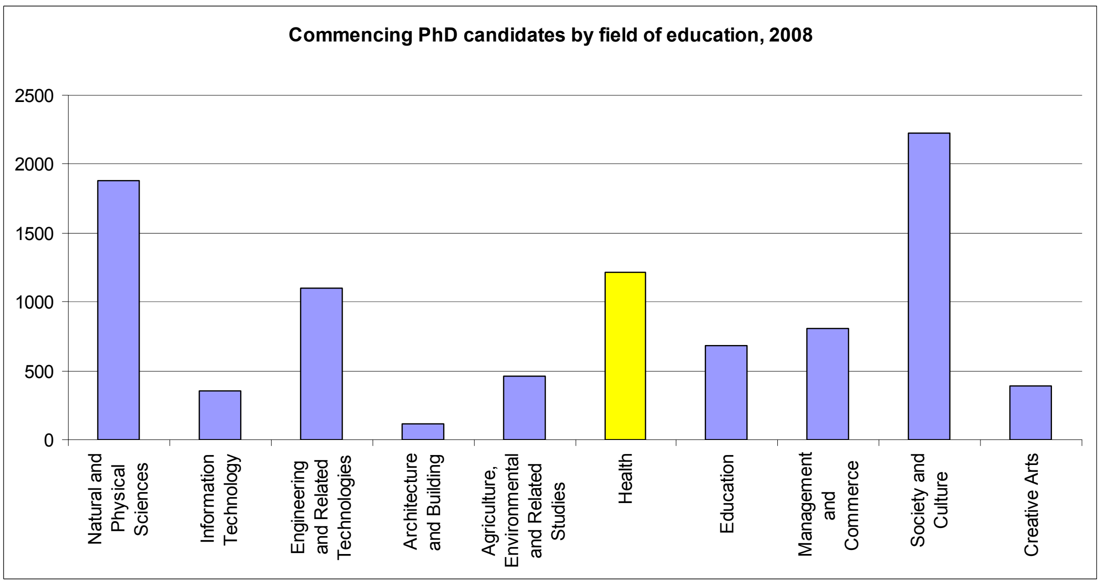
- *Australia's health research workforce is in constant flux due to ongoing inflows and outflows of HDR qualified individuals and shifts in the number of research active staff in different parts of the economy.*
- *With respect to inflows of health HDR skills, the primary source is Australia's research training system through completions of domestic and international Doctorate by Research students. Examination of historic trends of both commencements and completions provides a gauge (in combination with graduate destination surveys and migration data) of the pipeline of the skills that can be expected to be available to the workforce in future years.*
- **Figure 44** shows that the number of domestic PhD commencements in health sciences has grown substantially from 2001 to 2007, with downward movements in 2005 and 2008. Domestic PhD completions have shown similar growth from 2001 to 2008 with slight falls in 2004 and 2007. Overseas PhD commencements have also grown over the period, with especially strong growth from 2005 to 2008. Overseas PhD completions have also grown but at a slower rate than commencements.
- Declines in both commencements and completions of domestic Masters by Research degrees (in common with most other disciplines) have been almost offset by modest increases from overseas candidates.
- **Figure 45** indicates the size of the commencing health PhD cohort in comparison to other fields of education. This illustrates that the health discipline is the third largest of all fields.
- **Figure 46** illustrates that Australia's performance is moderate compared to other OECD countries in terms of the proportion of health graduates of 'advanced research degrees' – the international measure closest to our PhD compared to all graduates. Australia performs better than Canada and New Zealand and is on a par with the United States. However, compared to Australia, Japan, Korea, Germany and the United Kingdom, among others, have a significantly greater share of health graduates among graduates in advanced research degrees of all fields.
- **Figure 47** shows that the prior educational pathway before commencing a health PhD is quite similar for PhD and Masters by Research candidates. Around half of the candidates for each HDR came from an undergraduate award, while around one third of masters and 40 per cent of PhD candidates had a prior postgraduate qualification before commencing their HDR.

Figure 44: Health sciences HDR completions and commencements, 2001-2008



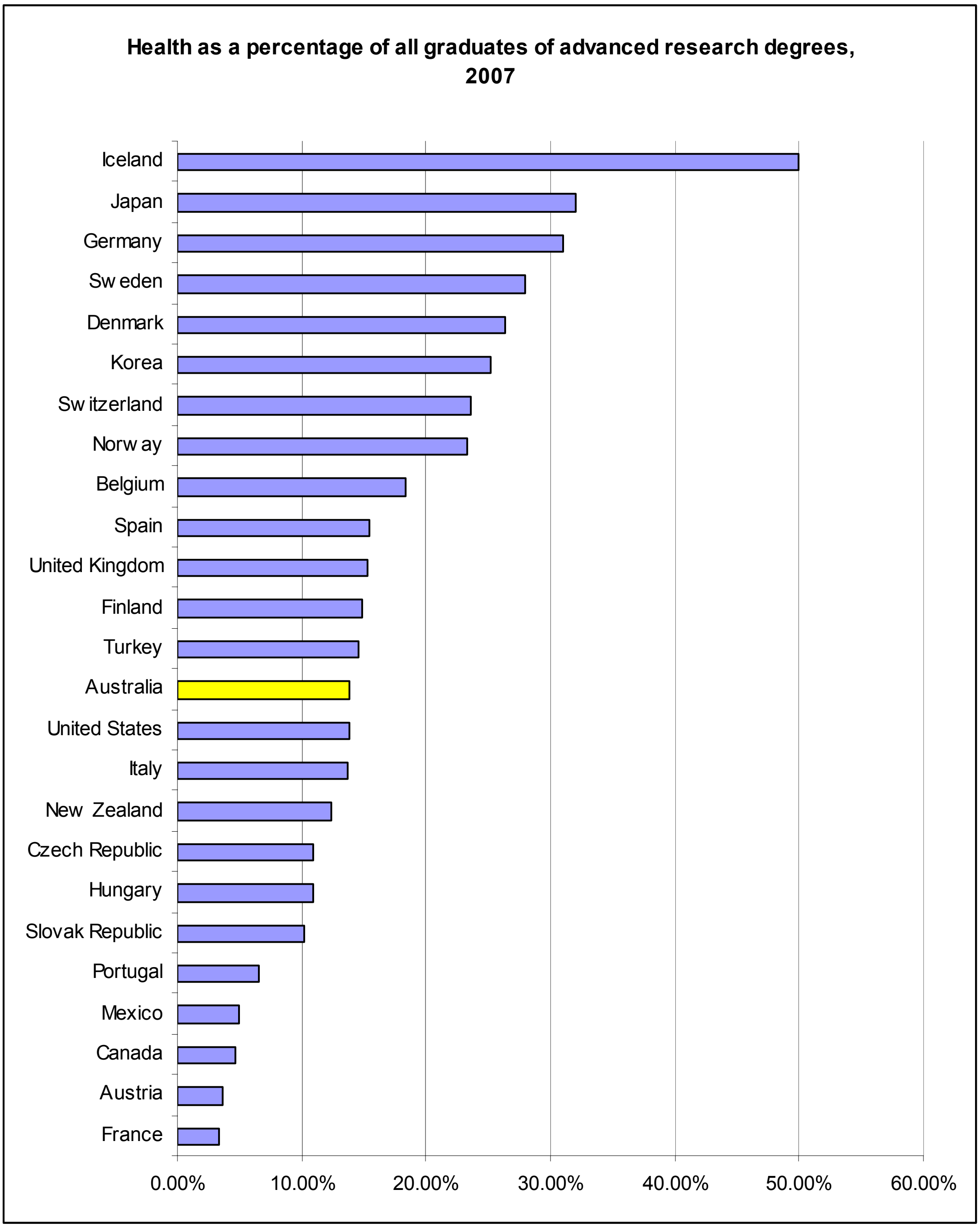
Source: DEEWR University statistics, unpublished data.

Figure 45: PhD commencements by field of education 2008



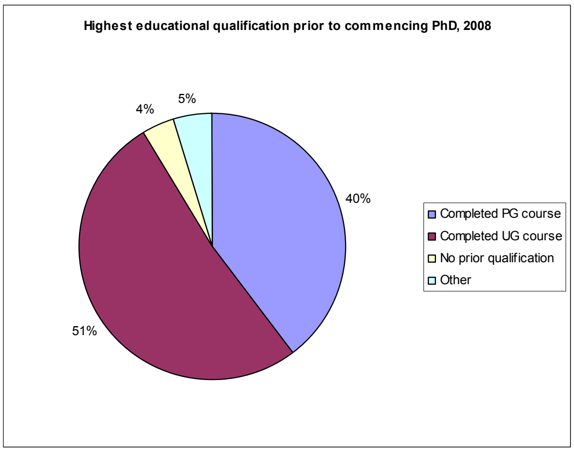
Source: DEEWR University statistics, unpublished data.

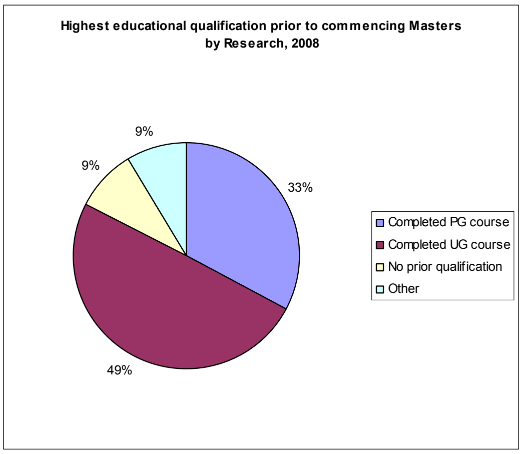
Figure 46: Health graduates as a percentage of all graduates of advanced research degrees, 2007



Source: *OECD Stat Extracts* Online Database.
Note: This data should be approached with care – differences in higher education systems can produce anomalous results when countries try to standardise their information to possibly incompatible OECD reporting requirements.

Figure 47: Highest educational qualification prior to commencing a health HDR, 2008





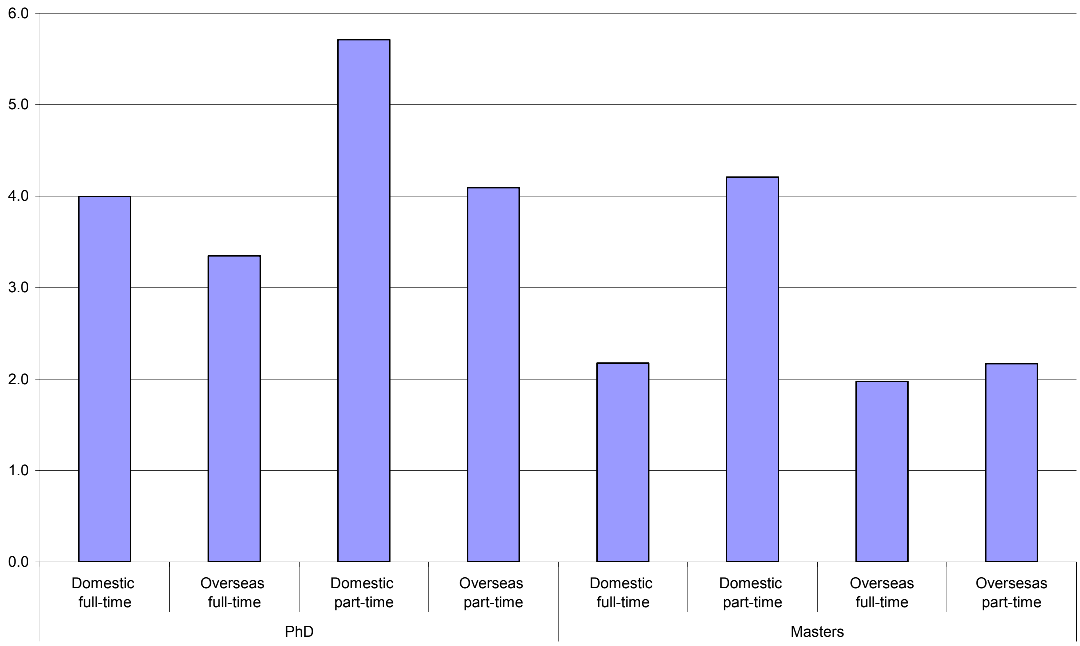
Source: Published and unpublished DEEWR Unistats data.

HDR time to complete

Key Points

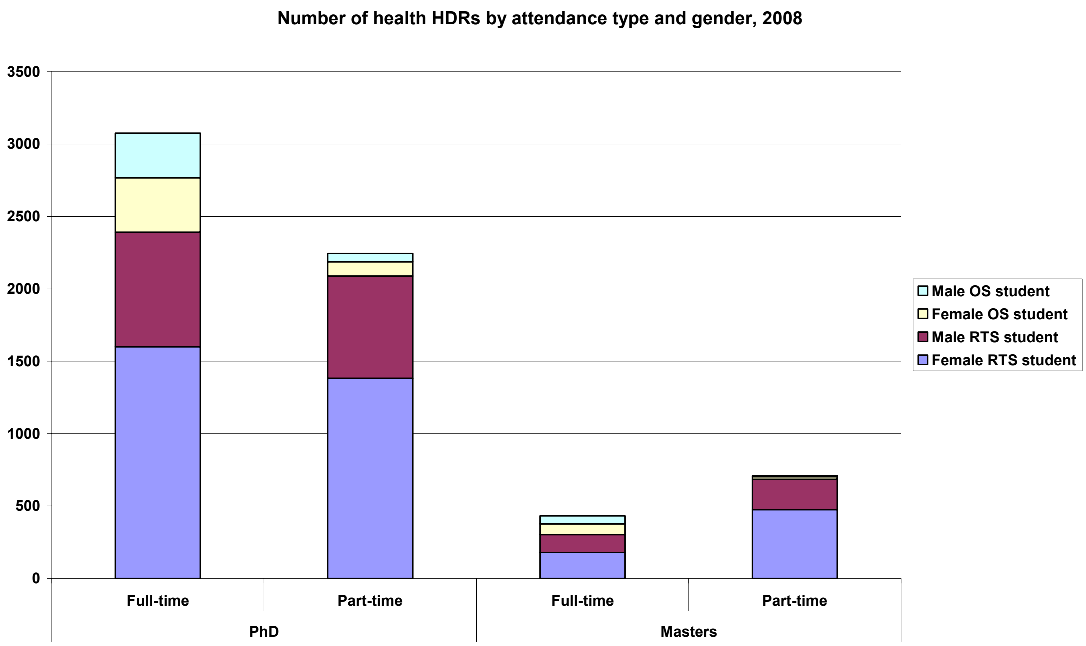
- *The time taken to complete HDR studies and mode of study (full-time versus part-time status) provides an indicator of the efficiency of the pipeline from research training to the workforce.*
- **Figure 48** indicates that on average, domestic full-time health PhDs complete in 4.0 years while domestic part-time PhDs complete in 5.7 years, compared to the overall mean completion times of 4.1 years and 6.0 years respectively for students across all disciplines in 2008. International PhD candidates complete in 3.3 years while their part-time counterparts complete in 4.1 years.
- The majority of PhD candidates were in full-time study in 2008 (and significantly so for international PhDs) while there were more part-time than full-time candidature for Masters by Research (**Figure 49**).

Figure 48: Health HDRs average time to complete, 2008



Source: Published and unpublished DEEWR Unistats data.

Figure 49: Health HDR candidates by attendance mode and gender, 2008



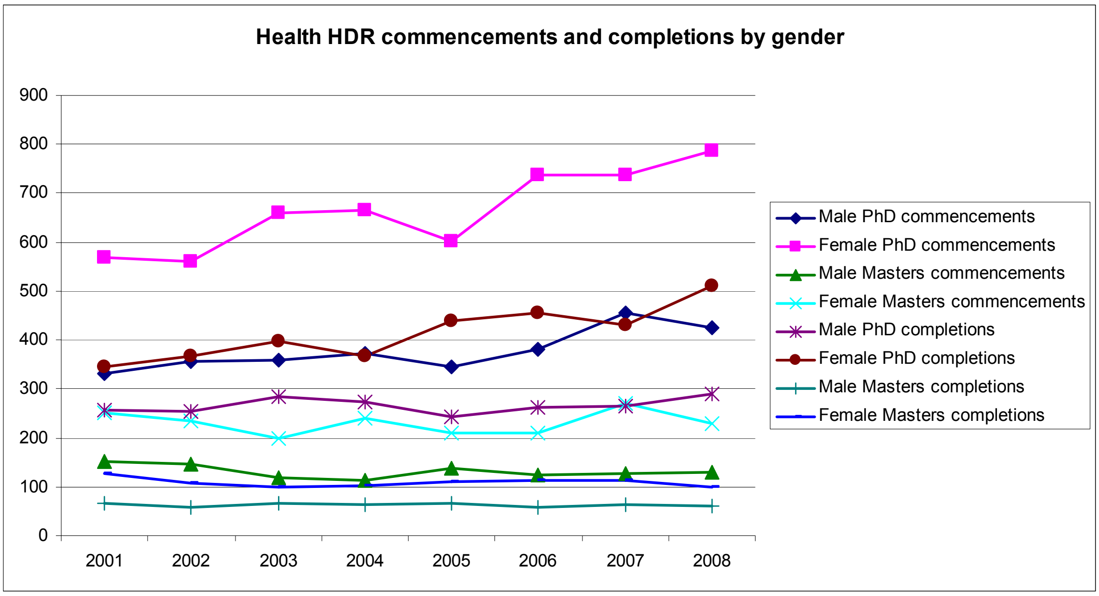
Source: Published and unpublished DEEWR Unistats data.

Demographic data – commencements and completions by age and gender

Key Points

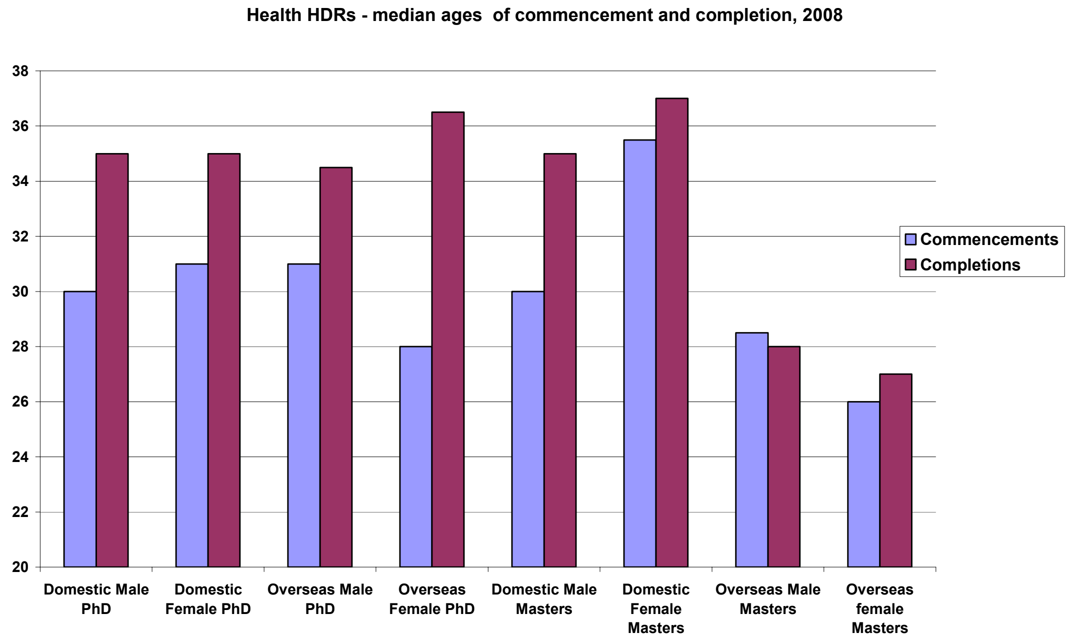
- *The age of health HDR students provides a useful (but not conclusive) gauge of the potential workforce contributions of graduates (based on years to retirement), while gender may reveal any persistent inequalities in participation in HDR degrees between the genders.*
- **Figure 50** shows a significant disparity between male and female commencement and completions. Around double the number of females commence HDRs in health than males and the gap is widening.
- Within the discipline there are, for example, some greater gender disparities such as in nursing. There are now more female medicine commencements at the undergraduate level than males, but this has not translated fully to HDR candidates. The AIHW 2007 survey indicates that there was double the number of male medical practitioners working as researchers than females.
- **Figure 51** shows that health HDR candidates tend to be slightly younger than the average for all disciplines (37.1 years for domestic HDR completions). The median age for commencing male and female PhDs was 30 and 31 years respectively. Female international PhD students tend to be younger, with a median commencing age of 28 years.
- Median ages of male and female completions of domestic PhDs in health were the same at 35 years. However, despite starting at an earlier age, female international PhD candidates had median completion ages of 37.

Figure 50: Health HDR commencements and completions by gender, 2001 to 2008



Source: Published and unpublished DEEWR Unistats data.

Figure 51: Median ages of commencing and completing health HDRs, 2008



Source: Published and unpublished DEEWR Unistats data.
Note: The chart shows median ages for two different cohorts – those that commenced and completed their HDRs in 2008.

Supply through migration

Key Points

- *A further key source of supply of health HDR-qualified individuals to Australia is through both temporary and permanent migration.*
- *While available data makes it difficult to discern the scale of supply for health researchers through migration, previous studies (ACER, 2009) have estimated that approximately 22 per cent (including international students staying on in Australia following completion of studies) of Australia's overall supply of HDR skills is achieved through this source.*
- Health researchers can currently migrate to Australia under a number of visa classes, most notably based on their professional clinical qualifications. Within the general skilled migration program, health researchers can apply under the SOL Schedules 2 and 4. They are also eligible to apply under the Employer Nomination Scheme and have access to a variety of temporary visa classes for work, collaboration or study.
- While quantification of the scale of supply of medical and health sciences PhDs to the workforce from international sources is limited by the granularity of data collected, Hugo's (2009) analysis of census data reveals that research disciplines related to health have a lower than average proportion of overseas born than other sectors. However, the Census data in 2006 also indicates that 48 per cent of health Doctorate holders were born overseas, almost exactly equal to the proportion across all fields. This indicates that immigration may be a moderate to average source of researchers in this field.

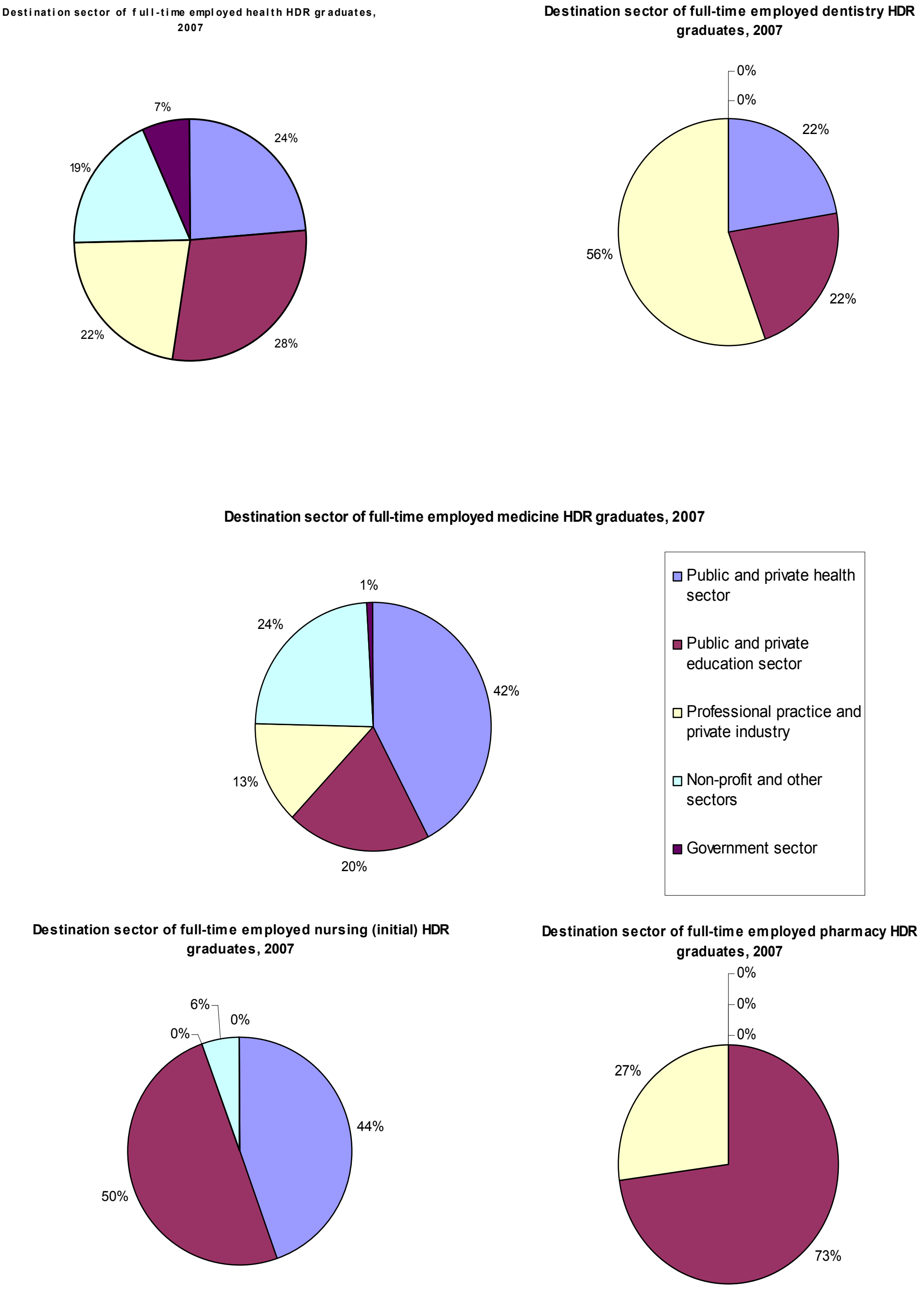
Note: SOL Schedule 2 applies to previous visa holders or those who applied for skilled independent work visas before 8 February 2010 and who are now applying for new work visas. This includes those who held student visas as of 8 February 2010 and may submit their applications until 2012. SOL Schedule 4 applies to visa applicants sponsored by state or region to work in Australia.

5.1.3 Demand and career prospects for health researchers and HDRs

Key Points

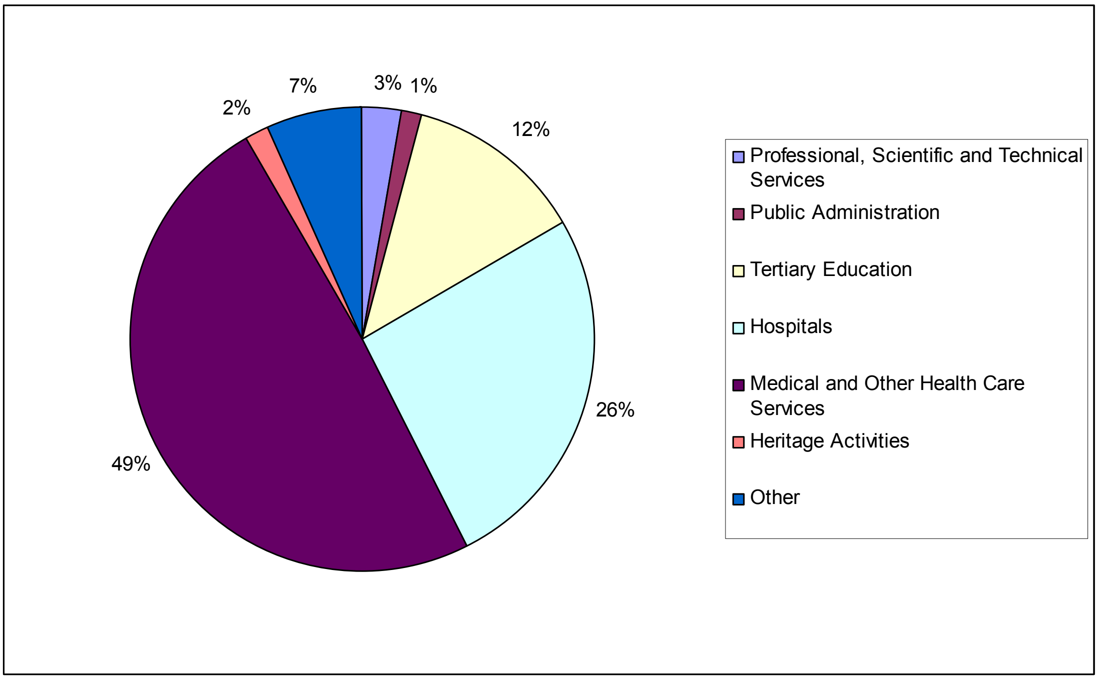
- *The immediate employment outcomes (employability and sector of employment) of health researchers and HDR graduates gives a sense of employer demand for research skills in this area. Graduate reflections on their preparedness for employment additionally provide a gauge of any mismatch between experience and skills garnered through research training and subsequent employment needs.*
- **Figure 52** shows that there is very little commonality in the employment sector of HDR graduates within the health 'umbrella'. Possibly the most surprising aspect is the low number of research-trained people employed in the health sector, given that all HDR graduates in these fields have health qualifications. A case in point is the high proportion of nursing HDRs (56%) not employed in the health sector (albeit that many of them may be nursing educators).
- **Figure 53** shows the industry of employment for Doctorate holders in health from the 2006 Census (noting the caveat around the use of Doctorate data in health disciplines). Overwhelmingly, Doctorate holders in employment were engaged in medical and health care services, including in hospitals.
- Responses to Australia's 2008 Graduate Destination Survey indicate that the majority (73%) of health HDR graduates considered their HDR qualification a formal requirement or important to their job – a percentage very close to the average across all disciplines (72%).
- Also according to the 2008 Graduate Destination Survey, the starting salaries for full-time employed HDR graduates health disciplines ranged from around $60,000 to $84,000, significantly above the average for all HDR graduates of $61,000.

Figure 52: Employment sector destinations for full-time employed health HDR graduates, 2007



Source: Grads online database of the Graduate Careers Council of Australia Ltd.

Figure 53: Industry sector of employment for health Doctorate holders, 2006



Source: ABS Census 2006 special tabulation.

5.1.4 Summary points

Taken together, the quantitative trends examined in this case study suggest the following:

- The health doctorate-qualified workforce is a significant (around 21%) component of Australia's total doctorate-qualified workforce (although for reasons related to professional qualifications, this share is open to debate).
- Australia's impacts in many areas of this discipline are among the highest of all disciplines, suggesting that Australia 'punches above its weight' in this area.
- Australia's supply of health research skills through the research training system is currently growing moderately. However, increasing employer demand may result in pressures in the future suggesting that Australia's continuing good performance in this area may be at risk.
- Australian health HDR completions as a proportion of all HDR completions are generally on a par with other countries but appear low in comparison to key competitors.
- Employment prospects of health HDR graduates appear very positive, with graduates finding employment across a number of sectors, although most work in the health sector. There appears to be little variability in employment prospects across the professional disciplines within health.
- The number of research active staff in health is difficult to gauge from available data but qualitative information collected as part of the case study suggests a large number of clinical staff across different disciplines are engaged, at least for part of their time, in research activities. A corollary to this is the number of research-trained individuals from other disciplines finding a home in health research.

5.2 What are the key influence factors (current and future)?

Pipeline issues

Sources such as university admissions and undergraduate completions indicate that the number of students with the necessary grounding and skills to undertake an HDR in many disciplines within health is increasing, but not all areas are increasing at the same rate.

Of particular concern is the case of medical clinicians undertaking research training. A typical trained physician who wants to formalise his/her research qualifications will have studied at undergraduate level for a minimum of five years (seven years is the norm for graduate-entry medical programs), will have undertaken a one year residency and followed this up by between three and six years of specialist training. Enrolling in a full time PhD requires a further major time commitment along with a substantial pay reduction.

The introduction of graduate entry medical degrees has been cited as a possible impediment to pursuing a research career, on the grounds that graduate medical students are more likely to have already decided that medicine rather than research is their vocation. This issue is also borne out by a drop in the number of laboratory science graduates coming through the higher education system to undertake clinical studies or research degrees.

The relatively older age profile of nursing academics is also a potential issue, with a higher than average retirement related turnover expected in the future.

Skills issues

Expert group members reported that industry employers have difficulty in finding researchers with skills in management, commercialisation (including product development and intellectual property) and the ability to work across teams (particularly large multidisciplinary teams).

The group felt that opportunities for health researchers to gain exposure to industry during their research training would assist both in overcoming this shortage and in providing sustainable career paths for graduates. Similarly, the group were of the view that mobility between public and private sector employment for health researchers needs to be facilitated.

Members also commented that health research is often carried out by multi-disciplinary and/or collaborative teams. This type of collaborative research effort requires people with a good understanding of the other disciplines which make up such teams and high level communication and teamwork skills.

The group expressed some concern that recent graduates are not emerging with the breadth of knowledge they require to fill these roles, and some graduates are lacking generic skills such as communication and the ability to work productively in teams.

The role of clinical research

Expert group members emphasised the importance of clinical research in the health research spectrum. Given the nature of health research, they highlighted that it is crucial that clinicians have the capacity and opportunity both to absorb and apply research outcomes, and conversely that research is properly informed by clinical experience.

However, there was concern about this on two fronts. First, the group felt that there is a lack of coherence across the health research effort that may inhibit the achievement of a proper balance between clinical and non-clinical research.

Second, the group noted that it has been widely reported that it is very difficult for hospital based clinical researchers to find adequate time and resources to conduct their research. Heavy clinical caseloads combined with scarce funding and a hospital culture that may not be very supportive of research activities may combine to put significant barriers in the way of clinical researchers.

Research career issues

Expert group members reported a number of barriers to successful research careers in health.

First, the low success rate for research grants, in common with other disciplines, creates a number of problems. Fewer than half of all eligible grant applications are successful, which leads to a significant degree of frustration among researchers and job insecurity for research scientists, post-doctorates, research assistants and technicians.

Second, research institutes often find it difficult to offer continuous career paths due to the nature of their funding. While several of these institutes have reasonably consistent base funding from endowments and charitable donations, their research programs are often funded purely through competitive grants. For a clinician employed in an institute, loss of a grant generally means returning to a lucrative clinical career, but for the research scientists, technicians and research assistants it can result in unemployment.

Third, problems in combining a research career with family or other responsibilities is an issue across the research workforce, impacting particularly on women. This is exacerbated where there is a lack of flexible financial support or employment or where workplace culture favours long hours. Finally, the expert group members felt that there is considerable confusion among graduates and early career researchers both about the range of career options available and about the best way to develop and pursue a coherent career path.

Areas of potential future shortfall

Most areas of health research are growing strongly, but continuation of this growth is dependent on further investment and a supply of HDRs coming through the school and university sectors.

The focus on excellence in research funding

While excellence in research is clearly a key factor in the allocation of research funding, the expert group expressed concern that a focus on academic excellence at the expense of broader research outcomes and impact may have unintended consequences. In particular, it may discourage industry focussed research, with a downstream effect on the supply of industry experienced and relevant researchers.

Visa issues
Most areas in health are included in the new SOL. The SOL has a greatly reduced list of occupations which can be used by potential independent migrants under the General Skilled Migration visa program but this has not reduced opportunities for potential migrants with research qualifications in health disciplines.

The expert group suggested that a potential problem which could impinge on the ability of researchers to move to Australia is that of age. Health researchers have a median HDR graduation age of 34, so it is likely that many researchers will not have an established research career until their late 30's or early 40's – at which stage immigration eligibility criteria start to make it difficult to qualify for Australian residency.

5.3 Health research workforce score-card

Score-card

	Quantity of supply through the research training system	Quality of supply through the research training system	Research workforce equity	Research workforce shortfalls	Employment prospects	Research career pathway support
Current	🟠	🟢	🟠	🟠	🟢	🔴
Future	🔴	🟠	🟠	🟠	🟢	🟠

Legend:

🟢	Green (performing well/stable/positive outlook)
🟠	Amber (some challenges/weaker than expected performance)
🔴	Red (poor performance/area(s) of concern/significant challenges)

5.4 How can Australia better position itself for the future?

Addressing information gaps

Analysis conducted by DIISR indicates that much of the currently available information about the state of health does not relate directly to the training of or demand for research-trained individuals. Coordinated career information, starting in early secondary education, may help to fill this information gap.

More funding to increase grant application success rates

The expert group were of the view that increasing the pool of funding available for competitive grants in health research and increasing the length of the grant cycle would have the double benefit of improving health outcomes and supporting a larger number of health researchers.

The group also considered that more funding (with better success rates) would improve career pathways and encourage more people to take up research careers.

Skills issues

The expert group felt that greater opportunity for research trainees to be exposed to industry during their training (e.g. the Bio21 UROP scheme) would be very valuable in helping to prepare HDR graduates for future employment. The Bio21 UROP scheme is a paid employment scheme designed to give undergraduate students an early opportunity to experience work in a research laboratory and gain insight into careers in biomedical research.

More attention to 'generic' or 'transferable' skills during research training (e.g. team work, commercialisation) was also considered to be important.

It was suggested by the expert group that long-term government support programs, similar to those instituted in China and other countries may drive career choices into areas where research skills are in short supply.

6 History and Archaeology

For the purposes of this case study, the definition of 'history and archaeology' correspond to that outlined in Division 21 of the *Australian and New Zealand Standard Research Classification* which includes archaeology, curatorial and related studies, historical studies and other history and archaeology.

6.1 How is Australia tracking?

The following areas have been selected for analysis:

- The scale of the history and archaeology research workforce in Australia – PhDs (and to some extent Masters by Research) in the workforce;
- The history and archaeology research environment in Australia – research and development expenditure and ERA 2010 results; and
- Supply to the history and archaeology research workforce – HDR completions in Australia and through long-term or permanent migration.

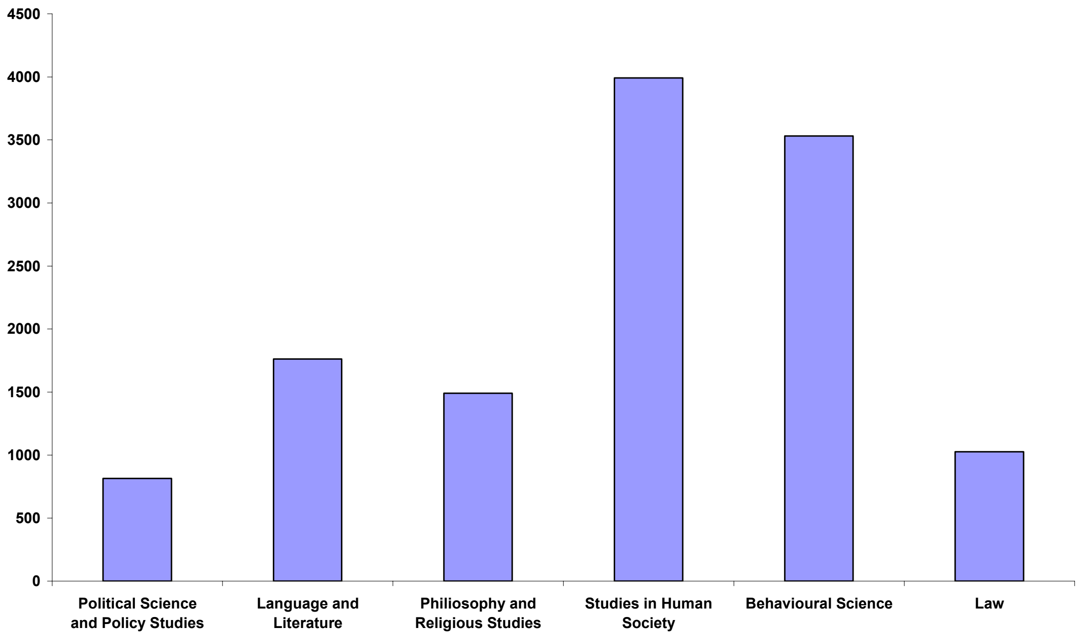
6.1.1 History and archaeology research workforce and its environment

PhD qualified individuals in the workforce

Key Points

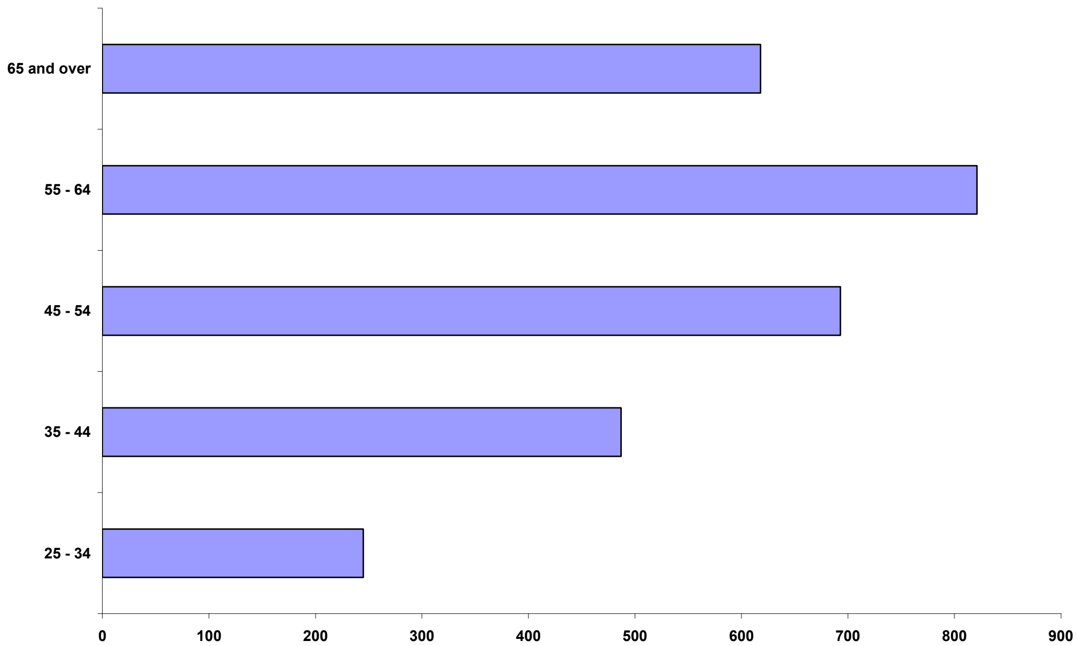
- *The number of individuals in the workforce with a history and archaeology HDR qualification gives an indication of the scale of Australia's research human capital in the discipline (i.e. our capacity for research in this discipline)*.
- **Figure 54** indicates that studies in human society represent approximately 5.5 per cent of Australia's PhD workforce in 2006. History and archaeology PhDs contribute half of the PhD workforce in studies in human society.
- According to the Census data analysis, the top employers of history and archaeology PhDs in 2006 were the training and education sector, public administration, professional, scientific and technical services (excluding computer system design and related services) and heritage activities.
- Data limitations make it difficult to establish how many of these individuals are research active or to make robust cross-country comparisons.
- Within the university sector, a study by Graeme Hugo (2008) indicates a relatively high proportion (53.2%) of academic staff in the studies in human society were in the age bracket of 50 years and over in 2006. This is consistent with the findings of Census data, which indicate that the largest proportion of persons with doctoral level in history and archaeology were in the age bracket of 55-64 years (**Figure 55**).

Figure 54: Number of Doctorates Employed, by Field of Education, 2006



Source: ABS Census of population and housing 2006, special tabulation.
Note: History and archaeology are included under Studies in Human Society.

Figure 55: Age of Doctorates, History and Archaeology, 2006



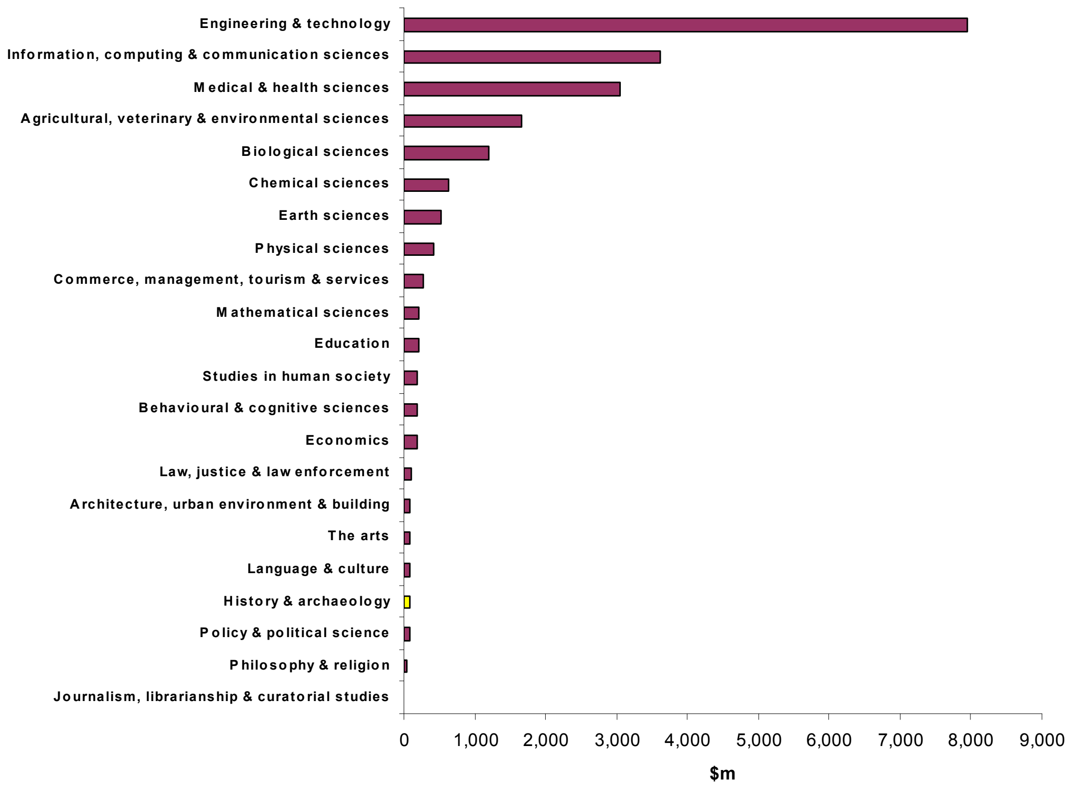
Source: ABS Census of population and housing 2006, special tabulation.
Note: Doctorates aged between 15-24 years are excluded due to very low numbers.

R&D expenditure on history and archaeology

Key Points

- *The scale of the research workforce in history and archaeology is likely to be influenced by a number of factors. Investment is a particularly important factor as it influences the demand for research staff in different sectors of the economy (e.g. business, government, universities, not-for-profit organisations etc).*
- Expenditure on R&D in the field of history and archaeology stood at $89 million, which was approximately 0.4 per cent of the total expenditure in 2006-07.
- History and archaeology ranked in the bottom four in terms of R&D expenditure by field of research (**Figure 56**).
- R&D expenditure in history and archaeology is performed mainly in the higher education sector.

Figure 56: R&D expenditure by field of research, 2006-07



Source: ABS cat. No. 8112*.0 Research and Experimental Development, All Sector Summary, 2006-07*.
Note: The major sources of funds for R&D expenditure were from the Commonwealth Government, State and Territory governments, business, overseas and other Australian sources.

ERA 2010 results for History and Archaeology

The ERA 2010 results show that in the History and Archaeology field, 33 higher education institutions were assessed at the broad two-digit level with a national rating of 3.0. Four institutions are performing well above world standard (a rating of 5). Six institutions are performing at above world standard (a rating of 4) and 11 institutions are performing at world standard (a rating of 3).

At the specific four-digit level, Australia is performing well in Curatorial and Related Studies with an average rating of 4.0, while. Archaeology has an average national rating of 3.5 and Historical Studies an average national rating of 3.1.

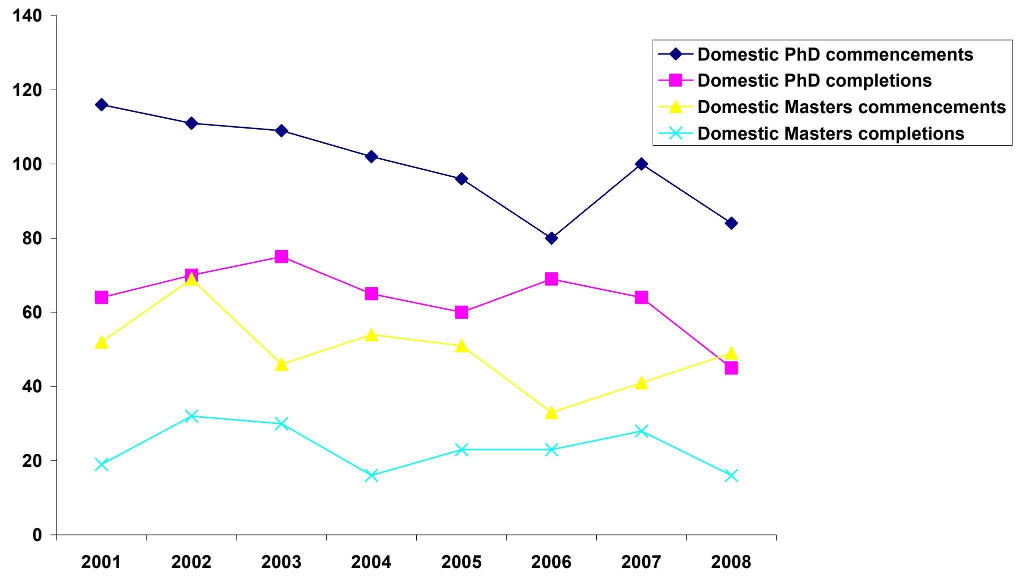
6.1.2 Supply to the history and archaeology research workforce

HDR commencements and completions

Key Points

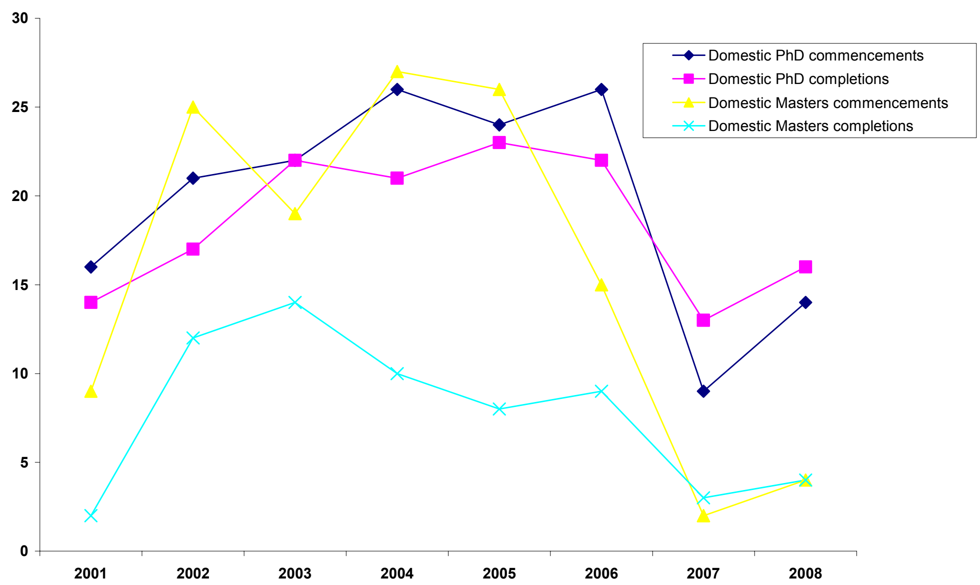
- *With respect to inflows of history and archaeology HDR skills, the primary source is Australia's research training system through completions of domestic and international doctorate by research and masters by research students. Examination of historic trends of both commencements and completions provides a gauge (in combination with migration data) of the pipeline of the skills that can be expected to be available to the research workforce in future years.*
- **Figure 57** shows that domestic PhD commencements and completions in history have both trended downward over the years. A contradictory pattern was observed in domestic Masters in history, with domestic commencements demonstrating an upward trend while domestic completions showed a downward pattern.
- **Figure 58** shows domestic PhD commencements and completions in history had a sharp fall in 2007 however they both appear to be on the rise for 2008. Overall, Masters commencements and completions in archaeology have significantly decreased, notably Masters commencements which declined since 2005.
- In 2008, PhD commencements in history and archaeology represented 1.1 per cent of PhD commencements for all disciplines while Masters represented 2.1 per cent of Masters commencements for all disciplines. PhD completions in history and archaeology represented 1.2 per cent of PhD completions for all disciplines.
- Overall, there were very small cohorts of archaeology HDRs (below 25 HDR students) both in commencements and completions from 2001 to 2008.
- Overseas PhDs and Masters commencements and completions have not been included in the analysis, as the numbers are very small.

Figure 57: History domestic HDR completions and commencements, 2001-2008



Source: DEEWR University statistics, unpublished data.
Note: Overseas HDR commencements are not included as the size is too low.

Figure 58: Archaeology domestic HDR completions and commencements, 2001-2008



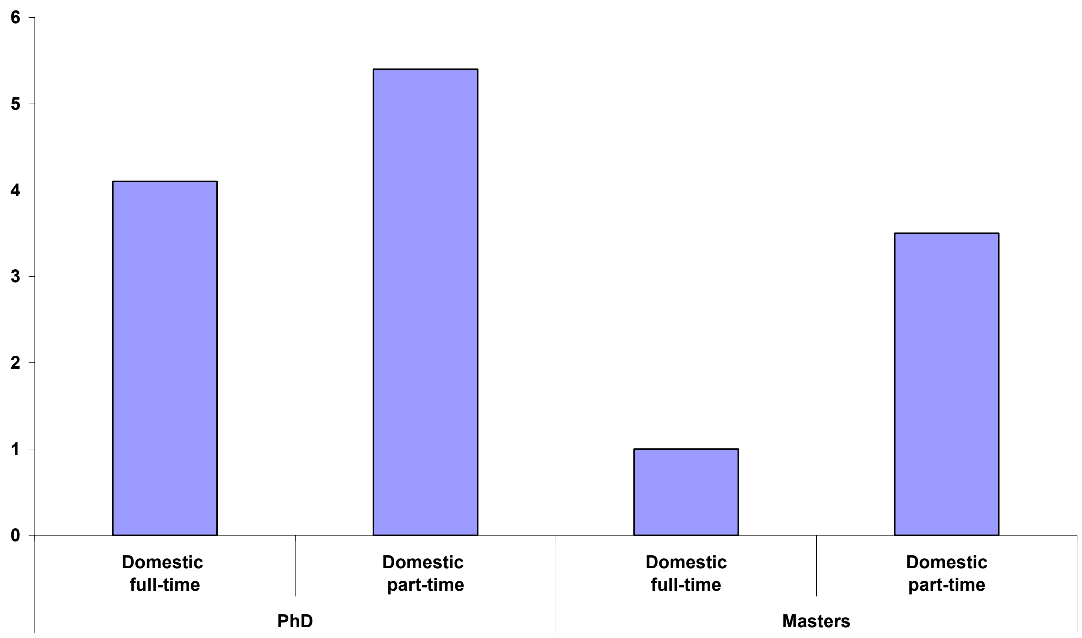
Source: DEEWR University statistics, unpublished data.
Note: Overseas HDR completions are not included, as they are very few in number.

HDR time to complete

Key Points

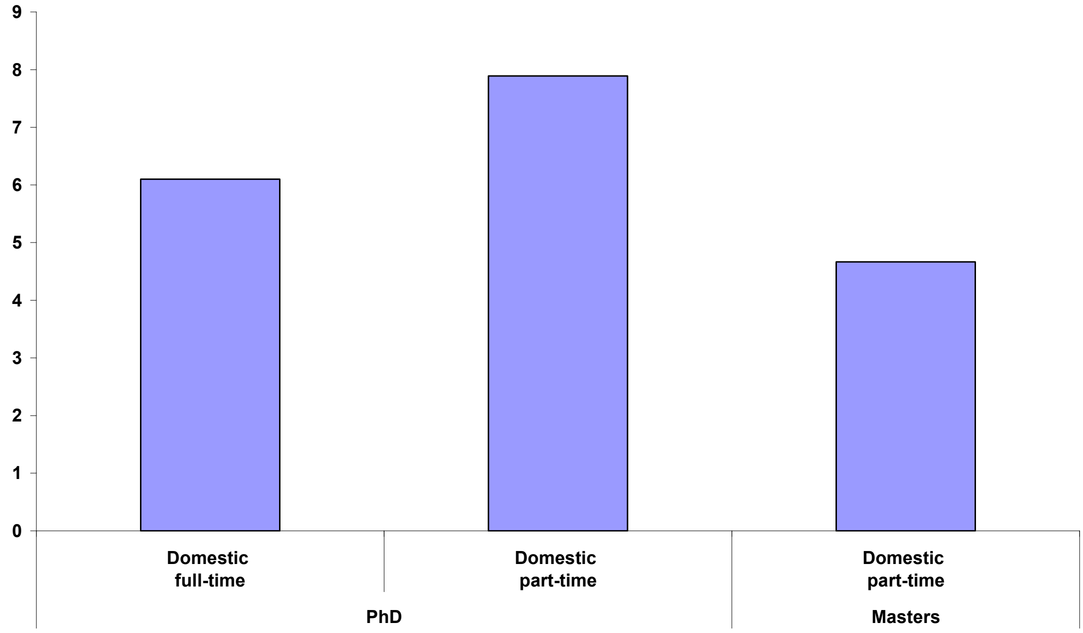
- *The time taken to complete HDR studies and mode of study (full-time versus part-time status) provides an indicator of the efficiency of the pipeline from research training to the workforce.*
- **Figure 59** indicates that, on average, domestic full-time history PhDs complete in 4.1 years (the same as the average for PhD candidates across all fields), while domestic part-time history PhDs complete in 5.4 years (compared to 6 years on average for domestic part-time candidates across all disciplines) in 2008.
- The majority of domestic HDR students in history were in part-time study in 2008 (34 compared to 17 in full-time study).
- **Figure 60** indicates that on average, domestic full-time archaeology PhDs complete in 6.1 years (2 years longer than the average completion time for PhD candidates across all fields) while domestic part-time archaeology PhDs complete in 7.9 years (1.9 years longer than the average completion time for PhD candidates across all fields) in 2008. Archaeology PhDs may take longer to complete than other disciplines because they may involve extensive research projects requiring a significant amount of field work.
- Half of domestic HDR students in archaeology were in part-time study in 2008.
- Caution should be exercised in interpreting the results due to small numbers of HDRs in archaeology.

Figure 59: History domestic HDRs average time to complete, 2008



Source: Published and unpublished DEEWR Unistats data.
Note: Overseas HDRs are not included as the sample size is too low.

Figure 60: Archaeology domestic HDRs average time to complete, 2008



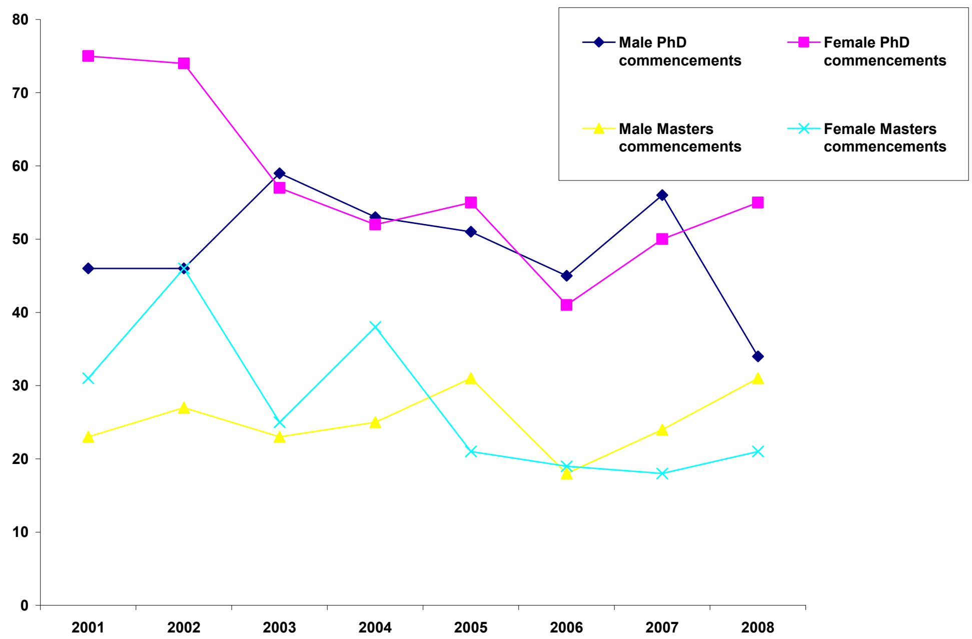
Source: Published and unpublished DEEWR Unistats data.
Note: Domestic full-time Masters and overseas Masters/PhDs are not included as the sample size is too low.

Demographic data – commencements and completions by age and gender

Key Points

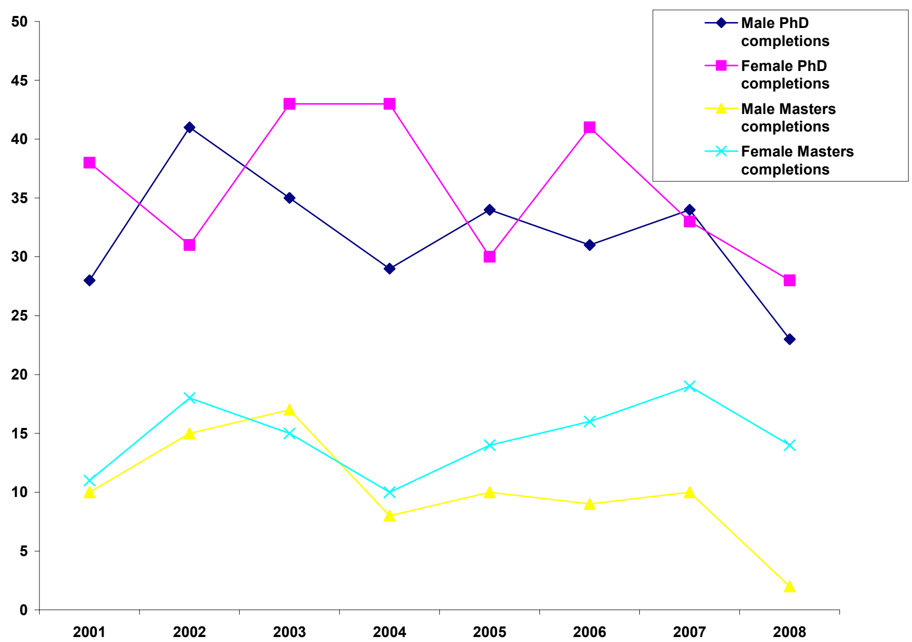
- *The age of history and archaeology HDR students provides a useful (but not conclusive) gauge of the potential workforce contributions of graduates, while gender may reveal any persistent inequalities in participation in HDR degrees between genders.*
- The majority of PhD and Masters commencing candidates in history over time were females. The gender gap for commencing PhD candidates in history narrowed down from 2003 to 2007 but it was not sustained when the number of women commencing history PhDs was on the rise again in 2008. In contrast, the number of male Masters commencements in history had been improving over time to the extent that it is now exceeding the number of female Masters commencements in history (**Figure 61**).
- Women tend to dominate PhD and Master completions in history. In 2008, 55 percent of female candidates completed their PhDs in history and 88 percent of female candidates completed their Masters in history **(Figure 62**).
- Overall, PhD and Masters commencements and completions in archaeology were dominated by female candidates over time. The gender difference is, however, more pronounced in commencing Masters by Research candidates than commencing PhD candidates in archaeology in 2008. (**Figure 63 and 64**).
- In 2008, the median age of commencing domestic male PhD in history was 36 years while commencing domestic female PhD was 28 years. Overall, the median age of commencing domestic PhD in history was the same for all disciplines, at 31 years. In contrast, the median age of domestic PhD completion in history (36 years) was slightly younger than the average domestic PhD for all disciplines (37 years) (**Figure 65)**.
- There was a significant gender difference in the median ages of commencing PhD candidates in archaeology in 2008; domestic female commencing PhDs was at 46 years while domestic commencing male PhDs was at 28 years. However, no significant age difference was observed between completing domestic male and female PhDs in archaeology (**Figure 66**).

Figure 61: History HDRs commencements by gender, 2001 to 2008



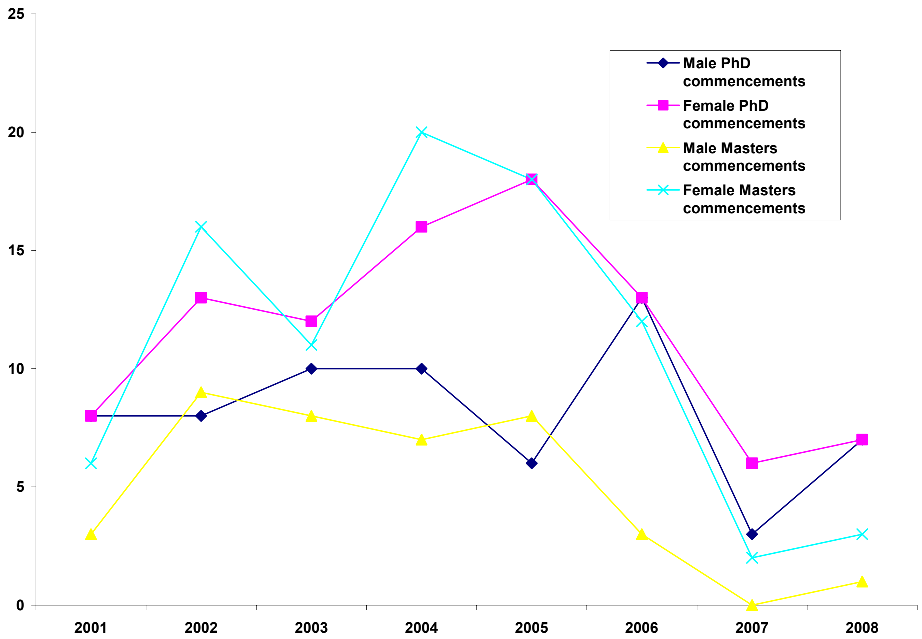
Source: Published and unpublished DEEWR Unistats data.

Figure 62: History HDRs completions by gender, 2001 to 2008



Source: Published and unpublished DEEWR Unistats data.

Figure 63: Archaeology HDRs commencements by gender, 2001 to 2008

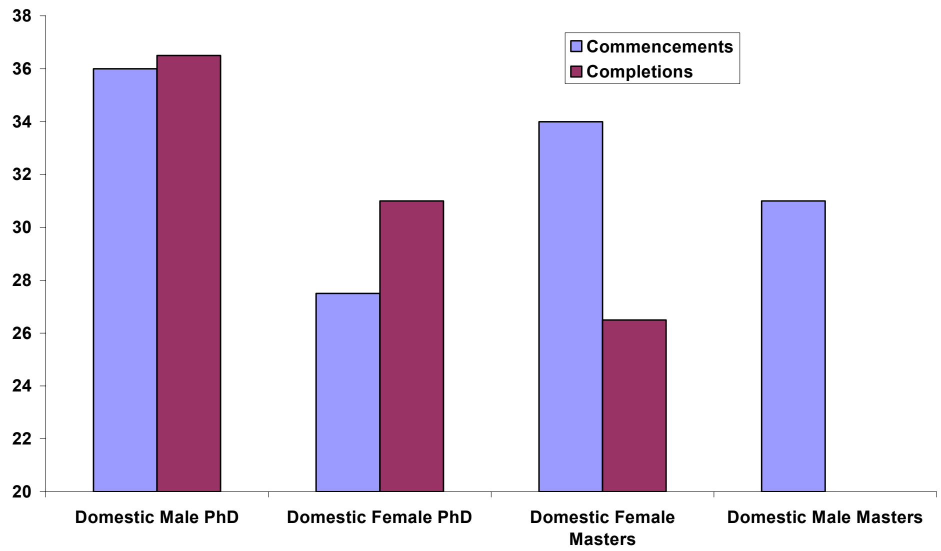


Source: Published and unpublished DEEWR Unistats data.

Figure 64: Archaeology HDRs completions by gender, 2001 to 2008

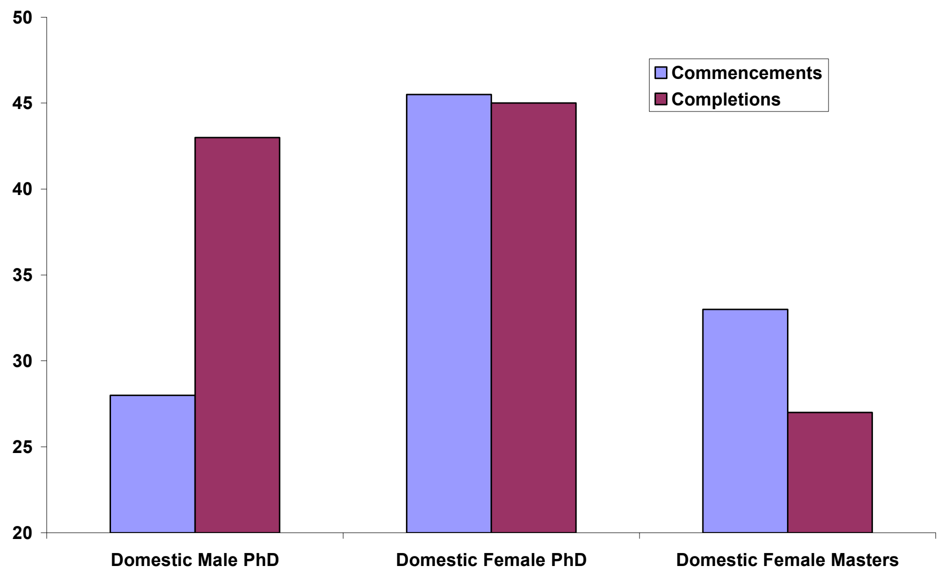
Source: Published and unpublished DEEWR Unistats data.

Figure 65: Median ages of commencing and completing domestic history HDRs, 2008



Source: Published and unpublished DEEWR Unistats data.
Note: Domestic male Masters completions and overseas HDR (commencements and completions) are not included, as the sample size is too low.
The chart shows median ages for two different cohorts – those that commenced and completed their HDRs in 2008.

Figure 66: Median ages of commencing and completing domestic archaeology HDRs, 2008



Source: Published and unpublished DEEWR Unistats data.
Note: Domestic Male Masters and overseas HDR commencements and completions are not included, as the sample size is too low.
The chart shows median ages for two different cohorts – those that commenced and completed their HDRs in 2008.

Supply through migration

Key Points

- *A further key source of supply of history and archaeology HDR-qualified individuals to Australia is through both temporary and permanent migration.*
- *While available data makes it difficult to discern the scale of supply for history and archaeology through migration, previous studies (ACER, 2009) have estimated that approximately 22 per cent of Australia's overall supply of HDR skills is achieved through this source.*
- Historians and archaeologists (listed under social professionals not elsewhere classified) can currently migrate to Australia under a number of visa classes in the GSM scheme. Within the GSM program, historians and archaeologists can apply under the SOL Schedules 1, 2 and 4. However, historians and archaeologists cannot apply under SOL Schedule 3 which applies to all new general skilled migration applications, including applicants eligible for transitional arrangements. Nevertheless, historians and archaeologists are eligible to apply under the state sponsored scheme.
- While quantification of the scale of supply of history and archaeology PhDs to the workforce from international sources is limited by the granularity of data collected, analysis of census data reveals that nearly 34 per cent of doctorate holders in history and archaeology were born overseas, suggesting that international sources may only be moderately significant in maintaining Australia's base of history and archaeology researchers.

Note: SOL Schedule 1 applies only to General Skilled Migration (GSM) applicants who lodged their application prior to 1 July 2010. SOL Schedule 2 applies to previous visa holders or those who applied for skilled independent work visas before 8 February 2010 and who are now applying for new work visas. This includes those who held student visas as of 8 February 2010 and may submit their applications until 2012. SOL Schedule 3 applies to SOL Schedule 4 applies to visa applicants sponsored by state or region to work in Australia.

6.1.3 Summary points

Taken together, the quantitative trends examined in this case study suggest the following:

- The doctorate-qualified workforce in studies in human society (where history and archaeology PhDs are included) is a small (5.5%) component of Australia's total doctorate-qualified workforce in the 2006 census.
- According to the census data analysis, the top employers of history and archaeology PhDs in 2006 were the training and education sector, public administration, professional, scientific and technical services (excluding computer system design and related services) and heritage activities.
- Within the university sector, academics in studies in human society are more likely to be within the older (50+) age bracket, suggesting a significant replacement demand due to retirement within this sector in future years.
- Despite the fact that R&D expenditure in the history and archaeology represented only 0.4 per cent of Australia's overall R&D expenditure in 2006-07, history and archaeology research output rates above the world average, indicating a strong capability within its research workforce.
- Australia's supply of history and archaeology research skills through the research training system has declined significantly in recent years. Growth in overseas

student number in history and archaeology were both dropped in the analysis because of their insignificant contribution.
- The majority of history and archaeology HDR students are women and in part-time study.
- On average, history and archaeology HDR candidates commence their courses at much later ages than most other disciplines, suggesting a shorter research career.

6.2 What are the key influence factors (current and future)?

Difficulty in recruiting quality PhD students

Members of the expert group reported that it is difficult to recruit high quality PhD students in history and archaeology. In the case of history, high quality PhD students are reported to seek more secure employment in fields such as journalism, government, and cultural management.

For history, expert group members noted two possible reasons for this. First, students in history may go overseas to pursue HDR training in specialist areas such as Asian or medieval history, etc., where for obvious reasons, archival sources and expertise may not be as strong in Australia. The group felt that a higher proportion of gifted Australian students are pursuing HDRs in history overseas than are being recruited to Australia in these fields. Second, potential history PhD students are reported to be taking up more secure employment in fields such as journalism, government and cultural management.

In the case of archaeology, the group reported that there is a very strong tendency (particularly in archaeological science) for students to undertake an HDR in the UK where resources are much greater. This is also the case for particular sub-fields of archaeology (medieval, classical, African and so on) where there may be no or few potential supervisors in Australia.

Further, the expert group reported that the serious shortfall of trained archaeologists in Australia means archaeology tertiary graduates are in high demand in heritage management industries and mining and development industries and are able to attract high salaries. In this situation, postgraduate qualifications offer little or no competitive advantage. Loss of potential income may impact particularly on people in their late 20s through to late 30s age bracket, who are likely to be starting families. This is a critical demographic factor for recruiting potential PhD students.

Archaeology's role as both a science and an arts discipline

By its nature, archaeology operates across the traditional disciplinary boundary between arts and sciences faculties. The expert group felt that the compartmentalisation of humanities and sciences and a lack of cross faculty collaboration works against archaeology as a discipline in which students need to be grounded in both the humanities (for example classical and historical archaeology) and the sciences (for example geoarchaeology or palaeoanthropology).

A related issue identified by the group is that archaeology departments are almost exclusively found in humanities or arts faculties. Students who for whatever reason would prefer a science degree (for example they may feel that a science degree will open up a broader job market) may be more likely to pursue archaeological studies in science disciplines such as earth sciences. One effect of this may be that some archaeology PhDs are reported as PhDs in physics or geology, for example, rather than in archaeology.

Archaeology and history as low cost subjects under the Research Training Scheme

Under the funding formula for the Research Training Scheme (RTS), HDR completions in high-cost disciplines are weighted higher than HDR completions in low-cost disciplines. Because history and archaeology are counted as low-cost disciplines, universities receive less funding for history and archaeology HDR candidates than, for example, pharmacology HDR students.

The expert group were strongly of the opinion that history and archaeology are not accurately described as low-cost subjects. The group noted that research training in archaeology involves extensive laboratory and field work and that, similarly, history HDR training frequently involves travel and fieldwork. Archival research was also cited as being a high cost activity. The group felt that universities are less likely to encourage take-up of history and archaeology given that the high cost of research training in these areas is not reflected in the RTS high/cost low cost weightings.

Research infrastructure

The emerging field of archaeological science (for example biomolecular archaeology and geoarchaeology) is increasingly important in providing a career path for archaeology researchers and research students. The expert group however reported that many archaeology departments lack access to the expensive research infrastructure needed for research and research training in areas such as spatial analysis, isotope or ancient DNA. These new emerging fields are highly attractive to international graduate students from India, China and South American nations such as Chile, but lack of training opportunities in these fields means that many of these students attend universities in Europe or Canada in preference to Australia.

The expert group for history also reported difficulty in meeting the costs of infrastructure, for example IT infrastructure involved in the digitising of historical records, which offers huge benefits for researchers and HDR students. Similarly, meeting the costs of maintaining a good library collection was considered a pressing need for universities offering HDR training in history.

Research training support

The expert group members felt that the difficulty in recruiting quality PhD students is exacerbated by the low level of scholarship funding. For example, tertiary graduates in both history and archaeology are reported as choosing to go into consulting, government work or teaching rather than undertaking a PhD because the APA rate is so low.

The group also reported that few universities are able to provide adequate computer equipment and office space for HDR candidates.

Research training quality

The expert group members expressed reservations about the current capacity of the research training system to produce graduates with the depth and breadth of skills required by employers.

In particular, the group felt that the current 3-3.5 yrs allowable under APAs limits the scope to include coursework that may be needed to produce well-rounded graduates. The group was of the view that the US system, which includes coursework, performed better in this regard. In contrast, it was felt that the Australian system tends to train graduates with limited skills sets and a consequent restriction in their future work opportunities.

For example, the group identified an unmet need in history for training in specialist sub-fields such as statistical analysis. The expert group also felt that there was an overall need for more 'vocational' or professional training as part of the PhD training of history and archaeology.

Lack of opportunities for international exchange

Expert group members expressed concerns that Australian HDR students in history lack opportunities for international experience due to insufficient funding sources. The group emphasised that it is vital for graduate students (along with early to mid career researchers) to gain significant international experience to make them competitive in the job market and to that ensure that their research is exposed to international scholarly scrutiny.

The group considered that opportunities for international exchange were particularly important for students whose area of study lay outside of Australia.

Need for foreign language training

Both historians and archaeologists may require foreign language (particularly European and Asian languages) training to pursue their research, particularly where source documents are in a language other than English or where the main research nexus is in a non-English speaking area. The expert group reported that Australian universities rarely have the opportunity to promote foreign language training at graduate studies level, and that this requires urgent attention if the new generation of researchers are to be successful in their careers.

Lack of career pathways for academic researchers

The expert group members expressed concern about career pathways for early and mid career researchers in history and archaeology. In the case of history academics, the group felt that the lack of job security for early and mid career researchers (particularly those reliant on short-term competitive funding arrangements such as post-doctoral fellowships) has been exacerbated by the decline in the number of history departments around the country. The group considered that there is a need to review opportunities for early career researchers.

Similarly, archaeology expert group members raised concerns about a lack of opportunity to convert post-doctoral fellowships into research positions – a situation which has been aggravated by the slow growth in teaching, and research positions in universities.

The situation may be more positive in at least the science based sub-disciplines of archaeology, where an expert group member reported an increase of research support by short-term competitive funding such as ARC grants.

Employment outside of academia

While there are relatively few openings as professional historians outside educational and cultural institutions, it is increasingly the case that PhD training in history is seen as providing invaluable training for those involved in formulating social policy as well as in the transmission of culture.

In general the group felt that there needs to be a wider recognition amongst Australian public and private sector employers of the value of graduates with humanities PhD training.

Information gaps

The expert group members reported information gaps for history and archaeology. There is very little data documenting the basic profile of history and archaeology in Australia and what exists is not collected in detail. For example, Census data classifies history and archaeology under Studies in Human Society. Obtaining data specifically on history and archaeology involves making a special request to the ABS to disaggregate the data. This involves extra effort and expense, and makes it very difficult both to determine the contributions of history and archaeology and to make cross-disciplinary comparisons.

Further, the group expressed concern over whether people engaged in archaeology but not situated in an archaeology department (for example, in related fields such as biology or earth sciences), are included in the data collection. The group noted that this issue extends to students that will typically graduate with a science degree, but may have written a thesis that was almost entirely archaeological in nature. For instance, these students may be involved in the development of a scientific method but its application and interpretation of the results are archaeological in nature. Data will be skewed if they are not included in the data collection for archaeology.

This problem was also perceived to occur in history where there are also difficulties in the identification of history training, due to its occurrence in other departments and faculties. For example, historical methods and modes of analysis are drawn upon in areas such as education (history of education), science (in history of science or the history of medicine, which is quite a vigorous field), visual arts (art history) and economics (economic history). There are also historical topics in associated areas such as museum studies and literary and cultural studies.

Finally, the Postgraduate Destinations Survey that reports on the work and study outcomes of postgraduates does not report on history and archaeology as separate discipline areas.

6.3 History and archaeology research workforce score-cards

Score-card: History

	Quantity of supply through the research training system	Quality of supply through the research training system	Research workforce equity	Research workforce shortfalls	Employment prospects	Research career pathway support
Current	🟠	🟢	🟠	🟠	🟠	🔴
Future	🟠	🟠	🟠	🟠	🟠	🔴

Score-card: Archaeology

	Quantity of supply through the research training system	Quality of supply through the research training system	Research workforce equity	Research workforce shortfalls	Employment prospects	Research career pathway support
Current	🟠	🟠	🟢	🟠	🟢	🟠
Future	🔴	🟠	🟢	🔴	🟢	🟠

Legend:

🟢	Green (performing well/stable/positive outlook)
🟠	Amber (some challenges/weaker than expected performance)
🔴	Red (poor performance/area(s) of concern/significant challenges)

6.4 How can Australia better position itself for the future?

Improved data collection

The expert group members suggested a need for improved data collection in relation to history and archaeology. For example, it is important to know where history and archaeology graduates are employed once they have completed their formal studies. Data on these areas for history and archaeology would be useful for informed decision/policy making.

Enabling international experience

The expert group suggested that short-term fellowships specifically targeted at the ability to take up international opportunities should be provided for early to mid career academic researchers.

The group also felt that there would be benefit in examining international programs such as the European Region Action Scheme for the Mobility of University Students (ERASMUS)[12] program with a view to seeing how international mobility for HDR students could be better facilitated.

Recognition of the value of HDR training

The group considered that universities need to be more proactive in promoting the skills of HDR training to help potential employers to fully understand the skills research history or archaeology graduates bring to the workplace. These include transferable skills such as analytical thinking and problem solving, as well as the development of specialist expertise.

Improving the quality of research training - skills

Both history and archaeology expert group members reported a need for more 'vocational' or professional training as part of the PhD training in order to enhance their attractiveness to employers. Members felt that PhD training in history should include broadly based vocational training along with training in methodological, theoretical and analytical approaches. For example in history, research training might include internships in applied areas like heritage assessment or oral history.

In archaeology, group members considered that a skill base should include knowledge of Geographic Information Systems (GIS) and related technologies, as well as basic geomorphology and database creation and management. Members felt that it was also important to maintain and develop opportunities for overseas graduate study in non-Australian fields of history and archaeology to enhance research training quality. Members suggested that international exchange opportunities should be seen as an important part of HDR training.

Further, group members considered that action needs to be taken to ensure the adequacy and availability of foreign language training for HDR students, particularly in history. This means that there is a need to adequately fund foreign language

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[12] The ERASMUS programme is a European Union student exchange programme established in 1987. It forms a major part of the EU Lifelong Learning Programme 2007-2013, and is the operational framework for the European Commission's initiatives in higher education.

training at a graduate level so that universities will be able to offer foreign language training as part of postgraduate research studies in history.

Improving the quality of research training – enrichment through collaboration

The expert group was of the view that greater collaboration between universities, government and industry in teaching and learning would greatly improve the quality of research training. For example, HDR students and early career researchers would benefit from opportunities to gain vocational experience in the workplace.

For history, the group considered it would be helpful to integrate the experience of the professional world within historical training by encouraging greater interaction between researchers in academia and those with historical training in the cultural heritage industry. In the case of archaeology, the group highlighted the importance of greater involvement of industry groups, private sector, museums, and Indigenous groups in archaeological teaching and learning design in the research training of archaeology.

The group felt that greater collaboration across departments and faculties within universities would encourage diversity in history studies given crossovers with humanities and social sciences. In particular, the group considered that drawing on other fields such as economics, statistics, language studies (i.e. languages other than English), performance and visual culture studies, public policy, etc., would help to enhance the quality of research training.

Archaeologists in the expert group felt that that traditional discipline boundaries and lack of cross-faculty collaboration was working against archaeology as a discipline. Due to the nature of the discipline, the group considered that archaeology should be grounded in both the arts (humanities) and the sciences. The group also considered that there was a need for cross-faculty training because archaeologists will be best equipped if they have been exposed, for example, to informatics, earth sciences, physical sciences and humanities. The expert group reported that cross-faculty training is not unusual abroad where many overseas universities allow students to do subjects across different faculties.

Overcoming difficulties in recruiting HDR students

The expert group members were of the opinion that providing more PhD scholarships and increasing their stipends would help to address the problem of recruiting quality PhD students in history and archaeology.

The group suggested that PhD recruitment in history could be improved by promoting greater interaction between university departments and museums, major civic libraries and galleries (overseas as well as in Australia), to provide greater opportunities for collaborative training arrangements. They reported that public history has already made great advances in this respect, particularly with regard to local history, but initiatives could be extended to the broader study of history, outside as well as within Australia.

To address the shortfall of HDR of students in archaeology the expert group members suggested the need, for example, to convince the heritage management industry to see the value of postgraduate training and for its practitioners to recognise the need to develop skills and competencies through HDR training.

Funding levels for history and archaeology

The group suggests that the classification of history and archaeology as low cost disciplines under the RTS should be reviewed, given the high cost of providing quality research training in these areas.

7 Mathematical Sciences

For the purposes of this case study, the definition of 'mathematical sciences' corresponds to that outlined in Division 1 of the *Australia and New Zealand Standard Research Classification* and includes mathematics, statistics, and mathematical aspects of the physical sciences, except where explicitly excluded. It is acknowledged, however, that not all issues will be applicable to these areas equally.

7.1 How is Australia tracking?

The following areas have been selected for analysis:

- The scale of the mathematical sciences research workforce in Australia – PhDs in the workforce;
- The mathematical sciences research environment in Australia – research and development expenditure and ERA 2010 results;
- Supply to the mathematical sciences research workforce – HDR completions in Australia and long-term or permanent immigration to Australia; and
- Demand for mathematical sciences researchers – employability and remuneration.

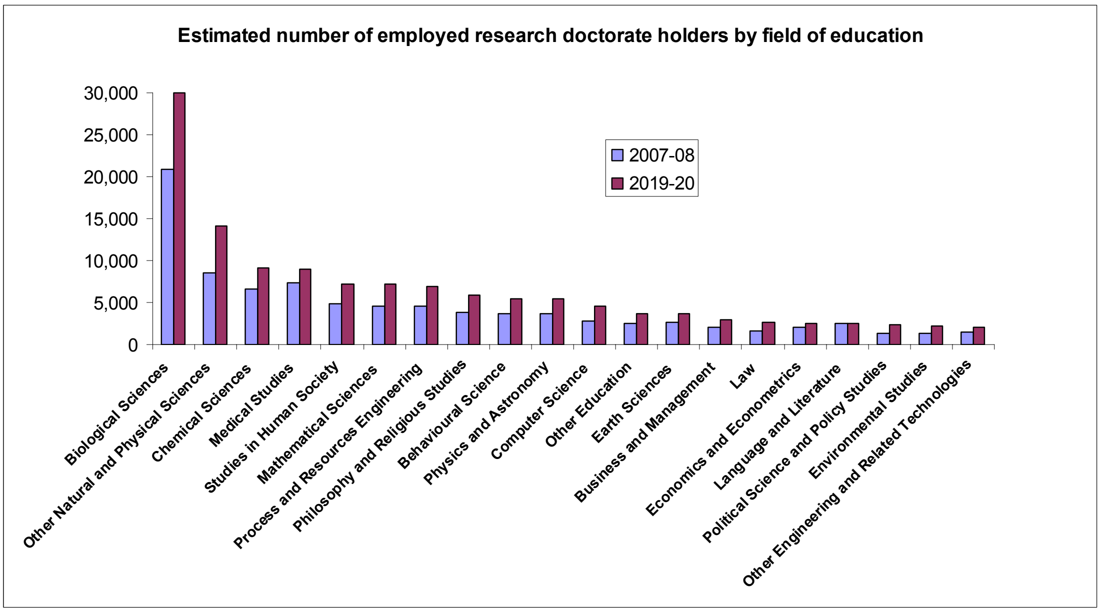
7.1.1 The mathematical sciences research workforce and its research environment

PhD qualified individuals in the workforce

Key Points

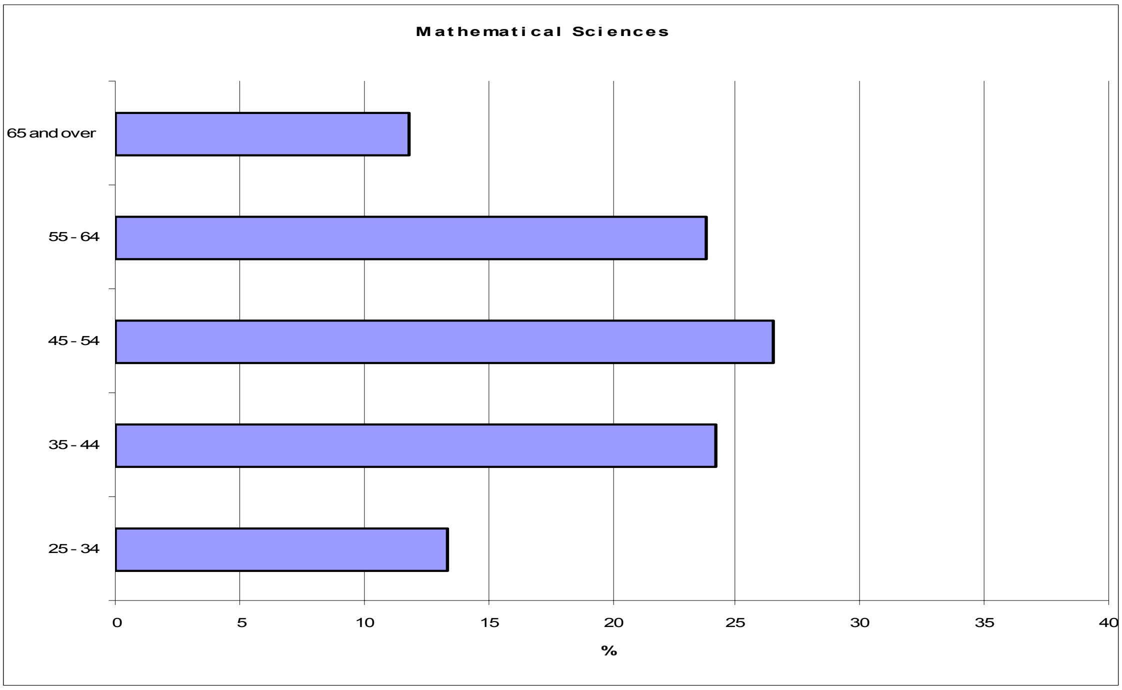
- *The number of individuals in the workforce with a mathematical sciences HDR qualification gives an indication of the scale of Australia's research human capital in the discipline (i.e. our capacity for research in this discipline).*
- **Figure 67** indicates that mathematical sciences PhDs represent approximately 5.2 per cent of Australia's PhD workforce in 2007-08. The PhD workforce in the mathematical sciences is projected to grow by just over 50 per cent by 2020.
- Data limitations make it difficult to establish how many of these individuals are research active or to make robust cross-country comparisons.
- Within the university sector, a 2010 study for Universities Australia by Graeme Hugo indicates that a significant proportion (52.7%) of academic (predominantly research active) staff in the mathematical sciences discipline were in the older age brackets (50+) in 2006, suggesting the potential for strong replacement demand for mathematical sciences research staff in this sector in future years. Work by Edwards and Smith in 2010 furthermore indicates that mathematical sciences was the only discipline within the natural and physical sciences cluster that saw a net decline in academic staff numbers over the period 2002 to 2007.
- The 2006 Census data indicates that most doctorate holders in the mathematical sciences are in the 45 to 54 age bracket, but with significant cohorts in both the 25 to 34 and 35 to 44 age brackets (**Figure 68).**

Figure 67: Estimated number of employed research Doctorate holders, by field of education, 2007-08 to 2019-20



Source: Australian Council for Education Research, *Supply, Demand and Characteristics of the Higher Degree by Research Population in Australia*, Report for the Department of Innovation, Industry, Science and Research, June 2009, p. 54.

Figure 68: Age distribution of mathematical sciences Doctorate holders, 2006



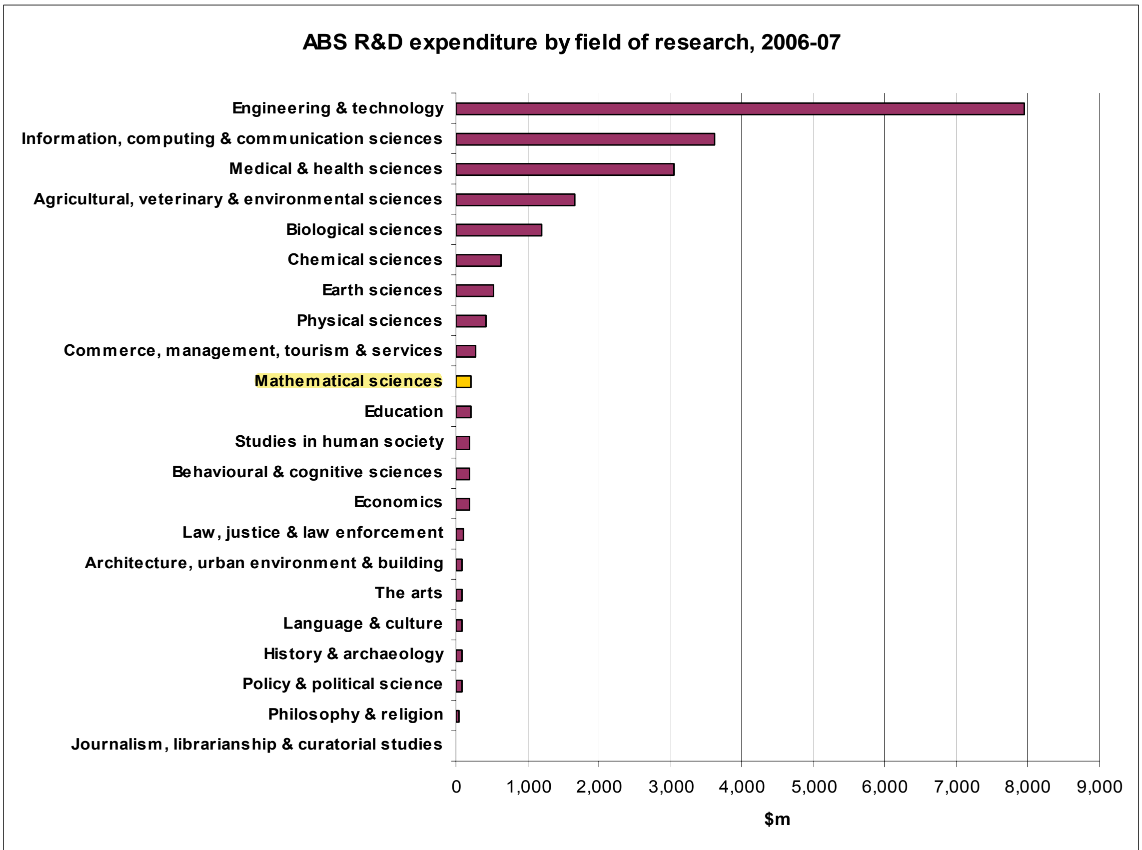
Source: ABS Census of population and housing 2006, special tabulation.

R&D expenditure on the mathematical sciences

Key Points

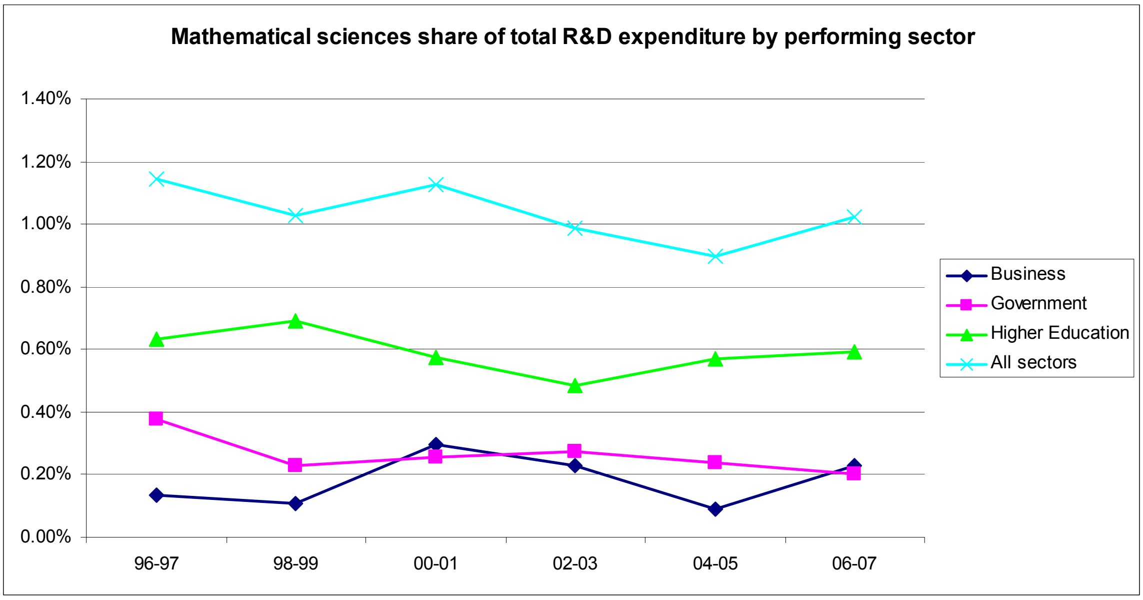
- *The scale of the research workforce in mathematical sciences is likely to be influenced by a number of factors. Investment is particularly important in this context as it influences the demand for research staff in different sectors of the economy (e.g. business, government, universities, not-for-profit organisations etc).*
- Expenditure on R&D in the field of mathematical sciences stood at $215 million in 2006-07. The share of mathematical sciences total R&D expenditure dropped from 1.2 per cent in 1996-97 to 1 per cent in 2006-07. Mathematical sciences is ranked number 10 in terms of R&D expenditure by field of research (**Figure 69**). This figure ranks expenditure against all major fields of research as identified by the ABS in accordance with international practice.
- R&D expenditure in the mathematical sciences is performed mainly in the higher education sector (**Figure 70)**. This is consistent with investment in most other disciplines.

Figure 69: R&D expenditure by field of research, 2006-07



Source: ABS cat. No. 8112.*0 Research and Experimental Development, All Sector Summary, 2006-07.*
Note: The major sources of funds for R&D expenditure were from the Commonwealth Government, state and territory governments, business, overseas and other Australian sources.

Figure 70: Mathematical sciences share of total R&D expenditure by performing sector



Source: ABS cat. No. 8112.*0 Research and Experimental Development, All Sector Summary* 2006-07.
Note: The *All sectors* figure includes expenditure on R&D performed by the private non profit sector as well as the business, government and higher education sectors.

ERA 2010 results for Mathematical Sciences

The ERA 2010 results show that in the Mathematical Sciences field, 24 higher education institutions were assessed at the broad two-digit level with a national rating of 3.2. Two institutions are performing well above world standard (a rating of 5). Six institutions are performing at above world standard (a rating of 4) and 10 institutions are performing at world standard (a rating of 3).

At the specific four-digit level, Australia is performing well in Mathematical Physics with an average rating of 4.5.

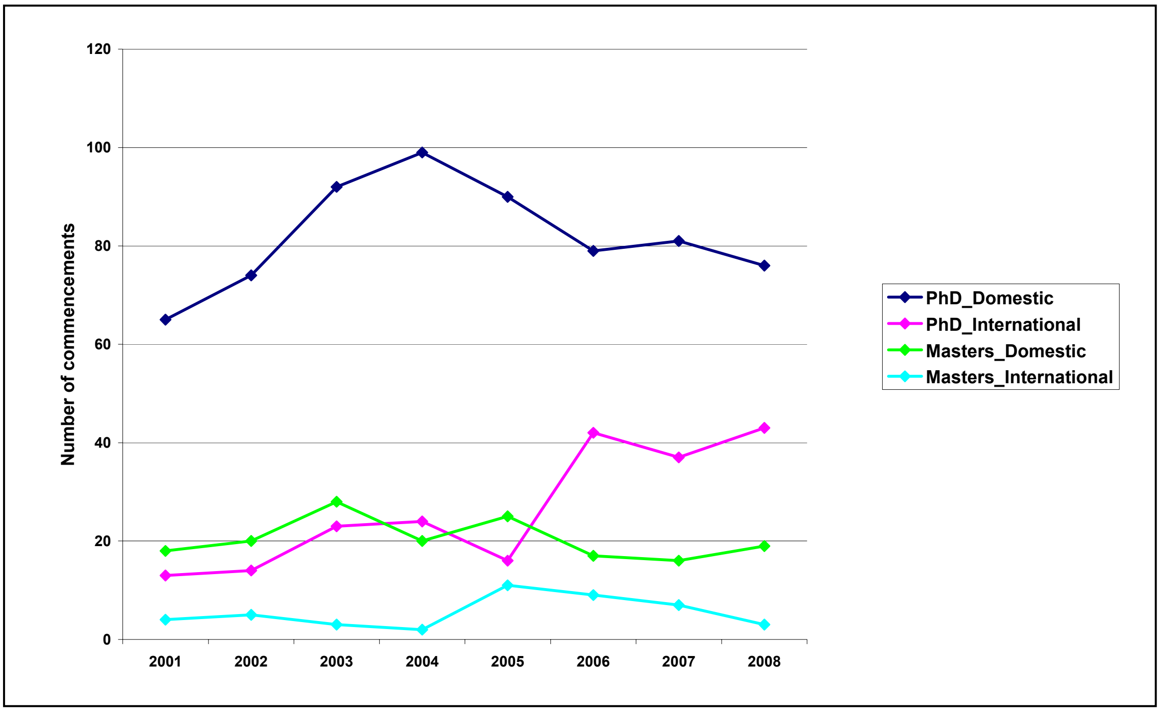
7.1.2 Supply to the mathematical sciences research workforce

HDR commencements and completions

Key Points

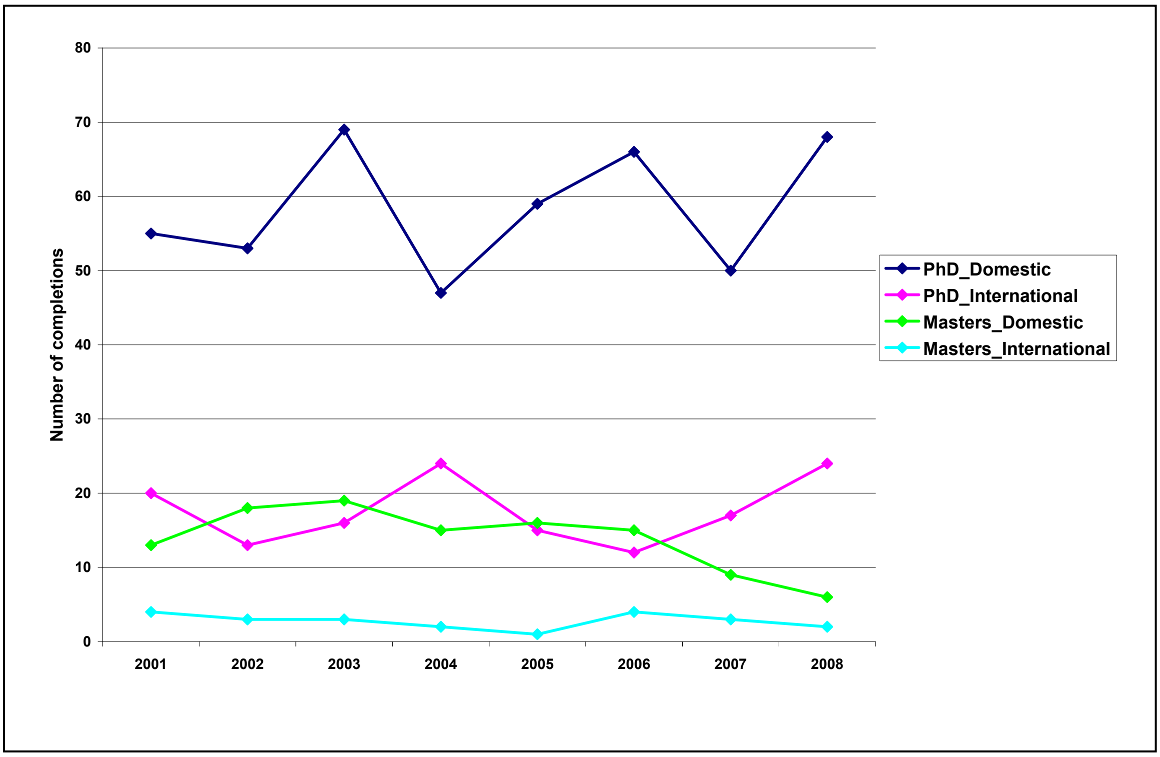
- *Australia's mathematical sciences research workforce is in constant flux due to ongoing inflows and outflows of HDR qualified individuals and shifts in the number of research active staff in different parts of the economy.*
- *With respect to inflows of mathematical sciences HDR skills, the primary source is Australia's research training system through completions of domestic and international doctorate by research and masters by research students. Examination of historic trends of both commencements and completions provides a gauge (in combination with graduate destination surveys and migration data) of the pipeline of the skills that can be expected to be available to the workforce in future years.*
- **Figure 71** shows that the number of domestic PhD commencements in mathematical sciences appears to have levelled out, following strong growth from 2001 to 2003. In contrast, after overseas PhD commencement levels declined briefly in 2005, they have continued to increase from 2005 to 2008.
- **Figure 72** shows that domestic PhD completions in mathematical sciences have fluctuated around an average of 58 over 2001-2008, while slowly trending upwards over this period. Masters by Research numbers (both in completions and commencements) in the mathematical sciences are slowly declining, in line with a general cross-disciplinary trend towards a decline in the Masters by Research qualification.
- **Figure 73** indicates the size of the commencing mathematics PhD cohort in comparison to other natural and physical sciences. This illustrates that mathematical sciences is quite small and is only slowly growing compared to the field of other natural and physical sciences (which includes emerging fields such as forensic science).
- **Figure 74** illustrates that in terms of all graduates of advanced research degrees (i.e. the international measure closest to the PhD), Australia has a lower percentage share of mathematics or statistics graduates in comparison with other OECD countries in 2007. However, this could be due to a range of factors, including variations in R&D investment patterns and employment opportunities between countries. While Australia performs better than New Zealand and Korea; the United States, Canada and the United Kingdom each have a significantly greater share of mathematics and statistics graduates among graduates in advanced research degrees across all fields.
- **Figure 75** shows the highest educational qualification gained prior to commencing a mathematical sciences PhD. For the majority (62%), this was an undergraduate degree. However, 20 per cent of candidates report a prior postgraduate qualification, while 15 per cent reported no prior attainment (or did not report at all).

Figure 71: Mathematical sciences HDR commencements, 2001-2008



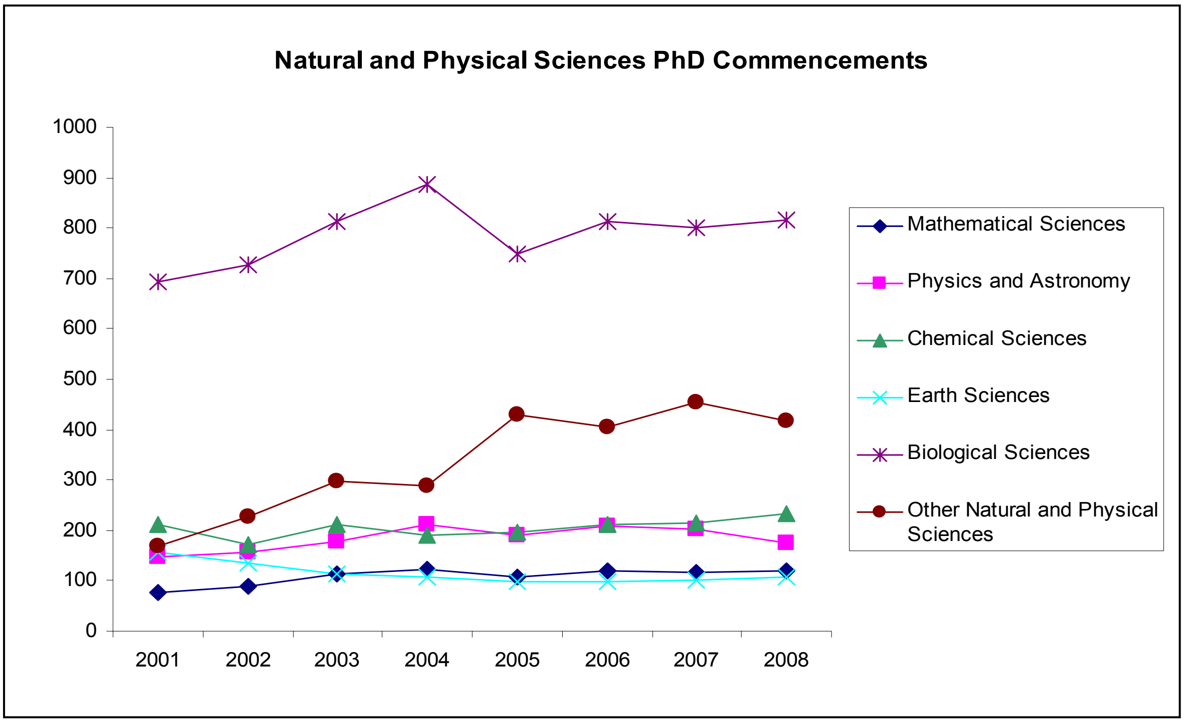
Source: DEEWR University statistics, unpublished data.

Figure 72: Mathematical sciences HDR completions, 2001-2008



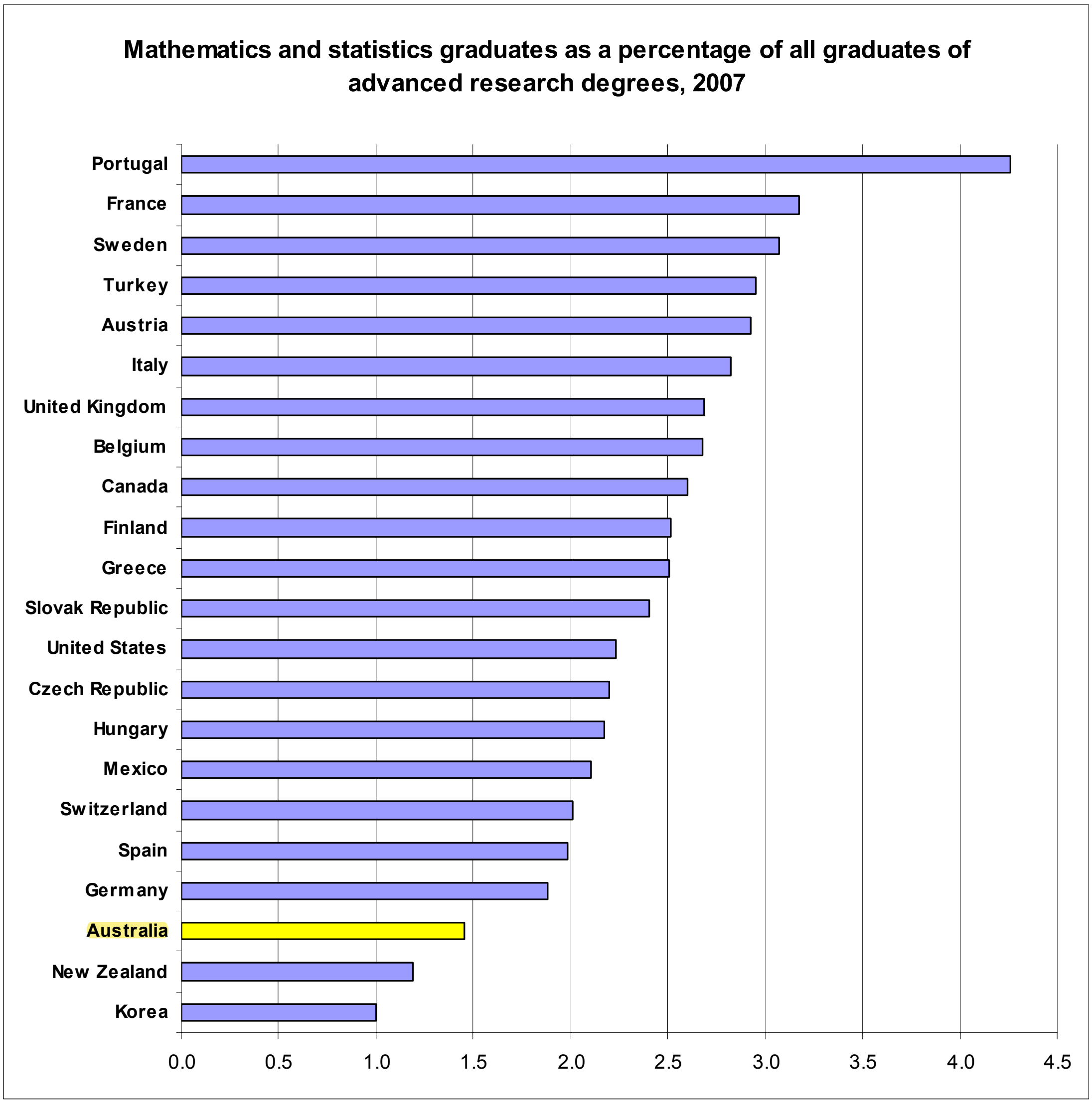
Source: DEEWR University Statistics, unpublished data.

Figure 73: Comparison of HDR commencements in the natural and physical sciences, 2001-2008



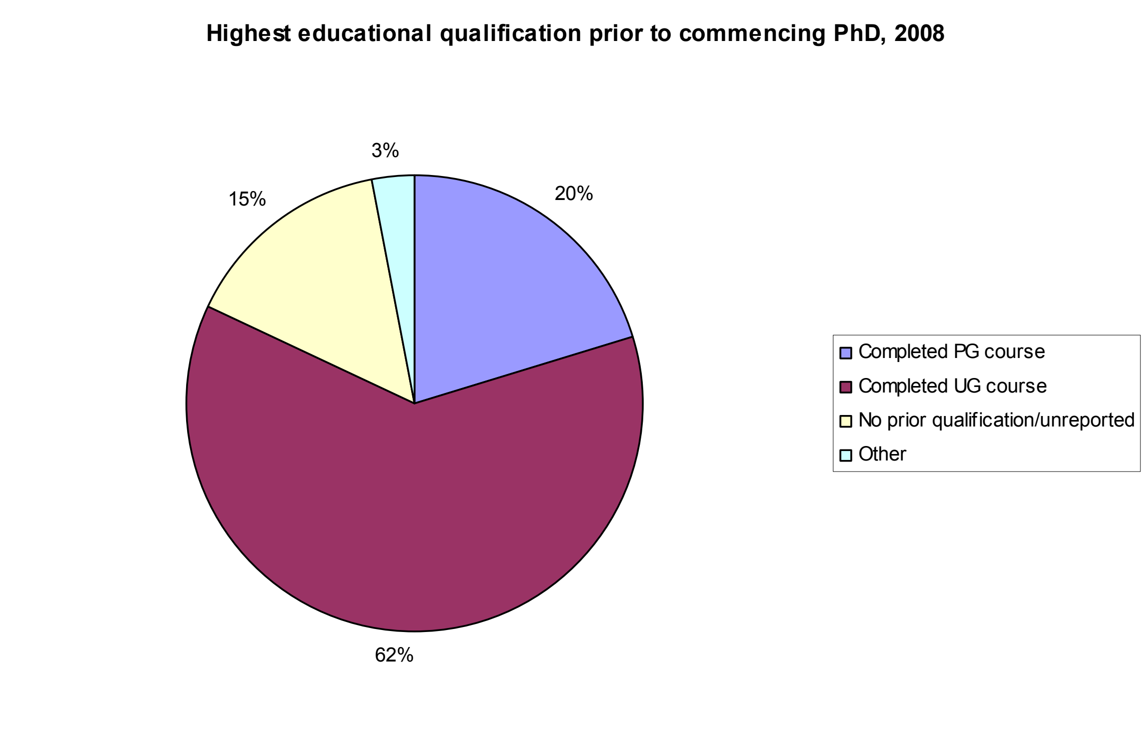
Source: DEEWR University statistics, unpublished data.

Figure 74: Mathematics and statistics graduates as a percentage of all graduates of advanced research degrees, 2007



Source: *OECD Stat Extracts* Online Database.
Note: This data should be approached with care – differences in higher education systems can produce anomalous results when countries try to standardise their information to possibly incompatible OECD reporting requirements.

Figure 75: Highest educational qualification prior to commencing a mathematical sciences PhD, 2008



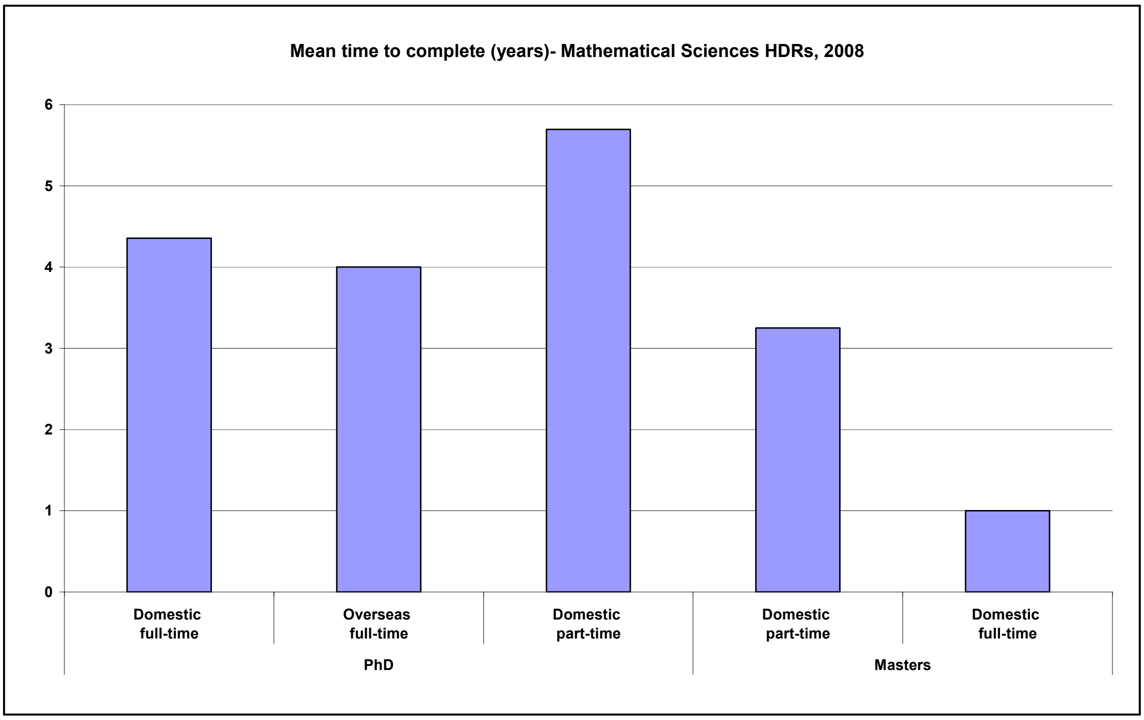
Source: DEEWR University Statistics, unpublished data.

HDR time to complete

Key Points

- *The time taken to complete HDR studies and mode of study (full-time versus part-time status) provides information on the pipeline from research training to the workforce.*
- **Figure 76** indicates that on average, domestic full-time mathematical sciences PhDs complete in 4.4 years (compared to a mean completion time across all disciplines of 4.1 years) while domestic part-time PhDs complete in 5.7 years, compared to an overall mean completion time of 6 years for domestic part-time students across all disciplines. Full time international PhDs complete on average in 4 years. The majority of both domestic and international HDR students are in full time study.

Figure 76: Mathematical sciences HDRs average time to complete, 2008



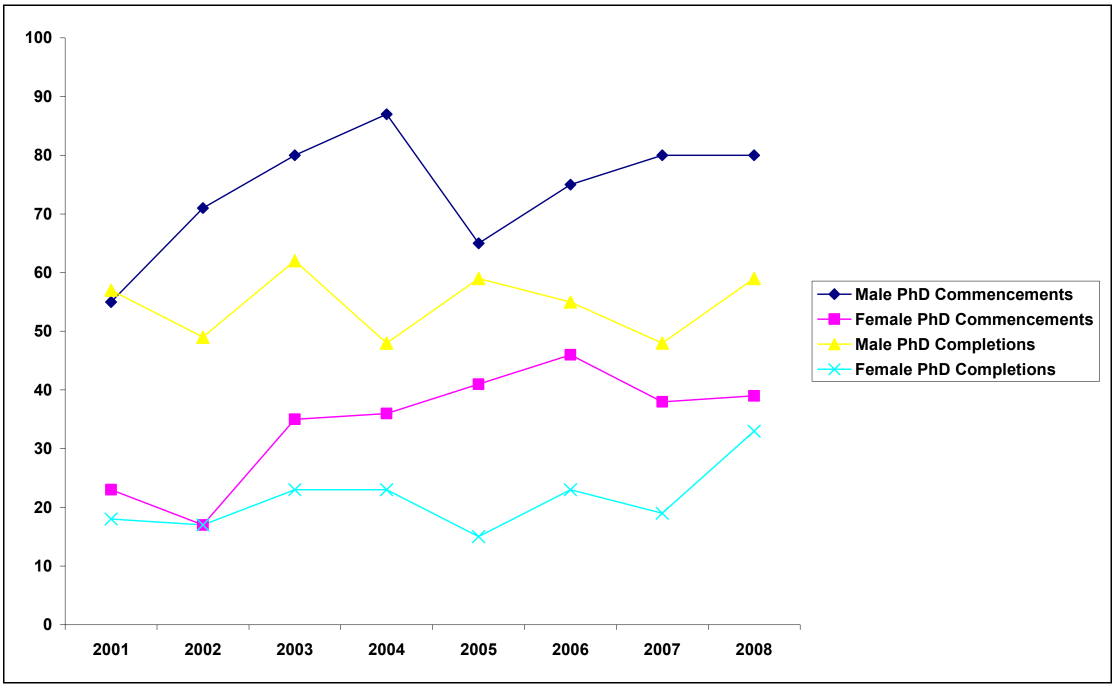
Source: Published and unpublished DEEWR Unistats data.
Note: International part-time PhDs and all international Masters students are not included, as the sample size is too low.

Demographic data – commencements and completions by age and gender

Key Points

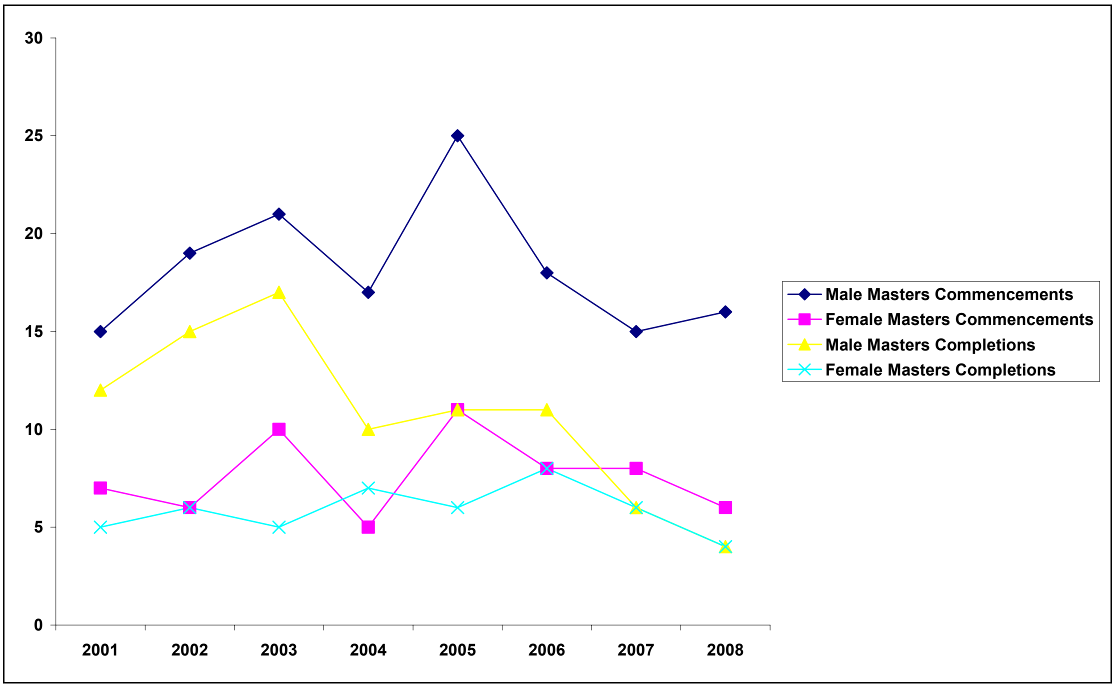
- *The age of mathematical sciences HDR students provides a useful, but not conclusive, gauge of the potential workforce contributions of graduates, while gender may reveal any persistent inequalities in participation in HDR degrees between the genders.*
- **Figures 77a** and **77b** show a significant disproportion between male and female commencements and completions (both Masters and PhDs) in mathematical sciences. This 2:1 ratio on average of males to females for both commencements and completions in mathematical sciences is more marked than for the other natural and physical sciences disciplines, but not as pronounced as, for example, engineering (8:3 ratio).
- While the gender gap is narrowing, it is still more pronounced than the cross-disciplinary average. In 2008, for example, nearly 51 per cent of commencing PhD candidates were female, compared to 33 per cent for mathematical sciences.
- **Figure 78** shows that mathematical sciences HDR students tend to be younger than the median for all disciplines (33 for domestic HDR completions). The median age for commencing male PhDs was at 23 years while commencing female PhDs was at 25 years in 2008. International PhD students tend to be slightly older, with commencing male and female PhD median ages of 26 and 25 years respectively.
- Median ages of male and female completions of domestic PhDs in mathematical sciences were broadly similar, at 30 and 31 years respectively.

Figure 77a: Mathematical Sciences PhDs commencements and completions by gender, 2001 to 2008



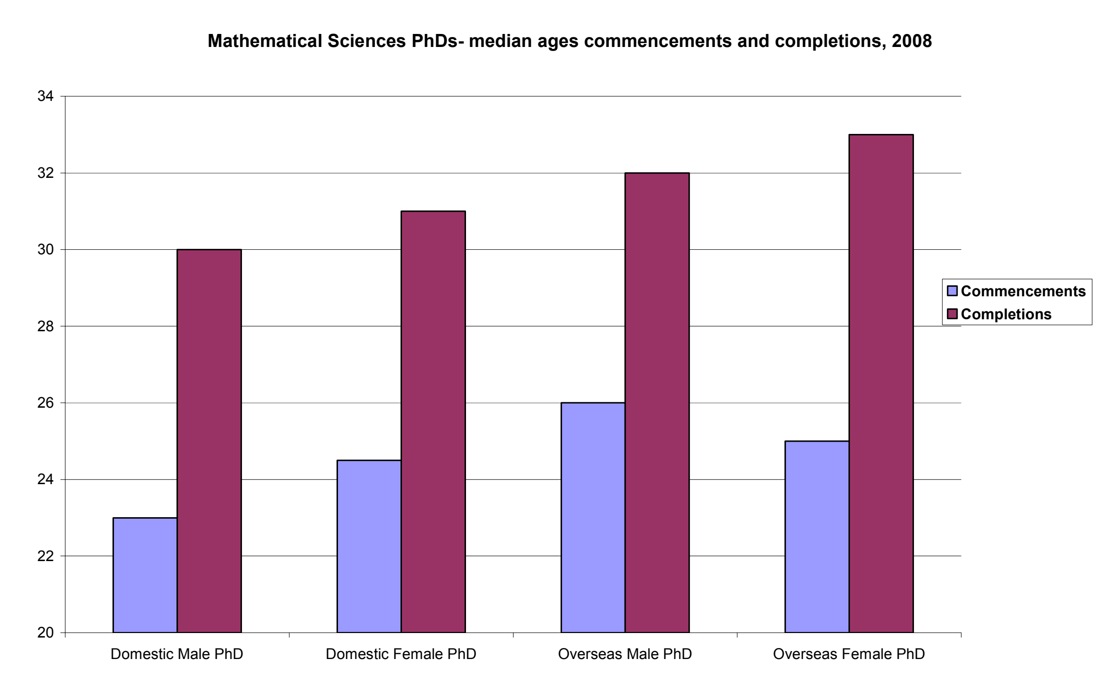
Source: Published and unpublished DEEWR Unistats data.

Figure 77b: Mathematical Sciences Masters commencements and completions by gender, 2001 to 2008



Source: Published and unpublished DEEWR Unistats data.

Figure 78: Median ages of commencing and completing mathematical sciences PhDs, 2008



Source: Published and unpublished DEEWR Unistats data.
Note: The chart shows median ages for two different cohorts – those that commenced and completed their HDRs in 2008.

Supply through migration

Key Points

- *A further key source of supply of mathematical sciences HDR-qualified individuals to Australia is through both temporary and permanent migration.*
- *While the data available makes it difficult to discern the scale of supply for the mathematical sciences through migration, previous studies (ACER, 2009) have estimated that approximately 22 per cent of Australia's overall supply of HDR skills is achieved through this source.*
- Mathematicians and statisticians can currently migrate to Australia under a number of visa classes. Within the general skilled migration program, mathematicians and statisticians can apply under the SOL Schedules 2 and 4. They are also eligible to apply under the employer nomination scheme and have access to a variety of temporary visa classes for work, collaboration or study.
- While quantification of the scale of supply of mathematical sciences PhDs to the workforce from international sources is limited by the granularity of data collected, ABS 2006 census data reveals that a significant proportion (47%) of doctorate holders in mathematical sciences were born overseas, suggesting that international sources may be highly significant in maintaining Australia's base of researchers in this discipline.

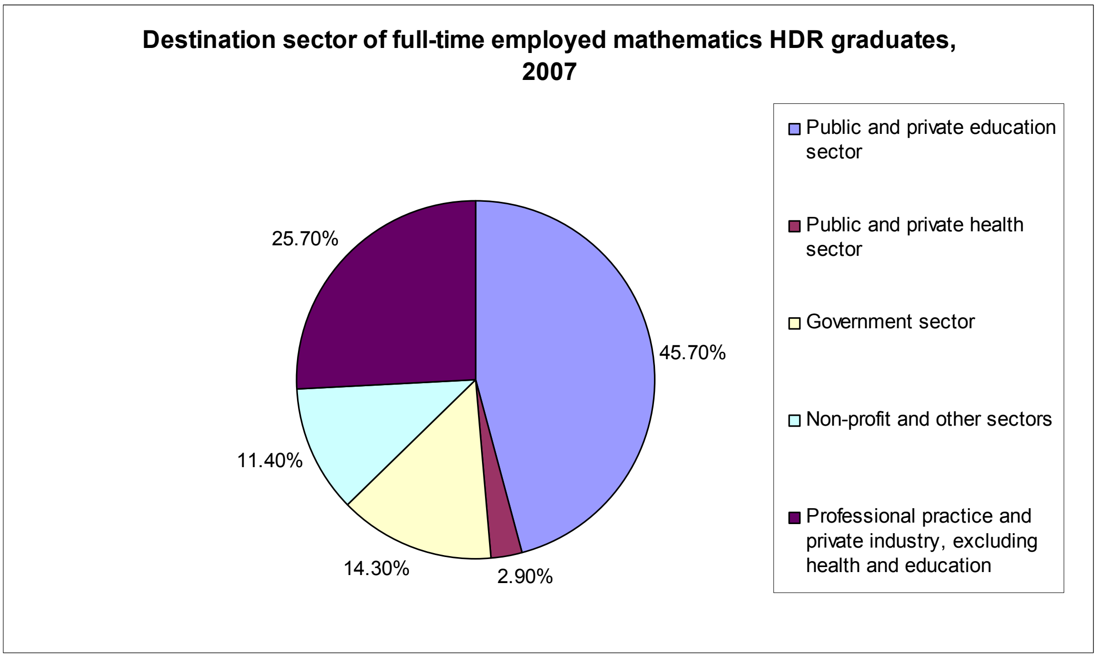
Note: SOL Schedule 2 applies to previous visa holders or those who applied for skilled independent work visas before 8 February 2010 and who are now applying for new work visas. This includes those who held student visas as of 8 February 2010 and may submit their applications until 2012. SOL Schedule 4 applies to visa applicants sponsored by state or region to work in Australia.

7.1.3 Demand and career prospects for mathematical sciences researchers and HDRs

Key Points

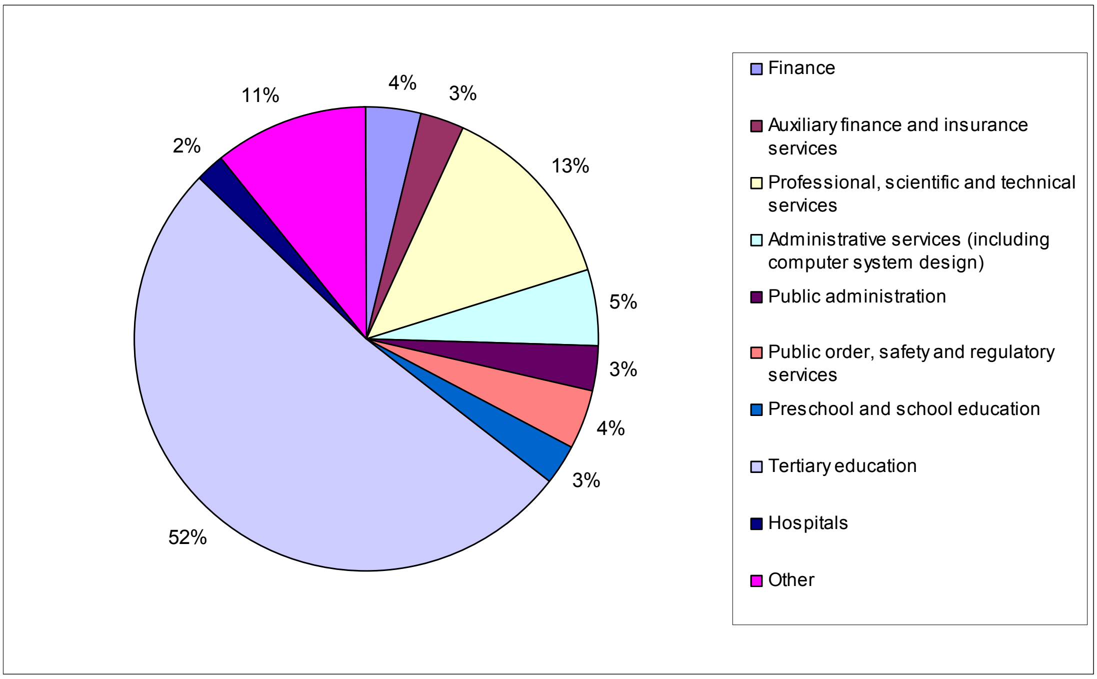
- *The immediate employment outcomes (employability and sector of employment) of mathematical sciences researchers and HDR graduates give a sense of employer demand for research skills in this area. Graduate reflections on their preparedness for employment additionally provide a gauge of any mismatch between experience and skills garnered through research training and subsequent employment needs.*
- According to the 2007 Graduate Destinations Survey, taken four to six months after submission of a thesis, recent mathematics graduates were most likely to be employed in the education sector (**Figure 79**).
- Mathematics and statistics HDR graduates are more likely to be employed in education than the natural and physical sciences disciplines, and less likely to be employed in private industry.
- Mathematics HDR graduates participating in the 2008 Graduate Destination survey had starting salaries of around $63,500.
- Examination of 2006 Census data relating to industry of employment for mathematical sciences Doctorate holders shows a moderately different pattern to that for recent graduates. Almost 52 per cent of this cohort was employed in tertiary education, with smaller, but still significant numbers in professional, scientific and technical services (13%), public administration (7%), finance and related services (7%) and administrative services, including computer system design (5%). (**Figure 80**).
- Responses to Australia's Graduate Destination Survey 2008 indicate that the majority (82.8%) of mathematical sciences HDR graduates considered their HDR qualification a formal requirement or important to their job – percentages significantly above the average across all disciplines (72%).

Figure 79: Employment sector destinations for full-time employed mathematics HDR graduates, 2007



Source: Grads online database of the Graduate Careers Council of Australia Ltd.
Note: Mathematics is used as a proxy indicator in the absence of mathematical sciences as fields of study.

Figure 80: Industry sector of employment for mathematical sciences Doctorate holders, 2006



Source: ABS Census 2006 special tabulation.

7.1.4 Summary points

Taken together, the quantitative trends examined in this case study suggest the following:

- Australia's mathematical sciences doctorate-qualified workforce is a small (just over 5% of the total) but important component of Australia's total doctorate-qualified workforce.
- While R&D expenditure in the mathematical sciences represents a tiny proportion of Australia's overall R&D expenditure, Australia's impact in this discipline is among the highest of all disciplines, suggesting that Australia 'punches above its weight' in this area.
- Australia's supply of mathematical sciences research skills through the research training system is currently stable. However, a recent declining trend in domestic commencements suggests that this may not remain the case in the future, putting at risk Australia's continuing good performance in this area. Moreover, Australian mathematical sciences HDR completions are lower than many other countries as a share of HDR completions across all disciplines, which may influence competitiveness in this discipline in future years. Finally, although gender inequality is diminishing, there still remains an imbalance between the genders, in particular in HDR students.
- Employment prospects of mathematical sciences HDR graduates appear positive, with the education sector being the most common immediate employment destination of graduates (i.e. around four to six months out from graduation).
- The number of research active staff in the mathematical sciences is difficult to gauge from available data but qualitative information collected as part of the case study suggests a wide dispersion of research effort across different sectors of the economy and across different disciplines. This may take the form of enabling contributions to other fields not formally reported as mathematical sciences expenditure/effort, for example in the social sciences, health and biological sciences, information technology or banking and finance.
- There is some evidence for a decline in the numbers of mathematical sciences research staff in the university sector in recent years, and the potential for strong replacement demand as the academic workforce ages.

7.2 What are the key influence factors (current and future)?

Pipeline issues

We know from various sources[13] that the number of students from the secondary education system with the necessary grounding and skills to engage in higher education in mathematics or statistics is decreasing, and that this trend is exacerbated by a shortage of specialist mathematics teachers in many jurisdictions.

While pipeline issues are not the focus of this study, clearly the supply of researchers is closely connected to both the number and the capacity of students wishing to undertake HDR studies. This is likely to be influencing both recent commencement

[13] For example: Group of Eight (2009) *Review of Education in Mathematics, Data Science and Quantitative Disciplines;* Australian Academy of Science (2006), *Mathematics and Statistics: Critical Skills for Australia's Future, The National Strategic Review of Mathematical Sciences Research in Australia;* Australian Mathematical Sciences Institute (2009) *A National Strategy for Mathematical Sciences in Australia,* among others.

and completion trends and can be expected to impact on future mathematical sciences HDR availability through the research training system if not addressed.

The dispersed nature of the mathematical sciences

A defining characteristic of the mathematical sciences, by virtue of its key role as an enabling discipline, is that mathematicians and statisticians tend to be dispersed across research areas in many organisations. For example, in a university setting, mathematicians and statisticians can be found not only or even largely within mathematics departments, but also within social sciences, physical and biological sciences, engineering, education, computing and information technology, agriculture, public health and medical research departments.

The effect is that mathematical sciences departments can find it difficult to maintain the critical mass necessary for a vibrant research culture while at the same time much of the mathematics and statistics being conducted within a university tends to be invisible at the organisational level.

Reported declines in mathematics and statistics departments

The 2006 report *Mathematics and Statistics: Critical Skills for Australia's Future*[14] reported a severe contraction in the number of academic staff teaching in mathematical sciences departments, resulting in departments reducing in size or disappearing altogether. This finding is supported by a Group of Eight study, which reports that several mathematics departments are now unable to offer mathematics majors[15].

A number of members of the expert group were of the opinion that the position of statistics as a stand-alone discipline was already critical, with up to one third of statistics departments or faculties closing or merging in recent years and no immediate prospects for a reversal of this trend.

A variety of causes has been suggested for this, including declining undergraduate enrolments, the tendency of mathematicians and statisticians to disperse within a university, design features of government funding mechanisms for research training (in particular the high/low cost differential under the RTS[16]). Expert group members argued that while mathematical sciences are in general low cost in terms of infrastructure, providing academic supervision in mathematics and statistics is both intensive and time consuming. This means that the number of students a supervisor can take on is limited and more staff capable of supervision are required.

If this trend towards contraction in mathematics and statistics departments continues, there may be adverse consequences for the quantity and diversity of research output,

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[14]Australian Academy of Science (2006), *Mathematics and Statistics: Critical Skills for Australia's Future, The National Strategic Review of Mathematical Sciences Research in Australia* pp34-37.

[15] Group of Eight (2009) *Review of Education in Mathematics, Data Science and Quantitative Disciplines*.

[16] Under the funding formula for the RTS, HDR completions in high-cost disciplines are weighted higher than HDR completions in low-cost disciplines. Because mathematical sciences is a low-cost discipline, universities receive less funding for mathematical sciences HDR students than, for example, pharmacology HDR students.

threatening Australia's ability to keep up with recent overseas developments in mathematics and statistics. A reduced research base in mathematics and statistics is also likely to impact negatively on both the quantity and quality of HDR training.

Members of the expert group were particularly concerned about a downwards, self-reinforcing spiral effect in which poorly resourced departments are unable to attract students – leading to fewer courses being offered and fewer staff available to teach them. The group also suggested that the lack of a viable academic career path at universities is a key factor impeding revitalisation of mathematical sciences departments, driven in part by the preponderance of short term project funding at the expense of permanent positions. Anticipated age-related retirements of mathematical sciences academics are likely to further reinforce the impact of these issues.

Workforce demand in non-academic/non-research areas

The expert group reported that good students were being 'head-hunted' by industry before commencing or completing their HDR studies, and that high starting (and continuing) salaries for many mathematicians and statisticians have attracted graduates away from postgraduate study. The group also reported that businesses have targeted high-performing undergraduates with offers of employment upon graduation and prior to any opportunity to consider postgraduate options.

Areas of potential future shortfall

A number of areas in the mathematical sciences were identified as growth areas, with an anticipated increased demand for research trained mathematicians and statisticians in future years. These areas are: finance; data analysis and computability; manufacturing; health and medical research including biostatistics; defence and security; climate science and meteorology; and water and energy management.

Visa issues

Expert group members expressed concern about the effect of recent changes to the Migration Occupations in Demand List (MODL) which has been supplanted by the new SOL. The SOL has a greatly reduced list of occupations which can be used by potential independent migrants under the general skilled migration visa program. Tutors and lecturers and mathematicians and statisticians were listed on the previous MODL but are not listed on the SOL.

It should be noted that the SOL is based on medium term skills shortages and is subject to annual review. It should also be noted that state and territory lists include mathematicians and statisticians, offering the possibility of state and territory sponsored skilled migration to mathematical sciences HDR graduates and researchers.

Academic members of the expert group commented that while migration has the potential to supplement shortfalls in supply from domestic sources, many of their overseas HDR candidates are here on scholarships which require them to return home upon graduation rather than apply for residency.

However, group members also recognised that even where international students do not become part of the Australian research workforce, there are many benefits that accrue from Australian trained researchers returning to work in their home countries including those stemming from the development of productive networks and research linkages.

7.3 Mathematical sciences research workforce score-card

Score-card

	Quantity of supply through the research training system	Quality of supply through the research training system	Research workforce equity	Research workforce shortfalls	Employment prospects	Research career pathway support
Current	🟠	🟠	🟠	🔴	🟢	🟠
Future	🔴	🟠	🟠	🔴	🟢	🟠

Legend:

🟢	Green (performing well/stable/positive outlook)
🟠	Amber (some challenges/weaker than expected performance)
🔴	Red (poor performance/area(s) of concern/significant challenges)

7.4 How can Australia better position itself for the future?

Continuing efforts to address pipeline issues

The greatest area for concern with mathematical sciences is the pipeline from primary schooling through to undergraduate education. While there has not so far been a marked impact on HDR enrolments, it seems inevitable that if the decline in undergraduate enrolments continues there will be a flow on effect at the postgraduate level. Despite international enrolments currently holding up well, the expert group considered it unlikely that these alone will be able to remedy any shortfall in the supply of HDR qualified mathematical sciences researchers.

While this is outside the scope of the research workforce strategy, the expert group were of the view that a concerted effort needs to be made, building on existing positive initiatives across government and the education sector, to increase the supply of mathematical scientists by encouraging greater participation in mathematics in the school years.

Industry engagement

The expert group members were of the opinion that there needs to be more business support for the mathematical sciences. The discipline suffers because mathematicians and statisticians are only a small, and largely unrecognised, part of the workforce in most industries in which they are employed. In general, sponsorships, development opportunities and the like are more often directed to practitioners in a field, not the 'quants' who may not have high visibility.

Initial steps suggested include an awareness campaign and more use of internships and schemes such as the Researchers in Business program. For example, AMSI has recently launched an internship program in partnership with Enterprise Connect which aims to place at least 20 interns per year in small businesses to work on projects requiring mathematical and statistical skills.

The AMSI initiative is modelled on the Canadian MITACS Accelerate program. Under this program an HDR student or post-doctoral fellow undertakes a minimum four month internship to work on a research challenge faced by the industry partner. The position is funded jointly by the partner company and federal and provincial funding partner. The program has been successful in creating over 1500 internships in all industry sectors and academic disciplines.

Quantity and quality of mathematical sciences HDR graduate skills required by employers

Government bodies and research agencies involved in this case study (CSIRO and the ABS) were concerned about the adequacy of mathematical science graduate generic skills. Communication skills and the ability to work in multi-disciplinary teams were often regarded as poorly developed in new recruits.

Both agencies indicated that they had in place training programs to develop the required additional skills. In particular, CSIRO has comprehensive schemes in place to attract and retain well qualified applicants, including internships, scholarships and post-doctoral positions where applicants work in CSIRO while gaining requisite skills and/or qualifications.

The identification of this issue in a number of recent studies[17] and the diverse career pathways experienced by mathematical science HDR graduates suggests that it is an area that may warrant further attention within university research training programs.

Building critical mass

The dispersed nature of mathematical sciences researchers throughout universities has made it difficult for departments to maintain critical mass. In particular, academic statisticians and a number of growing areas of applied mathematics and statistics are either too small or too dispersed to perform the role of providing a focus for researchers and an attractant for aspiring researchers.

Expert group members suggested several potential strategies to address this issue. These included mathematical sciences fellowships and post-doctoral positions to build numbers in individual institutions, clusters of universities supplying resources to form a 'centre of excellence' and collaboration between smaller institutions and those with critical mass in statistics and/or mathematics.

Another suggestion to address the critical mass problem while at the same time raising awareness of the enabling role of mathematical sciences, was for universities to adopt the model currently used in the statistics department of Stanford University. All academic faculty members of the department must hold a joint appointment with another faculty, either on the basis of their research interest or because of teaching duties. However the group cautioned that a move towards joint appointments would need to be carefully designed and monitored to ensure effectiveness in building critical mass.

Addressing information gaps

Much of the currently available information about the state of mathematical sciences does not relate directly to the training of or demand for research-trained individuals.

This lack of information is exacerbated by the dispersed nature of the mathematical sciences, meaning that there appears to be no accurate measure of the number of mathematicians and statisticians engaged in research. Similarly, there is a lack of data concerning the demand for research-trained mathematicians and statisticians[18] in public and private sector employment and a lack of data to support the career pathways experienced by individuals with qualifications in this area.

There is an opportunity for improved data gathering both by universities and by government to fill these gaps.

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[17] The Allen Consulting Group 2010, *Employer Demand for Researchers in Australia*, Report for the Department of Innovation, Industry, Science and Research.

[18] Edwards, Daniel, 2010, "The future of the research workforce: estimating demand for PhDs in Australia", *Journal of Higher Education Policy and Management*, Vol.32 (No 2).

8 Appendix A – Expert Group Members

Case Study	Name	Affiliation
Chemical Sciences	Professor Ian Rae	Australian Academy of Technological Sciences and Engineering
	Professor Judy Raper	University of Wollongong
	Professor Curt Wentrup	University of Queensland
	Professor Aibing Yu	University of New South Wales
Education	Dr Helen Askell-Williams	Flinders University
	Dr Sharon Broughton	Research Branch, Queensland Department of Education and Training
	Professor Stephen Dinham	Australian Council for Education Research
	Professor Toni Downes	Australian Council of Deans of Education, Charles Sturt University
	Dr Sarah Howard	Australian Association for Research in Education, University of Wollongong
	Professor John Loughran	Monash University
	Professor Jo-Anne Reid	Australian Association for Research in Education, Charles Sturt University
	Professor Peter Renshaw	University of Queensland
	Professor Sue Willis	Australian Council of Deans of Education, Monash University

Case Study	Name	Affiliation
Engineering	Professor Hugh Durrant-Whyte	Centre for Social Robotics, University of Sydney
	Professor Rob Evans	Victoria Research Laboratory, NICTA
	Professor Archie Johnston	University of Sydney
	Dr Lindsay Lowes	Water Corporation
	Scientia Professor Veena Sahajwalla	Centre of Sustainable Materials Research and Technology, University of New South Wales
Health	Dr Maryanne Aitken	Murdoch Children's Research Institute
	Dr Moira Clay	Telethon Institute for Child Health Research
	Professor Terry Dwyer	Murdoch Children's Research Institute
	Dr Nick Gough	Nick Gough and Associates Pty Ltd
	John Grace	Consultant
	Professor Ian Gust	University of Melbourne
	Professor Judith Whitworth	Australian National University, WHO Global Advisory Committee on Health Research
History and Archaeology	Professor Kate Darian-Smith	University of Melbourne
	Dr Zenobia Jacobs	University of Wollongong
	Professor Iain McCalman	University of Sydney
	Professor Constant Mews	Monash University
	Professor Tim Murray	La Trobe University

Case Study	Name	Affiliation
Mathematical Sciences	Professor Kaye Basford	University of Queensland
	Professor John Carlin	Murdoch Children's Research Institute University of Melbourne
	Dr Frank de Hoog	Commonwealth Scientific and Industrial Research Organisation
	Professor Tony Guttmann	University of Melbourne
	Associate Professor Barry Hughes	University of Melbourne
	Professor Geoff Prince	Australian Mathematical Sciences Institute
	Ms Jan Thomas	Australian Mathematical Sciences Institute
	Dr Shiji Zhao	Australian Bureau of Statistics

9 Appendix B – References

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