Forging New Directions in Physics Education in Australian Universities

Graduates in the Workforce

A report on the findings of the Graduates in the Workforce strand of the 2007-9 Physics Project, funded by the Australian Learning and Teaching Council

March 2009

Editors
John O’Byrne
Alberto Mendez

“In my opinion the project has done a splendid job of bringing key issues of science education to light in a way that physicists take seriously and will engage with. Through them, it has forged a national community of practice.”

Professor John Rice
Executive Director, Australian Council of Deans of Science
Forging New Directions in Physics Education in Australian Universities

Graduates in the Workforce Working Party Report

Report prepared by John O’Byrne and Alberto Mendez

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Forging New Directions in Physics Education in Australian Universities

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March 2009


Project website which includes the report in electronic format at:

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2009
# CONTENTS

1. **PREAMBLE** ................................................................................................................. 1
2. **METHODOLOGY** ........................................................................................................... 2  
   2.1 Survey development .................................................................................................... 2  
   2.2 Graduate and employer surveys ................................................................................. 2  
   2.3 Locating physics graduates ......................................................................................... 3  
   2.4 Initial data gathering ................................................................................................... 3  
   2.5 Data management and analysis .................................................................................. 4  
   2.6 Follow-up survey and graduate profiles ..................................................................... 4  
   2.7 Employer survey ........................................................................................................ 4  
3. **GRADUATE SURVEY RESULTS** .................................................................................. 5  
   3.1 General statistics ........................................................................................................ 5  
   3.2 Geographic coverage .................................................................................................. 5  
   3.3 Range of tertiary qualifications .................................................................................. 6  
   3.4 Reasons for doing physics ......................................................................................... 7  
   3.5 First job after graduation ........................................................................................... 8  
   3.6 Current / most relevant job ....................................................................................... 11  
   3.7 Physics as useful training for workplace .................................................................... 12  
   3.8 Features of undergraduate physics helpful / a hindrance to learning ....................... 13  
   3.9 Graduate attributes developed in undergraduate physics ....................................... 13  
   3.10 Features of postgraduate physics helpful / a hindrance to learning ......................... 16  
   3.11 Graduate attributes developed in postgraduate physics ......................................... 16  
4. **RESULTS OF FOLLOW-UP QUESTIONS TO SELECTED GRADUATES** .................... 18  
   4.1 General statistics ....................................................................................................... 18  
   4.2 Summary of findings .................................................................................................. 18  
   4.3 Sample responses ....................................................................................................... 18  
5. **EMPLOYER SURVEY RESULTS** .................................................................................. 21  
   5.1 General statistics ....................................................................................................... 21  
   5.2 Employers’ general view of graduates with an undergraduate degree ..................... 21  
   5.3 Employers’ view of graduate attributes .................................................................... 22  
   5.4 Employers’ general view of graduates with a postgraduate degree ........................... 22  
6. **DIFFERENCES BETWEEN GRADUATE SURVEY DATA SUBSETS (TO DISCOVER BIASES)** ......................................................................................................................... 23  
   6.1 Preamble .................................................................................................................... 23  
   6.2 Differences across subsets .......................................................................................... 23  
      Geographical coverage ................................................................................................ 23  
      Range of tertiary qualifications ................................................................................... 23  
      Reasons for doing physics .......................................................................................... 23  
      First job after graduation ......................................................................................... 24  
      Current / most relevant job ....................................................................................... 24  
      Physics as useful training for workplace ..................................................................... 24  
      Features of undergraduate physics helpful to learning ............................................. 24  
      Graduate attributes ................................................................................................. 24  
      Graduate attributes needing more attention ............................................................. 25  
   Acknowledgements .......................................................................................................... 25  
   References ....................................................................................................................... 26
In this report we present the basic findings of the Graduates in the Workforce strand of the ‘Forging New Directions in Physics Education in Australian Universities’ project funded by the Australian Learning and Teaching Council (ALTC). A version of this document appears as Appendix 5 of an extensive report sent to the ALTC, available for download on their website at www.altc.edu.au/. Alternatively, an electronic copy may be downloaded from the project website at www.physics.usyd.edu.au/super/ALTC/. Discussion of some of aspects of the data reported here can be found in the Formal Publications section of the project website.

1. Preamble

Physics educators often lack an awareness of graduate profiles and a good understanding of career paths for physics graduates who do not continue into a research career. The pilot study undertaken in our 2004/5 AUTC-funded project, ‘Learning Outcomes and Curriculum Development in Physics’ (www.physics.usyd.edu.au/super/AUTC), suggested that departments should rethink teaching and learning strategies in terms of their impact on employability of graduates. Understanding of graduate destinations should be seen as increasingly important as trends suggest a shortfall of graduates in physics in the near future.

The purpose of the current project’s Graduates in the Workforce strand was to identify graduate destinations and employer expectations, to explore the employment opportunities available to Australian physics graduates and determine the suitability of current course content, structures and learning activities. We aimed to disseminate the findings through workshops involving physics academics, contact with discipline leaders, a website showcasing graduate profiles and papers presented at national conferences.

In particular we sought to provide information that can be disseminated to school and university students. Rodrigues et al (2007) suggests that “high school students had little idea of the range of workplace possibilities opened up by a science degree” and “career advice prior to beginning university was completely inadequate”. We aimed to help address this lack of information.

This report is certainly not the only source of information about physics graduates. However, it is relatively large (although certainly not huge), Australian, drawing from many universities and all graduate levels. It is also restricted to physics and not the broader categories of ‘physical science’ or just ‘science’ found in many surveys and reports – for example McInnis et al (2000) and Rodrigues et al (2007).

There are many other sources of Physics careers information, for example:

- Graduate career information, including salaries, is available from Graduate Careers Australia: http://www.graduatecareers.com.au/
  - And the Careers in Physics booklet linked from: http://www.graduatecareers.com.au/content/view/full/3201
- A list showing the diversity of possible physics careers, originally in Physics Today: http://www.haverford.edu/astronomy/alumni/careers.php
- American Physical Society: http://www.aps.org/careers/
- Institute of Physics (UK): http://www.iop.org/activity/careers/
2. Methodology

2.1 Survey development

During 2007, two related surveys were developed to explore the diverse employment opportunities available to Australian physics graduates with the aims of:

- Identifying graduate destinations
- Identifying employer expectations of physics graduates
- Determining the suitability of current course content, structures and learning activities
- Providing realistic answers to students and parents: Why do physics? Where does it lead?

A graduate survey was developed that significantly expanded on questions asked to graduates in interviews in the 2004/5 AUTC project. Before full implementation in 2008 the survey was trialled with physics graduates from the University of Sydney. Graduates were contacted by email through the alumni database maintained by the School of Physics. The survey was hosted online on the school’s server and 20 responses were received in late 2007. These initial responses were evaluated and led to some modification of the survey questions.

At the same time, a parallel survey for employers was developed. This survey also used interview questions developed for employers in the earlier project as a starting point. Given the difficulties in locating employers of physics graduates, this survey could not be trialled, but it underwent similar modifications to those of the graduate survey after that was trialled, with the result that the employer questions closely complimented those of the graduate survey.

Both surveys were finalised at the beginning of 2008 and in February they and were placed online at SurveyMonkey, a professional survey hosting website. It was estimated that each survey should take 20 minutes to complete. Before commencing the online survey, respondents were provided with a one-page description of the project and why the survey data was being sought.

2.2 Graduate and employer surveys

The graduate survey (available for download on the project webpage) was extensive and consisted of over 40 questions spread over five separate sections:

1. Basic personal and education information
2. Career information
   a. Details of first job after graduation
   b. Details of current (or most relevant) job
   c. Recommendations concerning relevance of physics training
3. Undergraduate physics experience
4. Postgraduate physics experience (if applicable)
5. Any other comments

At the end of the survey, graduates were asked whether they were willing to partake in a further interview to probe some of the questions more fully. Additionally, they were advised that an employer survey was available and were encouraged to ask their employer to visit the website, to learn more about the project and hopefully complete the survey.

The employer survey (available for download on the project webpage) consisted of almost 30 questions divided into four sections:
1. Basic workplace information
2. Experience with undergraduate physics employees
3. Experience with postgraduate physics employees (if applicable)
4. Any other comments

At the end of the survey, employers were also asked whether they were willing to partake in a further interview to probe some of the questions more fully.

2.3 Locating physics graduates

The task of identifying, locating and contacting physics graduates nationwide was not easy. It was accomplished by working closely with each physics department in Australia, through the project’s wide range of contacts. One third of the 32 physics departments were able to assist in this task on a significant scale, by contacting more than a handful of graduates.

The intent was to utilise university or departmental alumni databases to contact a large number of graduates, however this only happened effectively at a small group of institutions. Only four departments had ready access to an alumni database. Of these, only one (University of Sydney) maintains a physics-only alumni list. The other three (University of Adelaide, Central Queensland University and Murdoch University) needed to ask the science faculty to filter their science graduates database for physics alumni. These four departments were able to contact (by a combination of email and regular post) approximately 500, 100, 200 and 150 graduates respectively.

In most other cases contact was made with a smaller number of recent graduates, by collating personal lists kept by individual academics. Some of these lists however, were of significant size. The University of Technology Sydney’s physics department, for example, managed to collate contact details for roughly 100 graduates. The University of New South Wales collected roughly half that.

The lack of departmental knowledge of their alumni is a significant observation from this process.

2.4 Initial data gathering

Due to the difficulties experienced by many physics departments in gathering alumni contact details, the data collection process extended from February to June. In this period, 151 responses were collected. Adding the 20 responses from the trial survey, a total of 171 physics graduates provided data to the project.

It was immediately obvious that many responses were stemming from older graduates. In fact, some respondents had graduated as far back as the 1950s. The explanation letter that was sent to all graduates (outlining the project and the reasons for the survey) stipulated that recent graduates (in the last 15 years) were particularly sought, but it didn’t place any age limit on who could complete the survey. The responses from older graduates are valuable but are less relevant to the purposes of this project: providing a current and realistic description of the employment outcomes for physics graduates and the value of a physics education in the workplace.

Most of the analysis was therefore restricted to those alumni who received their undergraduate physics degree after 1990. This cut-off point reduced the data set to 108 respondents who represent relatively recent experience of university education and the job market. The majority of respondents come from just seven universities, but these span a range in size and location:

University of Adelaide, Central Queensland University, Murdoch University, Royal Melbourne Institute of Technology, University of Sydney, University of New South Wales, University of Technology Sydney
2.5 Data management and analysis

The selected data set was collated and analysed using Excel spreadsheets. The analysis was mostly a statistical analysis of the quantitative data produced by the majority of the survey questions. A number of questions required sorting the responses into categories, which could then be enumerated. Among the statistical data compiled were:

- Mean and median age of respondents (see section 3.1)
- Gender ratio (see section 3.1)
- University at which degrees were awarded (see section 3.2)
- Type of undergraduate and postgraduate degrees (see section 3.3)
- Why graduates chose to do physics at university (see section 3.4)
- First job upon graduation (by job sector) (see section 3.5)
- Current job (by job sector) (see section 3.6)
- Usefulness of physics education in the workplace (see section 3.7)
- Most helpful features of physics education (see sections 3.8 and 3.10)
- Degree to which graduate attributes were developed in physics education (see sections 3.9 and 3.11)

Once this initial analytical process was complete we looked for biases in our sample to determine what effect they might have on the data. For this purpose we looked at various subsets of the overall data, for example female only graduates, graduates with a postgraduate degree in physics, and graduates with no postgraduate qualifications in any field. In most respects, no significant differences are revealed in the subsets relative to the full data set (see Section 6).

2.6 Follow-up survey and graduate profiles

As the initial data analysis neared completion, certain issues emerged which required some clarification and led to the seeking of additional data from graduates. In particular, graduate attributes emerged as an area of considerable interest (as it had in the earlier AUTC project) and a short follow-up survey was developed. The original notion of conducting face-to-face interviews was discarded because of the logistical and timing difficulties involved. Instead a set of five follow-up questions were sent by email in July 2008. Approximately 45 respondents who had indicated they were willing to partake in a further interview were contacted in this manner. Additionally, graduates were asked to provide a short profile of their work career and the part a physics education has played upon it.

Completed replies were received from 15 graduates, yielding extra information on aspects of graduate attribute development within physics. These responses were analysed alongside the data from the main survey. The personal profiles provided by graduates underwent some editing and standardising of format and, after approval was granted by each graduate, 13 were placed on the project website for nationwide availability.

2.7 Employer survey

The early response to the employer survey was somewhat underwhelming, with only a handful of graduates willing to ask their employer to complete the survey. By May only four employers had completed the survey. Following a second email request to graduates, the contact details for 15 employers were obtained. These employers were contacted by email and informed of the nature of the project and encouraged to participate. This resulted in a further six responses, bringing the total of the employer data set to ten. These data were analysed in a similar manner to the graduate data set, with the results providing a comparison between employee and employer attitudes towards the value of a physics education.
3. Graduate survey results

3.1 General statistics

There were a total of 171 responses to the graduate destinations survey: 20 to the trial version run in 2007 and 151 to the finalised version available online at SurveyMonkey during 2008. Those who graduated before the 1990s were removed from the reduced data set, as the study seeks opinions on current employment and learning and teaching issues. The main statistics characterising the reduced sample are:

- Number of graduates in reduced data set = 108
- Female to male ratio = 35 / 71 (1:2)
- Mean age = 33 years
- Median age = 32 years

Of the 108 responses, 60 graduated in the 1990s and 48 graduated during the 2000s. A total of 18 responses came from mature age students. About two-thirds of the graduates provided contact details.

3.2 Geographic coverage

By noting at which university the graduates undertook their undergraduate physics studies, a breakdown of responses by university (Figure 1) and state (Figure 2) was compiled. University of Sydney graduates were the best represented group; partly due to the trial version being run exclusively there (five of its 21 responses are taken from the trial). New South Wales leads the way with 45 responses but all the major states are well represented, especially when the number of universities in each state is taken into account.

![Respondents by university - undergraduate degree](n = 108)

Figure 1: Respondents by institution in which undergraduate physics degree was conferred.
3.3 Range of tertiary qualifications

Almost all graduates obtained a Bachelor of Science degree (n = 100), the vast majority with a single major in physics and a handful with a double major (physics + mathematics, or physics + computer science). Of the remaining eight, they either have an equivalent overseas qualification or a Bachelor of Technology degree. 61 graduates completed Honours in physics and 14 have an engineering degree. Figure 3 shows that about half of all graduates have a postgraduate degree in physics, with eight currently studying for a PhD or MSc. Just over half of these graduates completed their postgraduate studies at the same university as they undertook their undergraduate studies.
Respondents with no postgraduate degree in physics (n = 58)

- have no postgraduate degree at all (42)
- have a PhD in another discipline (7)
- have some other postgrad degree (9)

Figure 3: Breakdown of postgraduate qualifications.

The main statistics arising from Figure 3 are:

- Number of graduates with (or currently doing) a PhD or MSc in physics = 50
- Of the 58 remaining graduates, over one quarter possess postgraduate qualifications in another discipline
- Number of graduates with no postgraduate qualifications = 42

3.4 Reasons for doing physics

There reasons given for choosing to study physics at university are shown in Figure 4.

Figure 4: Reasons for respondents studying physics at university.
The three most cited reasons are:

- A deep interest in physics
- Enjoying the subject and/or getting good results in high school
- Wanting to know how things work

Other common motivations concern personal interest in the general discipline (science) and specific disciplines (e.g. astronomy). Interestingly, about one-tenth of graduates cite their choice of physics as part of a planned career path. There is no significant difference in the responses of graduates with postgraduate qualifications and those without.

3.5 First job after graduation

The jobs physics graduates (from both undergraduate and postgraduate physics studies) found immediately after graduating can be generally divided into the ten sectors given in Table 1. The average time spent in the first job was three and a half years.

<table>
<thead>
<tr>
<th>Position</th>
<th>Employer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Miscellaneous</strong></td>
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<tr>
<td>Administration Assistant</td>
<td>Australian Museum</td>
</tr>
<tr>
<td>Management Consulting</td>
<td>Boston Consulting Group</td>
</tr>
<tr>
<td>Mortgage Broker</td>
<td>Aussie Home Loans</td>
</tr>
<tr>
<td>Dairy Farmer</td>
<td></td>
</tr>
<tr>
<td>Technical Specialist (Telecommunications)</td>
<td></td>
</tr>
<tr>
<td>Marketing</td>
<td></td>
</tr>
<tr>
<td><strong>Patents / Law</strong></td>
<td></td>
</tr>
<tr>
<td>Patent Attorney</td>
<td>Davies Collison Cave</td>
</tr>
<tr>
<td>Patent Examiner</td>
<td>IP Australia</td>
</tr>
<tr>
<td>Patent Examiner</td>
<td>IP Australia</td>
</tr>
<tr>
<td>Special Counsel</td>
<td>Minter Ellison</td>
</tr>
<tr>
<td><strong>Financial Maths</strong></td>
<td></td>
</tr>
<tr>
<td>Derivatives Dealer</td>
<td>Schroders (now part of Citigroup)</td>
</tr>
<tr>
<td>Quantitative Analyst</td>
<td>St George Bank</td>
</tr>
<tr>
<td>Data Analyst</td>
<td>National Australia Bank</td>
</tr>
<tr>
<td>Market Development</td>
<td>Chicago Climate Exchange</td>
</tr>
<tr>
<td><strong>Defence Force</strong></td>
<td></td>
</tr>
<tr>
<td>Operational Analyst</td>
<td>ADI Limited (now Thales Australia)</td>
</tr>
<tr>
<td>Engineering Officer</td>
<td>Air Force</td>
</tr>
<tr>
<td>Experimental Scientist</td>
<td>DSTO</td>
</tr>
<tr>
<td>Research Scientist</td>
<td>DSTO</td>
</tr>
<tr>
<td>Professional Officer Class 1</td>
<td>DSTO</td>
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<tr>
<td><strong>IT / Computing</strong></td>
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<tr>
<td>IT Support</td>
<td>University of Technology, Sydney</td>
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<tr>
<td>IT Support</td>
<td>RMIT</td>
</tr>
<tr>
<td>IT Support</td>
<td>Endeavour Sports High School</td>
</tr>
<tr>
<td>Computer Technician</td>
<td>University of Sydney / SydUTech</td>
</tr>
<tr>
<td>Programmer</td>
<td>Wizard Information Services</td>
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<tr>
<td>Business Manager / Computer Technician</td>
<td>De Bon Informatique Pty Ltd</td>
</tr>
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<td>Intern</td>
<td>Royal Prince Alfred Hospital</td>
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<tr>
<td>Intern</td>
<td>St Vincents Hospital</td>
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<td>Doctor</td>
<td>Wollongong Hospital</td>
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<td>Radiation Oncology Medical Physicist</td>
<td>Nepean Cancer Care Centre</td>
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<tr>
<td>Junior Radiotherapy Physicist</td>
<td>Queensland Radium Institute</td>
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<td>Company/Institution</td>
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<tr>
<td>Medical Physics Trainee</td>
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<tr>
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<td>Laboratory Technician</td>
<td>Mount Scopus Memorial College</td>
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<tr>
<td>Science Teacher</td>
<td>Loreto Kirribilli</td>
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<tr>
<td>Science Teacher</td>
<td>Dept of Education</td>
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<tr>
<td>Science (Physics) Teacher</td>
<td>Presbyterian Ladies College</td>
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<tr>
<td>Science and Maths Teacher</td>
<td>Wesley College</td>
</tr>
<tr>
<td>Graduate Teacher</td>
<td>Warrnambool College</td>
</tr>
<tr>
<td>Science Communicator</td>
<td>Questacon</td>
</tr>
<tr>
<td><strong>Public Sector (Science and Engineering)</strong></td>
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<tr>
<td>JSPS Postdoctoral Fellow</td>
<td>KEK - High Energy Accelerator</td>
</tr>
<tr>
<td>Analyst</td>
<td>Public Sector</td>
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<tr>
<td>Trainee Meteorologist</td>
<td>Australian Bureau of Meteorology</td>
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<tr>
<td>Health Physicist</td>
<td>Australian Radiation Services</td>
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<tr>
<td>Postdoctoral Research</td>
<td>European lab for non-linear spectroscopy</td>
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<tr>
<td>Research Scientist</td>
<td>DSTO</td>
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<td>Research Scientist</td>
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<td>Research Assistant</td>
<td>CSIRO</td>
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<td>IT Support / Research</td>
<td>ANSTO</td>
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<tr>
<td>Experimental Physicist</td>
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<tr>
<td>Reactor Engineer</td>
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<td>Graduate Position</td>
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<td>Electronics Technical Officer</td>
<td>Gold Coast City Council</td>
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<tr>
<td>Electrical &amp; Electric Locomotives Coordinator</td>
<td>Queensland Rail</td>
</tr>
<tr>
<td>Support Scientist</td>
<td>Joint Institute for VLBI in Europe</td>
</tr>
<tr>
<td>Principal Officer</td>
<td>Dept of Natural Resources &amp; Water</td>
</tr>
<tr>
<td><strong>Private Sector (Science and Engineering)</strong></td>
<td></td>
</tr>
<tr>
<td>Technical Instructor</td>
<td>Honeywell Australia Ltd</td>
</tr>
<tr>
<td>Engineer / Manager</td>
<td>RTA Technology</td>
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<tr>
<td>Project Controls</td>
<td>John Holland Group</td>
</tr>
<tr>
<td>Standard Engineer (contractor)</td>
<td>Canon Information Systems Research Australia</td>
</tr>
<tr>
<td>Quality Control Officer</td>
<td>Ralflatac Oceania</td>
</tr>
<tr>
<td>Solar Cell Designer / Maker</td>
<td>Dyesol</td>
</tr>
<tr>
<td>Production Support Engineer</td>
<td>Phonak &amp; Unitron Pty Ltd</td>
</tr>
<tr>
<td>Research Scientist</td>
<td>Fluorosolar Systems Ltd</td>
</tr>
<tr>
<td>Civil Engineering Programmer</td>
<td>Keays Software</td>
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<tr>
<td>Technical Officer</td>
<td>GHD</td>
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<tr>
<td>Project Engineer - Instrumentation &amp; Controls</td>
<td>Esso Australia Ltd</td>
</tr>
<tr>
<td>Senior Systems Supervisor</td>
<td>Queensland Alumina Limited</td>
</tr>
<tr>
<td>Electrical &amp; ESD Engineer</td>
<td>EMF Griffiths</td>
</tr>
<tr>
<td>Project Officer</td>
<td>Direct Edge Corporate Development</td>
</tr>
<tr>
<td>Avionics Engineer</td>
<td>Jayrow Helicopters</td>
</tr>
<tr>
<td>Health Physics Technician</td>
<td>CH2M Hill Pty Ltd (and ThermoNutech)</td>
</tr>
<tr>
<td>Physicist/Mine Radiation Safety Officer</td>
<td>WMC Resources / BHP Billiton</td>
</tr>
<tr>
<td>Research and Design Manager</td>
<td>RTUNet</td>
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<tr>
<td><strong>Post Doctoral / Academia</strong></td>
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<tr>
<td>Graduate Assistant</td>
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<tr>
<td>LOFAR Fellow</td>
<td>University of Leiden (Netherlands)</td>
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<tr>
<td>Postdoctoral Research Associate</td>
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<td>Murdoch University</td>
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<tr>
<td>Tutor / Marker / Observer</td>
<td>University of Tasmania</td>
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<tr>
<td>Post doctoral Research Assistant</td>
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</table>
Table 1: The range of positions taken up by physics graduates upon graduating. A somewhat similar list can be found at [http://www.haverford.edu/astronomy/alumni/careers.php](http://www.haverford.edu/astronomy/alumni/careers.php).

For approximately one quarter of all graduates the first job after graduation was in the tertiary/university sector (see Figure 5). The private and public sectors of the science/engineering industry are a close second and third. Secondary school teaching, medical physics and IT comprise the middle tier of job sectors where graduates find employment after graduation. The areas of the defence force, financial mathematics and patents/law form the bottom tier, with less than 5% of graduates each.

Figure 5: Job sector breakdown for initial employment of physics graduates.

Figure 6 compares the job sector breakdown between those graduates with and without postgraduate qualifications. Not surprisingly, positions in the tertiary sector for graduates without a postgraduate degree are few. Interestingly, of these graduates with only an undergraduate degree, none went into secondary teaching or medical physics.
3.6 Current / most relevant job

The overall breakdown for the graduates’ current job (92% of respondents) or most relevant job (8% of respondents) is very similar to that seen for their first job (see Figure 7). One third of graduates are still in their first job, with one quarter having swapped job sectors. 94% are currently in full time employment.

**Figure 6: Job sector breakdown for initial employment - difference between those with, and those without, postgraduate qualifications.**
### Figure 8: Job sector breakdown for current employment – difference between those with, and those without, postgraduate qualifications.

When we look at only those graduates with no postgraduate qualifications (Figure 8), we see almost exactly the same trends we saw for their first job. Of the 42 graduates with no postgraduate qualification, 11 remain in their first job.

### 3.7 Physics as useful training for workplace

- Graduates who recommend a major in physics as useful training for their current job = 75
- Graduates who DON’T recommend a major in physics as useful training for their current job = 22
- Of the 22 who DON’T recommend a major in physics, 15 believe that a smaller physics component would be useful training for their current job.

Responding to a different question, graduates overwhelmingly feel that their physics education has proved to be an advantage in the workplace. Out of 81 total responses to the question specifically asking whether it’s been an advantage:

- 68 felt that it had been
- 7 were not sure
- Only 6 felt that they gained no advantage

High amongst the skills that physics graduates believe differentiates them from other graduates are:

- Problem solving skills
- An ability to look at the big picture
- Not being ‘phased’ by unfamiliar, difficult material

Overwhelmingly, graduates refer not so much to the specific knowledge learnt (only 4-5 graduates mention there is worth in attaining knowledge in a specialised area) but the range of skills that makes physicists good ‘jack-of-all-trades’. The following response is typical:
“The greatest advantages of having completed a physics degree are that firstly, you are almost unclassifiable in the workplace so the range of fields that you can enter is very wide. Also, there is still a significant mystique associated with such a degree and thirdly, I have not seen any other discipline that does provide such a fundamental understanding of the physical world and this can be applied to anything.”

This also hints at a concern that is brought up by a number of graduates, namely that employers can sometimes undervalue a physics degree. Because there are few jobs in Australia for undergraduate Physics where you can directly utilise physics knowledge, many employers don’t realise the full extent of the skills that physics graduates possess.

3.8 Features of undergraduate physics helpful / a hindrance to learning

The two most helpful features of a physics undergraduate education that foster learning are:

- The laboratory / practical component
- Problem solving and analysis practice

Figure 9 shows the complete list of features. Interesting lectures, dedicated staff and tutorials all poll well. There is little difference in the ranking of features between the postgraduate and no postgraduate subgroups in describing their undergraduate physics experience.

![Figure 9: Helpful features of a physics degree that foster learning.](image)

A significant number of graduates said that there were no aspects that were unhelpful to their physics learning (ten responses). The main negative aspects cited were boring, non-interactive lectures and lecturers (half a dozen responses each, mostly connected) and the first year laboratory (four responses).

3.9 Graduate attributes developed in undergraduate physics

The ranking of graduate attributes developed in undergraduate physics (see Figure 10) supports the results found in the previous, much smaller, AUTC study. Problem solving is the most developed skill, with laboratory and computational skills considerably further back in second and third place. Ethical and social issues are hardly touched upon and oral communication is very poorly developed.
All other graduates attributes are to be found in the some to quite a bit response range. Note that any two categories separated by more than 0.30 indicate a statistically significant difference.

Figure 10: Extent of the development of graduate attributes in undergraduate physics, as ranked by graduates.

If we examine the subset of 42 graduates with no postgraduate qualifications, there is almost no difference in their responses from the full set. This appears to make intuitive sense; in that all graduates are being asked about attributes developed in undergraduate physics only, and are therefore all reporting on the same thing. There is the concern however, that graduates with postgraduate qualifications might confuse the timing of the development of certain attributes. Research methodology is the one attribute that drops down the ranking order (by two places from a value of 2.70 to 2.39) for non-PhD graduates. This is suggestive of mixing of undergraduate and postgraduate experience, as research methodology should be a significant component in postgraduate studies.

When asked whether any other graduate attributes needed to be developed more in undergraduate physics (see Figure 11), half the graduates nominated oral communication – clearly the main area of concern. Worryingly, the other form of communication (written) is the second ranked area of concern, with over one-third of graduates nominating it as an attribute needing more attention. Problem solving and laboratory skills are at the other end of the scale.

Unsurprisingly perhaps, the two rankings of the level of development of graduate attributes in undergraduate physics mirror each other remarkably closely. Only ethical issues and social considerations spoil the symmetry somewhat. The majority of graduates state that these concerns are given scant consideration, yet only one-quarter of them believe they requires more emphasis.

When asked if any of the graduate attributes are better developed in another undergraduate course there is a somewhat mixed response. Only 59 graduates (half the data set) answered this question. Of these, almost half say that the majority of attributes weren’t better developed in other courses. Some mention that they were equally well developed in other areas, mostly mathematics and engineering. Table 2 shows how many people thought each attribute was better developed elsewhere.
Some interesting quotes regarding skills not well developed in physics:

“Design, and ethical considerations were more emphasised in electrical eng. I don't think ethics needs to be considered as much in physics as other fields such as biology and psychology …”

“Ethical issues were often addressed in my philosophy degree. Actually teaching philosophy of science as a discipline would be good …”

“I think that communications skills should be developed simultaneously, but necessarily from within the Physics department itself.”

Figure 11: Percentage of graduates believing certain graduate attributes require more development in undergraduate physics.

<table>
<thead>
<tr>
<th>Graduate Attribute</th>
<th>Better developed by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem solving</td>
<td>Engineering (2), Mathematics (1)</td>
</tr>
<tr>
<td>Information retrieval</td>
<td>Arts (2), Mathematics (1)</td>
</tr>
<tr>
<td>Computational skills</td>
<td>Mathematics (2), Computing (1)</td>
</tr>
<tr>
<td>Teamwork</td>
<td>Chemistry (2), Arts (1)</td>
</tr>
<tr>
<td>Research methodology</td>
<td>Mathematics (1)</td>
</tr>
<tr>
<td>Ethical and social issues</td>
<td>Engineering (2), Medicine (1), Arts (1)</td>
</tr>
<tr>
<td>Experimental design</td>
<td>Engineering (2)</td>
</tr>
<tr>
<td>Project planning</td>
<td>Engineering (4), Mathematics (1), Business (1)</td>
</tr>
<tr>
<td>Written communication</td>
<td>Arts (3), Engineering (2), Law (1), Business (1), Commerce (1), Education (1), Medicine (1)</td>
</tr>
<tr>
<td>Oral communication</td>
<td>Arts (2), Business (1), Commerce (1), Medicine (1)</td>
</tr>
</tbody>
</table>

Table 2: Disciplines where graduate attributes are better developed in undergraduate studies.
“The arts courses were much more valuable for developing written communication and information retrieval and I do think Physics graduate need these skills BUT as an academic I am 100% against reducing tradition physics content in favour of things like written communication, team work etc. These things must be taught a) more in secondary school and b) in conjunction with core physics material. As an example I get my 3rd year astrophysics class to write a telescope proposal which is peer-reviewed as a method of both enhancing core course content and developing generic skills - this is a much better way of teaching written communication, team work and information retrieval than many that I have seen and does not come at the expense of loss of core physics content.”

3.10 Features of postgraduate physics helpful / a hindrance to learning

There were 50 responses to the postgraduate section of the survey. The three most helpful features of a postgraduate physics degree that foster learning are:

- Independent nature of a PhD project (‘owning’ the project) = 7
- Interactions with other academics and collaborative work with other groups = 6
- Assistance and support of a good supervisor = 4

Many graduates mention the further development of graduate attributes, in particular written communication, project planning and research methods.

The main negatives cited were:

- Lack of support from academics / supervisors when things go bad (being left to your own devices) = 5
- A lot of paperwork and bureaucracy = 3

On the question of whether a postgraduate degree in physics is an advantage they have over other graduates, the majority agree that it is. However, quite a few graduates qualify this answer by saying that it is still the area they are working in and therefore of course it is an advantage. Opinion is somewhat divided as to whether a PhD in physics gives you an advantage going into other areas of work. A number of graduates say it has, but others reflect the following comment:

“Yes and no. Yes because it sharpens the ability to work alone and builds confidence. No because it forces you to specialise in a single area, and narrows your choice of future career considerably.”

3.11 Graduate attributes developed in postgraduate physics

The ranking of graduate attributes developed in postgraduate physics, shown in Figure 12, is somewhat different to the undergraduate list. Written communication skills, which are rather poorly developed in the undergraduate years, are now on top of the rankings. This shouldn’t be too surprising given the strong emphasis on writing both for the thesis and papers. Problem solving remains a highly developed attribute during this period but laboratory work, which ranked very high in undergraduate, is now at the bottom. Part of the explanation for this change is undoubtedly related to the fact that a large number of PhDs will be theoretical in nature and therefore many candidates may never enter a laboratory after their undergraduate years. Again ethical and social considerations are at the very bottom of the rankings, a significant distance from the next least developed attribute. All other attributes have increased in development from undergraduate years.
When asked whether any of these graduate attributes needed to be developed more in postgraduate physics, there were fewer *need more* responses than for the equivalent undergraduate question (see...
Figure 13). In fact, the attribute requiring most attention, project planning, was only voted by eight of the 37 graduates, so the statistical significance is low. Interestingly, oral and written communication feature in the top half of attributes requiring more attention, even though both (in particular written) score well in the skills developed. This points to the strong emphasis and value of communication skills in any workplace.

At the other end of the scale, laboratory skills were only thought to require more attention by one graduate. This may suggest that most of its development takes place in undergraduate work and at the postgraduate level it is more a refinement of techniques (for those who need it for their project).

4. Results of follow-up questions to selected graduates

4.1 General statistics

There were 15 responses to the follow-up questions sent out by email in mid 2008. The sample consists of eight females and seven males, with an average age of 32.5 years (essentially the same as the overall sample). Five graduated in the current decade and ten graduated in the 1990s. Six have a PhD in physics with three being first employed in academia as a postdoctoral fellow.

4.2 Summary of findings

It seems that a number of graduates think that disciplines like engineering are better able to develop certain attributes (e.g. teamwork, oral and written communication) because of the strong role that industry plays. Not only do the majority of engineering students go directly into the engineering industry but a lot of the lecturers have spent time in industry themselves. This means that educators and employers are not only more ‘in sync’ with what skills are required in the workplace but they tend to explicitly inform students about it and make it the focus of assessment.

As physics has no discernible main industry there is less communication between educators and employers and this can result in different ideas on what is, or should be, required. Even when there is agreement there is the perception by educators that these skills are being developed and there is no need to continually remind students about it. This subtlety is often is lost on students as it is rarely explicitly reinforced in assessment.

Other graduates however believe that even if physics isn’t developing all the graduate attributes equally, they are still doing a very good all-round job. Some believe that physics should be solely responsible for developing all these attributes whereas others believe a joint approach, possibly bringing in expertise from outside (other university disciplines and/or industry), is required. A couple of graduates are worried that developing these attributes shouldn’t take precedence over learning of physics knowledge and content.

Problem solving was far and away (at least ten of the graduates) the most useful skill developed as far as success in the workplace goes. Written communication was mentioned by three graduates as being as skill lacking which made their integration into the workforce more difficult.

4.3 Sample responses

Below we reproduce a selection of graduate responses to the follow-up survey that highlight the issues summarised in the preceding paragraphs. The bold text emphasis is attributed to the project team.
Q1. Do you agree that certain disciplines were better at developing certain attributes? If so, which disciplines? Can you provide concrete examples of how they achieved this?

“Yes, I agree completely. I think this is mostly achieved by the focus in the assessment, because this is how you make students work on various things, and to a slightly lesser extent, the example that a lecturer/teacher/mentor sets for their students. A concrete example would be physics vs engineering at undergraduate level. Physics is almost 100% about problem solving, and aside from a few lecturers who now more actively try to cultivate some of the other areas by adding them as components of the assessment, all the other attributes don’t really count. In physics, students can generally turn in any old ratty-looking garbage as long as the answers are correct, and get as good a mark as someone who has produced a professional-looking, well written and explained submission with the same level of 'correctness' in the answers. Hence the almost complete lack of 'other skills' development in a physics course. In contrast, undergraduate engineering courses tend to do a much better job of developing skills other than pure problem solving, in part because this is demanded by the employers and professional associations, a pressure that exists to a much lesser extent in physics.”

“Engineers also have emphasis on team work, doing team projects etc, and once again this is from necessity – it’s required in the workplace. Have to say, it would appear that the engineering education system seems to have a good handle on what’s required of their graduates, probably reflecting their close relationship with industry and the fact that many engineering instructors/teachers/lecturers have spent time in industry.”

“Attributes such as Oral and written communication are better developed during my undergraduate arts subjects ... simply by the nature of the inquiry and assessment.”

“I believe that within the different sciences ..., physics was one of the best courses in developing useful attributes in preparation for later work.”

“... other disciplines would be vastly superior to physics in developing certain skills, such as being able to deliver a reasoned argument in an oral form, and being able to cohesively argue points based on research.”

“... Physics was the only discipline I studied ... that was well balanced in teaching theoretical skills (fundamental equations and techniques) and practical skills (Giving oral presentations, writing reports, and even the structure of the Australian Research Council and grant application methodologies).”

Q2. Please comment on the difference between approaches by Physics and other disciplines in developing these attributes.

“In many physics subjects, all assessment was based on pen-and-paper solutions to mostly analytical problems. In this kind of assessment teamwork may have happened informally, with students working together to develop solutions.”

“... a common approach by all disciplines and that is to develop most of these attributes in the form of assessment – essays, lab reports, mathematics assignments. In physics I also had tutorials (in first year) to help with problem solving and when in lab classes was usually placed in a team for each experiment. Arts subjects often assign a tutorial to either a pair or individual in the class to lead, hence developing oral communication skills, research, presentation and when in a pair, teamwork.” I have experienced a couple of physics subjects in which oral presentations were made but very little guidance was provided for those students who had no experience in such things. Like most university education it was very self-directed, you learn from trial and error, observation and practice.”
Q3. Do you think that Physics should be responsible for developing all the above listed attributes? Or should it be left to other disciplines? Please provide reasons for your answer.

“Yes, I think it should and I think that traditional physics really lets its students down. For the most part, a traditional physics course is a war of attrition, aimed at eliminating out the chaff to find the next generation of scientists. This 'competition' continues right through the academic structure of physics. What it tends to do is produce a few excellent graduates, who probably already had a natural aptitude and talent for physics, but have benefitted from the additional mentoring nonetheless, and a sea of 'also-rans' who learn some physics along the way, but much less than they otherwise could if physics was not taught this way.”

“I think a collaborative approach is needed. The reality is, in the workforce you don’t just work with people of your own discipline. I think you need ‘experts’ or at least people experienced and with highly developed skills that they can transfer and demonstrate to students. As stated previously, 20 or 30 years teaching doesn’t give you skills to work in a work place, it gives you teaching skills. I think the capacity to draw from other disciplines to put together a package of attribute development is a logical and efficient approach. This may mean looking outside of the university environment.”

“Physics courses should be responsible for training graduates to work as a physicist. However universities organize themselves into disciplines is irrelevant, as long as the physics students cover the topics needed. If that means a compulsory arts subject, so be it. To put the skills listed in priority order according to the skills I have needed in my early physics career: problem solving, information retrieval, computational skills, laboratory skills, research methodology, experimental design, written communication, oral communication, teamwork, project planning. I'm not sure about ethical concerns. I've never had any training, or any call to use such skills. My workplace provides compulsory courses on teamwork, report writing, management etc so they obviously think it's important but don't expect graduates to have those skills already, whereas the top 6 in the list are definitely expected.”

Q4. Which of these graduate attributes developed in physics were important in your successful integration into the workplace? How so?

“Problem solving was the key attribute. Any challenge in the workplace can ultimately be approached as a problem, and a solution devised. Whether this is time management, project management, technical issues, etc. Each issue can be dissected and approached logically. Hence, problem solving is the most important attribute.”

Q5. Were any graduate attributes not fully developed in physics detrimental to your successful integration into the workplace? How so?

“When teaching at a religious school I sometimes felt unprepared with regard to the ethical and social implications of science. I’m not sure it is the place of a physics department to explore these issues in detail but since we didn’t encounter it at all during undergrad or postgrad physics.”

“Oral and written communication and information retrieval which were poorly developed in physics were developed further in my arts and honours studies and so was not detrimental to me personally but I can say without a doubt that if I had not studied this other disciplines I would have had a difficult time integrating as successfully as I have.”
5. Employer survey results

5.1 General statistics

There were a total of ten employer responses, all but one male. Of these, eight employers answered the section on undergraduates and five answered the postgraduate part, with only four answering both. Except for the two secondary schools all employers in the sample are within the science/engineering industry (private sector). The organisations represented were:

- **Fuji Xerox Australia** - document management services and solutions
- **Canon Information Systems Research Australia (CISRA)** - digital imaging technologies
- **Dow Corning Corporation** - development and distribution of silicon-based chemicals
- **Optiscan** - microscopic imaging technologies for medical diagnostic equipment
- **Warrnambool College** - secondary education
- **Phonak Australia** - supply hearing instruments and accessories
- **Fluorosolar Systems** - commercialising technology in daylighting
- **Australian Radiation Services** - health physics service provider
- **Oakhill College** - secondary education
- **Queensland Alumina Limited (QAL)** - mineral processing

5.2 Employers’ general view of graduates with an undergraduate degree

Employers report that a thorough understanding of mathematics (four responses) and physical processes and theory (three responses) are the principal special skills and knowledge that physics graduates bring to the job. A couple of employers mention a logical analytical approach and a solid science foundation.

When asked to comment on the ability of graduates to learn and adapt there is a somewhat mixed response. Whilst a couple of employers say that physics graduates can adapt and learn quickly and are flexible, some say that they can be a bit rigid and not so good at stepping outside their area of expertise. One employer says that physics graduates are the best candidates for their field of work, but this not surprising given they are a health physics service provider. In general however the eight employers who answered this section don’t see much difference between physics and other disciplines when it comes to the ability to learn and adapt.

A few employers would like to see physics graduates come in with a better understanding of the commercial/business aspects of the job, one suggesting that physics and business studies be combined. One employer mentions improved written and oral communication skills, and the ability to communicate science to non-science audiences.

About half the respondents believe that physics graduates remain distinct, from other disciplines, in time. They mention that physicists have a more balanced perspective, are more thorough and can think outside the box better:

“My assumption would be yes as they are not locked into one field of science and do not belong to a large peer group (e.g. more chemists and engineers exist). They tend to be more able to think outside the box from a highly influential peer group.”

Only two (out of eight) employers say they would look to employ physics graduates over graduates from other disciplines. A sample response:
“There are far more factors I would use in determining a hire than their education. Factors such as past experience, what motivates them, their knowledge and networks and how they perform in the interview would have higher or equal weighting.”

5.3 Employers’ view of graduate attributes

Due to the very small sample (six employers answered this question) not too much should be read from the ranking of graduate attributes as shown in Figure 14. More can be discerned by looking at employers’ responses to those attributes that require more development. The attribute that ranks lowest in this respect is teamwork (four votes), closely followed by oral communication and research methodology (three votes each). Written communication, problem solving, laboratory skills, experimental design, project planning all get two votes. The remaining attributes received one vote each.

In answer to the question *Is it reasonable to expect university graduates to come with these attributes or are they better learnt/developed at work?*, almost all employers believe that graduates need to have developed these attributes more so than they do at present. However they do realise that these attributes will (and should) be further developed in the workplace. One employer is scathing in his assessment of incoming graduates (particularly with physicists):

“I think the poor quality of oral and written skills comes from high school as many do not know how to structure a letter far less a report. Also the universities have reduced the entry level for school leavers and this has had a terrible effect on the students that graduate. In general the students are so wet behind the ears you have to train them from scratch on how to approach a project. There writing skills are in general terrible compared with students in other disciplines.”

5.4 Employers’ general view of graduates with a postgraduate degree

There is very little data for the postgraduate section of the questionnaire. A total of five employers have partially answered, of these only three completely (Fuji Xerox, Canon and Australian Radiation
Services). On the whole the answers mirror those for undergraduate, worryingly so in some areas where one would expect the further study to have made a difference:

“Sheespects of research methodology are weakest part, and highly variable between individuals. In particular searching and finding relevant literature and details of prior published research is not a very consistent skill.”

Issues still present include the weakness in written and oral communication, a lack of project planning capabilities and some difficulties in social skills such as teamwork and networking. At the same time, these employers say that physics graduates are as good, if not better, than graduates from other disciplines and that they do have the main advantage of both specialised and wide-ranging knowledge. A final comment:

“Physics training combined with additional vocation can provide a far more adaptable and value creating leaders in a company. Ability to manage people and build a business case (influence people) would greatly enhance a study of Physics alone.”

6. Differences between graduate survey data subsets (to discover biases)

6.1 Preamble

Conscious of certain biases in our sample of graduates, we set out to test the limitations of viewing our findings as being representative of the overall Australian situation. To this end we looked at the following subsets:

- Graduates with physics postgraduate degrees (n = 50)
- Graduates with NO postgraduate qualifications at all (n = 42)
- Female graduates (n = 35)
- Sydney University graduates (n = 21)

6.2 Differences across subsets

Geographic coverage

Central Queensland University is the most widely varying across the different subsets. It has predominantly male graduates who only do an undergraduate physics degree. As it is the main university in Queensland that provided a significant number of graduates for the survey, the difference in responses due to states is driven by CQU results.

Range of tertiary qualifications

Most graduates (80%) who complete an honours degree continue on to do a postgraduate degree.

Reasons for doing physics

The top three reasons for doing physics at university:

1. interested in physics,
2. enjoyed it and had good results in high school, and
3. want to know how things / the world works,

remains unchanged across the different subsets. The only slight difference is that at Sydney University as many students mention the overall second placed reason as the first.
First job after graduation

Few graduates who have no postgraduate qualifications stay in the university system. None of the graduates with a postgraduate qualification went into the medical sector or into high school teaching. Not surprisingly those with a physics postgraduate degree stay in the university sector in large numbers. They also favour the public over private science sector. The IT industry doesn’t appear to attract female graduates.

Current / most relevant job

The picture is very similar between the first job and the current/most relevant job. The biggest difference between the subsets is that only one in seven Sydney University graduates are still in their first job.

Physics as useful training for workplace

The percentage of graduates who recommend a major in physics as useful training for their current job remains at the overall data set level (~75%) for both female and Sydney University graduates. It goes down slightly for those without postgraduate qualifications and up for those with a physics postgraduate degree (by ± 10%).

Features of undergraduate physics helpful to learning

The main differences are again seen between those with a physics postgraduate degree and those with no postgraduate qualifications at all. For the former, practicing problem solving is of the utmost importance (ranking equal first with laboratory work) and for the latter, dedicated teaching staff is a significant factor in their learning.

Graduate attributes

Graduates with physics postgraduate degrees
- Almost identical rankings, similar scores
- Attributes with slightly increased scores (+0.15 or more relative to the larger data set):
  - problem solving, research methodology, oral communication
- Attributes with slightly decreased scores (-0.15 or more relative to the larger data set):
  - ethics, project planning

Graduates with NO postgraduate qualifications at all
- Almost identical rankings but somewhat lower scores
- No attributes with slightly increased scores (+0.15 or more relative to the larger data set)
- Attributes with slightly decreased scores (-0.15 or more relative to the larger data set):
  - problem solving, research methodology, oral communication, computational skills

Female graduates
- Almost identical rankings, similar scores
- Attributes with slightly increased scores (+0.15 or more relative to the larger data set):
  - information retrieval, computational skills,
- No attributes with slightly decreased scores (-0.15 or more relative to the larger data set)

Sydney University graduates
- Almost identical rankings, similar scores
Attributes with slightly increased scores (+0.15 or more relative to the larger data set):
  o teamwork (+0.5), ethics, project planning,
Attributes with slightly decreased scores (-0.15 or more relative to the larger data set):
  o Computational skills

Graduate attributes needing more attention

Graduates with physics postgraduate degrees
- Oral communication, written communication and project planning the top three most needed (like in overall set)
- More teamwork needed than in overall set

Graduates with NO postgraduate qualifications at all
- Oral communication, project planning and written communication the top three most needed (like in overall set, except project planning more needed than written communication)

Female graduates
- Oral communication and written communication the top two most needed (like in overall set)
- More teamwork needed than in overall set (in third place) whereas project planning much further down

Sydney University graduates
- Experimental design far and away the most needed (only fourth in overall set)
- Written communication much further down the list

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